NO. 18-1763

United States Court of Appeals for the Federal Circuit

AMERICAN AXLE & MANUFACTURING, INC.,

Plaintiff-Appellant,

v.

NEAPCO HOLDINGS LLC AND NEAPCO DRIVELINES LLC,

Defendants-Appellees.

Appeal from the United States District Court for the District of Delaware in C.A. No. 15-cv-1168, United States District Court Judge Leonard P. Stark

PRINCIPAL BRIEF OF PLAINTIFF-APPELLANT

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June 29, 2018

CERTIFICATE OF INTEREST FOR AMERICAN AXLE & MANUFACTURING, INC.

Pursuant to Federal Circuit Rules 26.1 and 47.4, counsel for Plaintiff-Appellant American Axle & Manufacturing, Inc. certifies the following:

1. The full name of every party represented by me is:

American Axle & Manufacturing, Inc.

2. The name of the real party in interest (if the party named in the caption is not the real party in interest) represented by me is:

Not Applicable.

3. All parent corporations and any publically-held companies that own 10% or more of the stock of any party represented by me are:

American Axle & Manufacturing Holdings, Inc.

4. The names of all law firms and the partners or associates that appeared for the party or amicus now represented by me in the trial court or agency or are expected to appear in this court (and who have not or will not enter an appearance in this case) are:

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5. The title and number of any case known to counsel to be pending in this or any other court or agency that will directly affect or be directly affected by this court's decision in the pending appeal:

   Not Applicable.

Dated: June 29, 2018

<u>/s/ James R. Nuttall</u>

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STATEMENT OF RELATED CASES

There are no pending cases known to counsel that would directly affect or be directly affected by this Court's decision in the present appeal.

STATEMENT OF JURISDICTION

The district court had jurisdiction over this case under 28 U.S.C. §§ 1331, 1338, and 2201. On February 27, 2018, the district court issued its memorandum opinion and order, granting defendants' motion for summary judgment of invalidity under 35 U.S.C. § 101. American Axle timely filed its notice of appeal on March 29, 2018. Therefore, this Court has jurisdiction over this appeal under 28 U.S.C. § 1291.

STATEMENT OF THE ISSUES

Whether the district court erred in determining on summary judgment that the claims in U.S. Patent No. 7,774,911 are invalid under 35 U.S.C. § 101 for claiming patent ineligible subject matter, even though the claims are methods for manufacturing propshafts with specifically designed liners, unknown in the art, that reduce multiple types of vibration to create improved propshafts.

STATEMENT OF THE CASE AND FACTS

I. TECHNOLOGY BACKGROUND

This case relates to driveline systems of automotive vehicles. In particular, this case relates to methods for manufacturing propshafts with new and improved liners that reduce vibration of the propshaft. The accused products are large aluminum propshafts (e.g., 7 feet long) that are manufactured by Neapco and provided to General Motors ("GM") for use in certain of GM's Canyon and Colorado pickup trucks.

Canyon

Colorado

Appx2021, Appx2375; Appx59-60.

A. Automotive Driveline Systems

Driveline systems—which typically include a transmission, propshaft, axles, and wheels—transmit power generated by an engine through the transmission to the propshaft, which is configured for rotation to provide rotary power to the axles and wheels. Appx31, Appx24. Figure 4 of the '911 patent illustrates a propshaft with a pair of "universal joints" used to couple it to the driveline system. Appx26, Appx32.

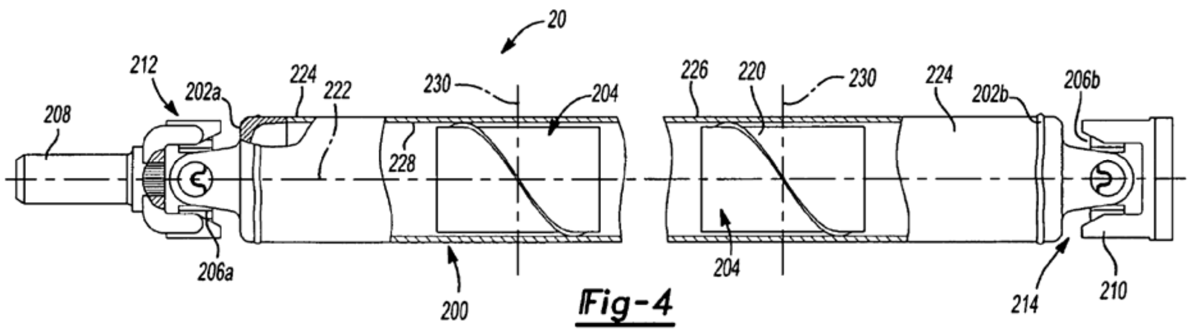


Fig-4

A propshaft is rotatably coupled on one end to the transmission and on the other end to the rear axle. *Id.* It transmits power generated by the engine to rotate the axle and wheels. Appx31-32, Appx24-26.

B. Propshafts are Prone to Vibration and Noise

Propshafts are commonly formed of relatively thin-walled metal and can therefore be receptive to various driveline excitation sources that cause vibration. Appx30. Vibration of the propshaft causes noise, which is usually readily detected by vehicle occupants who "increasingly expect" quiet in the interior of the vehicle Appx30; Appx1999. Vehicle manufacturers and their suppliers are accordingly under constant pressure to reduce noise and meet consumer expectations. Appx30.

C. Different Types of Propshaft Vibration

There are several types of vibration that propshafts may experience, including "bending," "shell," and "torsion" mode vibration. Appx26. Only the first two types of vibration—bending mode and shell mode—are at issue in this case. *See, e.g.*, Appx7198. As stipulated by the parties, and as illustrated by Figures 5 and 6 below, "bending mode vibration" is "vibration that causes a shaft to bend," and "shell mode vibration" is "vibration that causes the cross-section of a shaft to deflect or bend along one or more axes." Appx640; Appx26.

Bending Mode **Shell Mode**

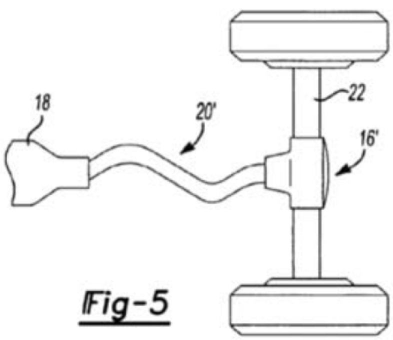


Fig-5

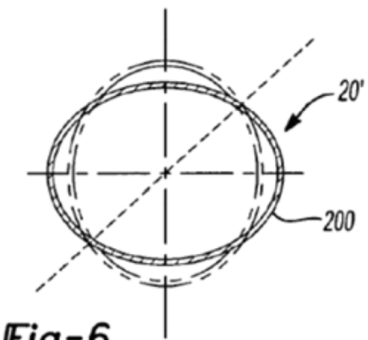


Fig-6

Appx26.

At certain frequencies of propshaft vibration, called "natural frequencies," the propshaft will experience greater levels of vibration. Appx32; Appx1999-2000; Appx5119. Propshaft natural frequencies are inherent properties of the propshaft and independent of the type or amplitude of excitation applied to the propshaft. *Id.*

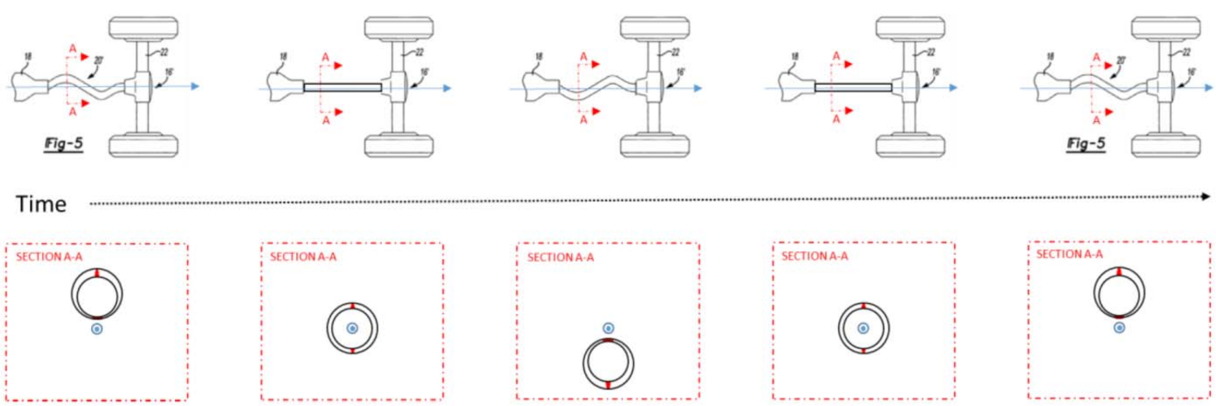
Propshafts can have several natural frequencies for both bending mode and shell modes. *Id*. Each natural frequency corresponds to a specific vibration "mode" associated with each type of vibration, starting with the first mode, which has the lowest natural frequency. *Id.* For example, a propshaft could have first, second, and third bending modes at 100Hz, 300Hz, and 500Hz, and first, second, and third shell modes at 150Hz, 250Hz, and 350Hz. Appx31-33, Appx26; Appx1999-2000.

D. Attenuation of Propshaft Vibrations

1. Reactive Attenuation of Bending Mode Vibrations

Bending mode vibration involves radial displacement of the propshaft and is addressed with reactive attenuation. Appx640; Appx26, Appx35; Appx1047; Appx2002-2003. "Reactive attenuation," is when an absorber "can oscillate in opposition to the vibration energy to thereby 'cancel out' a portion of the vibration energy." Appx30, Appx35; Appx1047; Appx2000-2002.

The schematic below illustrates the concept of reactive attenuation of bending mode vibrations.



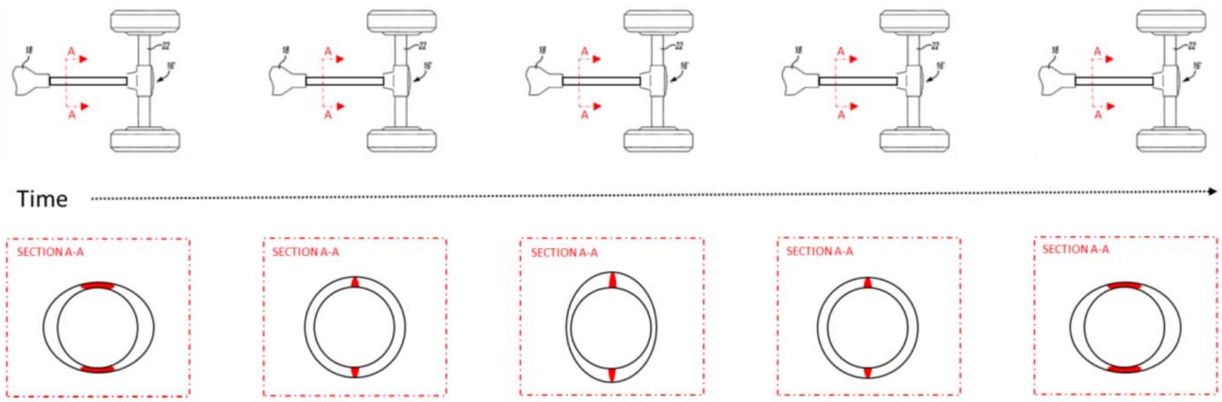
Appx2002-2003. The propshaft of Figure 5 is illustrated going through a complete cycle of bending mode vibration in a second bending mode. *Id*. As illustrated, cross section A-A of the propshaft (shown in the bottom figures) starts above the longitudinal axis of the propshaft (shown in blue) and cycles through to below the axis, and back. *Id*. The schematic also illustrates an absorber, such as a propshaft liner having resilient members (shown in red), configured for "reactive attenuation" of bending mode vibrations—as the propshaft moves down the liner moves up in opposition, and as the propshaft moves up the liner moves down in opposition. *Id*. In each case, the illustrated liner is configured for reactive attenuation as its opposing motion cancels out a portion of the bending mode vibration energy of the propshaft to dampen bending mode vibrations. *Id*.

Like propshafts, liners have different types of natural frequencies. Appx3156-3158, Appx3163-3165; Appx2404; Appx2395-2399. In order for a liner with a certain frequency to perform reactive attenuation, that liner frequency must match the propshaft frequency and involve translation of the liner to effectively couple with the propshaft bending mode. Appx2076-2077; Appx4036-4037; Appx5218. If the liner frequency is of another type that does not involve translation, the liner will not perform reactive attenuation of propshaft bending modes. *Id*.

2. Resistive Attenuation of Shell Mode Vibrations

Shell mode vibration is "vibration that causes the cross-section of a shaft to deflect or bend along one or more axes." Appx640; Appx26. To attenuate shell mode vibrations, an absorber, such as a propshaft liner, must be configured for "resistive attenuation," whereby the absorber can "deform[] as vibration energy is transmitted through it . . . so that [it] absorbs (and thereby attenuates) the vibration energy." Appx30; Appx1047.

The schematic below illustrates the concept of "resistive attenuation" of shell mode vibrations.



Appx2000-2002. In this schematic, the propshaft goes through a complete cycle of shell mode vibration as illustrated by cross section A-A of the propshaft (shown in the bottom figures). *Id*. As illustrated, the cross section A-A starts as a flattened oval shape and cycles through a circular shape to an elongated oval shape, and back. *Id*. The schematic also illustrates an absorber, such as a propshaft liner, configured for "resistive attenuation" of shell mode vibrations—as the propshaft vibrates in a shell mode, the liner and its resilient members (shown in red) compress relative to their initial shape, thereby deforming as the cross-section of the propshaft deflects or bends to dissipate shell mode vibration energy to dampen shell mode vibrations. *Id*.

E. Experimental Modal Analysis is Used to Determine Natural Frequencies and Damping

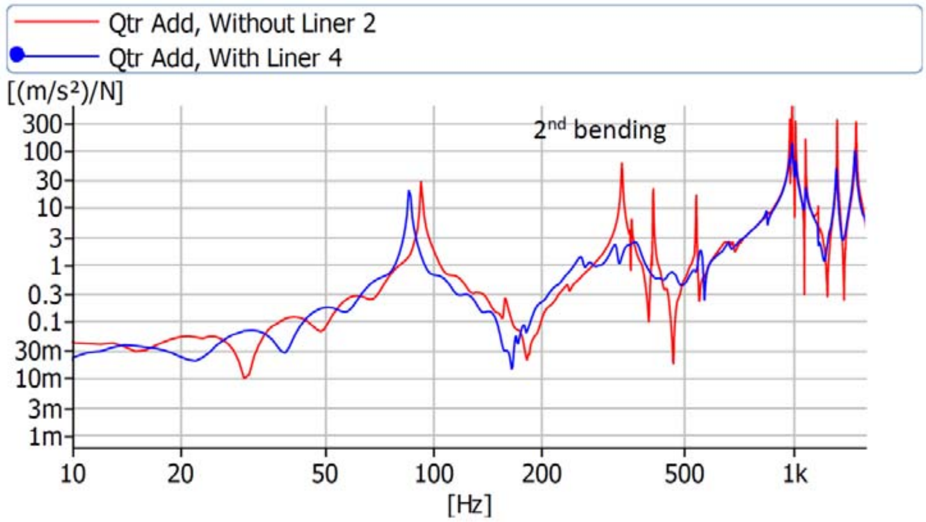
The methods for determining natural frequencies and damping are well known in the art. Appx2004-2014, Appx2373, Appx2375-2378; Appx3330-3336; Appx2774-2797; Appx5207-5208, Appx5225-5233; Appx7042-7049; Appx1939-1943; Appx2413-2414; Appx2416; Appx3432-3435; Appx6435-6437. "Experimental modal analysis" involves exciting the structure with an actuator and measuring the response using a sensor. Appx2004-2014; Appx2375-2378; Appx2413-2414; Appx2416; Appx3432-3433; Appx2774-2797.

The images below illustrate a test set-up performed by American Axle of a Neapco propshaft:

Appx2375. As shown, American Axle used an impact hammer to excite and cause the propshaft to vibrate, and accelerometers to measure the vibration response. *Id*. Like American Axle, Neapco and others in the automotive industry test for natural frequencies and damping of propshafts by performing experimental modal analysis. Appx5207-5208, Appx5225-5234; Appx7043-7049; Appx2774-2797.

Experimental modal analysis is also used to determine natural frequencies of vibration absorbers, such as liners. Appx1773; Appx2013-2014; Appx2822-2823, Appx2828; Appx3156-3158, Appx3163-3165; Appx5207-5208, Appx5225-5233; Appx2785-2789; Appx2377, Appx2395-2399; Appx2404-2405; Appx7042-7049; Appx6015-6016; Appx6634, Appx6640-6641; Appx6439-6453. In addition to identifying liner frequencies, modal analysis is used to determine the liner natural frequency mode or shape. Appx3156-3158, Appx3163-3165; Appx6015-6016; Appx6651-6652.

Experimental modal analysis often includes the use of a graphical output called a "Frequency Response Function," or "FRF." Appx2004-2014, Appx2378-2399; Appx2822. An FRF is a graph that shows the vibrational response of a structure as a function of frequency. *Id.* Reproduced below is an exemplary bending mode FRF of American Axle's experimental modal analysis of a Neapco propshaft having GM part no. 84059646 ("the 646 propshaft").

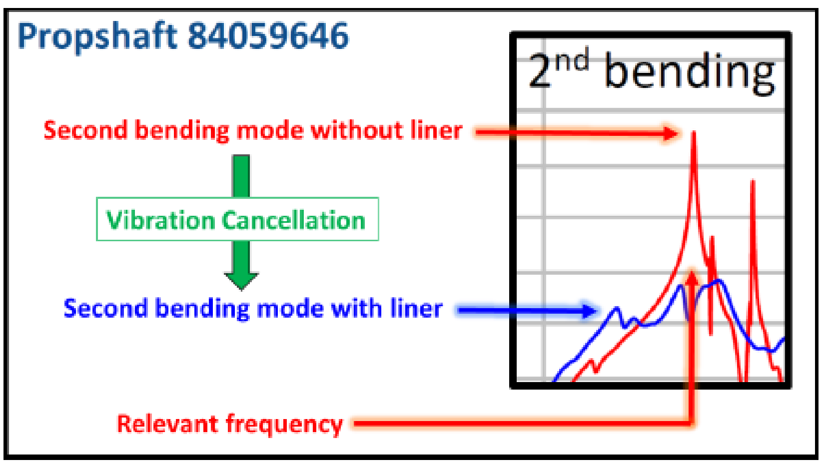


Appx2387.

The red line of the above FRF corresponds to the bending mode vibration of the untreated 646 propshaft, i.e., without its liners. *Id*. The blue line of the above FRF corresponds to the bending mode vibration of the treated 646 propshaft, i.e., with its liners. *Id*. The bottom axis corresponds to the frequency of the propshaft bending mode vibration, measured in Hz, while the side axis corresponds to the amplitude or amount of bending mode vibration. *Id*.; Appx2006-2007.

Persons of ordinary skill in the art can use FRFs to determine propshaft bending mode and shell mode natural frequencies. Appx2006-2009; Appx2822-2823, Appx2828. Because propshafts vibrate most at their natural frequencies, peaks in an FRF plot correspond to vibration modes being excited at a natural frequency. *Id*. In the above bending mode FRF of the 646 propshaft, for example, the untreated propshaft without liners (red line) has a second peak at 336 Hz corresponding to the second bending mode natural frequency. Appx2204-2211, Appx2387.

Persons of ordinary skill in the art can also use FRFs to measure damping. Appx2013-2014; Appx2204-2211; Appx2387; Appx2771; Appx2822-2823, Appx2828. The added bending mode damping is visually depicted on the above bending mode FRF and close-up below, which shows that the liners change the large and sharp peak at the second bending mode (red, without liners) to a smaller and rounded peak (blue, with liners).



Appx2209.

II. STATE OF THE ART BEFORE THE INVENTION

Prior to American Axle's inventions, the automotive industry used various dampers and absorbers to attenuate a single type of propshaft vibration. Examples include untuned liners, slip yoke dampers, internal tuned dampers, and plugs. Appx30. Those dampers and absorbers had several shortcomings, however, and there remained a "need in the art for an improved method for damping various types of vibrations in a hollow shaft" by facilitating the damping of multiple types of vibration. *Id*.

For example, slip yoke dampers, internal tuned dampers, and plugs were previously used to damp bending mode vibrations or torsion mode vibrations, but each were ineffective at reducing shell mode vibrations. *Id.*; Appx3504-3505; Appx3417-3422; Appx1967-1968.

Similarly, untuned liners were used to provide general broadband damping of shell mode vibrations but are ineffective at reducing bending mode vibration. Appx30; Appx3500-3502. Testing of the Econoline propshaft and liners—the only prior art product in this case—confirms that untuned liners are ineffective at reducing bending mode vibration and may even *amplify* bending mode vibrations. Appx5217-5218; Appx1887-1891; Appx3417; Appx2822-2823, Appx2828.

The concept of tuning a paper or cardboard liner was unknown at the time of invention. Appx1911. Dr. Rahn explained that the ideas that a liner could be a tuned at all and could attenuate bending mode vibrations were not in the prior art and were unexpected results. *Id.*

Neapco's corporate witness responsible for relevant engineering activities admitted that it was unknown to tune liners at the time of invention. Appx1327; Appx1309.

III. U.S. PATENT NO. 7,774,911

The American Axle inventors overcame this need in the art by conceiving of the novel and unconventional concept of "tuning" a liner to damp specific propshaft vibration modes. Appx30, Appx34-35. Furthermore, unlike previous dampers and absorbers, American Axle's tuned liners dampen multiple types of vibration, e.g., bending mode and shell mode vibration, through both reactive and resistive attenuation. *Id*.

A. The Specification

The specification of the '911 patent explains that American Axle's "tuned" liners include a structural portion (yellow) and one or more resilient members (blue). Appx32, Appx27. Liners are sized and designed to frictionally engage the inner wall of the propshaft. *Id*.

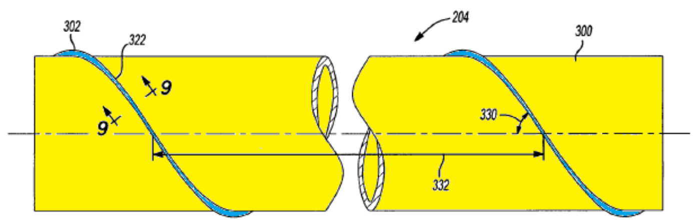


Fig-8

The specification teaches that the liner frequency should be tuned within about 20% or less of the frequency of the relevant propshaft vibration mode. Appx33-34. The specification of the '911 patent further explains that liners are tuned for damping by controlling "various characteristics" including, for example, mass, length, thickness, and outer diameter as to the cardboard; quantity, pitch, material, and angle as to the resilient member; and the location of the liners within the propshaft. Appx33 (also providing exemplary embodiment of tuned liners).

The specification explains that the liners are tuned to, and attenuate vibration at, both bending and shell mode natural frequencies. Appx33-35. In this regard, the specification explains that as the liner acts as "(a) a tuned resistive absorber for attenuating shell mode vibrations; and (b) . . . a tuned reactive absorber for attenuating bending mode vibrations." Appx33.

B. The Claims

The '911 patent claims various "method[s] for manufacturing" propshafts including, among other steps, inserting at least one "tuned" liner into the shaft assembly, wherein the tuned liners are configured to reduce both bending mode and shell mode vibrations through reactive and resistive attenuation. Appx34-35. The claims at issue in this appeal are claims 1-6, 12, 13, 19-24, 26, 27, 31, and 34-36. *Id*. Independent claims 1, 22 and 36 are all methods for manufacturing propshafts, but recite additional or different limitations. *Id*.

The district court construed several terms of these claims, often referred to by the parties as the "tuning" terms. Appx1046-1047. The court's constructions of the tuning terms require (1) controlling characteristics of a liner, (2) "matching" of a liner frequency to a relevant propshaft frequency or frequencies, and (3) reducing at least two types of vibration, e.g., bending and shell mode vibrations. *Id*. The court's constructions of the "tuned resistive absorber" and "tuned reactive absorber" limitations further require the "matching" liners absorb shell and bending mode vibrations in a particular manner, i.e., by "deforming as vibration energy is transmitted through the liner to absorb the vibration energy" and "oscillating in opposition to vibration energy to cancel out a portion of the vibration energy," respectively. Appx1047.

IV. THE AUTOMOTIVE INDUSTRY RECOGNIZED AND RELIED ON AMERICAN AXLE'S NOVEL AND UNCONVENTIONAL TUNED LINER INVENTIONS

A. General Motors Depends on American Axle's Tuned Liners

American Axle's tuned liner technology has proven to be an effective solution to propshaft vibration and has since been included in GM's aluminum propshafts for over the last ten years. Appx4232; Appx4234-4243; Appx3459-3462.

Early in the Canyon and Colorado ("the 31XXN program") development, NVH issues arose on certain propshafts provided by Neapco. Appx3459; Appx2022-2023; Appx3279-3282; Appx1307. For example, one Neapco propshaft had NVH issues due certain bending and shell modes. Appx4014; *see also* Appx2022-2023; Appx4000, Appx4004; Appx3496. To solve these NVH problems, GM requested that Neapco provide tuned liners. Appx328; Appx3496.

B. Neapco Studied American Axle's Patent and Commercial Products to Understand How to Tune Liners

To Neapco, GM's NVH issues were "currently #1 issue on GM31XXN and has executive attention." Appx4203. To satisfy GM's NVH needs, Neapco studied American Axle's '911 patent and commercial products to understand how to tune liners as part of its design and development effort for the 31XXN program.

Specifically, Neapco held a team meeting to discuss GM's NVH issues involving multiple modes and directed the team to American Axle's patents. Appx4203; Appx825 ("You may want to review the liner patents that American Axle was able to push through over the last few years – see attached."); Appx1918.

Neapco acknowledged that it had "catching up" to do and sought to understand how to tune liners to both bending modes and shell modes by looking to American Axle's patented inventions. Appx828; Appx1918-1919. For example, a Neapco engineer told the group:

> I think we have more homework to do to really understand how to tune a liner for specific shell mode, and that might be part of the issue we are seeing with the GM31XXN liners.

Appx1915-1916. Later the same day, Neapco suggested experimentally testing various permutations of liner designs—like American Axle—to tune liners for shell mode damping. Appx4245. Neapco noted that, while American Axle may have analytical models to measure shell mode damping, Neapco did not have that capability. *Id*. Neapco concluded that American Axle had "solved the issue":

> Current focus [s]hould be understanding AAM v. NDL. ***Obviously knowingly or unknowingly, they have solved the issue with an extremely low cost solution***. I want to know the mechanics.

Appx3513. Neapco then detailed a plan to experimentally test American Axle's commercial products. *Id*. Shortly thereafter, Neapco recirculated the '911 patent and instructed the group that attenuating both bending and shell modes was "what [Neapco was] trying to achieve with the GM31XXN liners." Appx3510.

Neapco also studied American Axle's commercial products to understand how to tune liners for the 31XXN program. Appx3524-3527. Several liner design variables that Neapco studied included outer and inner diameter, thickness, snugness (e.g., interference fit), rubber lip height, rubber lip thickness, and rubber lip cross-sectional design. Appx3526-3527. The '911 patent explains how those characteristics "can be controlled to tune [the liner's] damping properties in the shell mode and in one or both of the bending mode and the torsion mode." Appx33.

Eventually, Neapco began to design several of its own prototype liners having various permutations of liner characteristics described above, including diameter, thickness, mass, number of windings, durometer of windings, pitch of windings, and compression fit. Appx353; Appx3538-3539; Appx6013-6018 ("Driveshaft Liner Tuning Log").

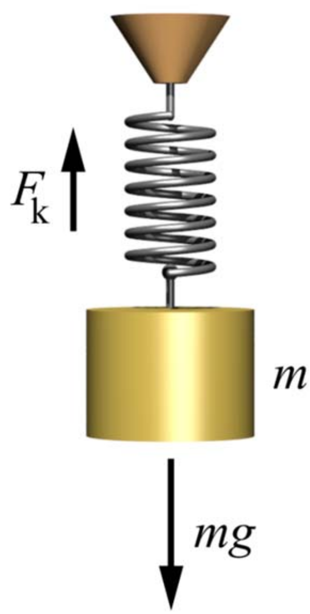
GM tested Neapco's proposed propshafts with the tuned liners (but did not test the tuned liners for their frequencies separately) and concluded that Neapco had successfully developed tuned liners. Appx6556.

V. OVERVIEW OF THE ALLEGED NATURAL LAWS

The natural laws relevant to this appeal are Hooke's law and friction damping.

A. Hooke's Law

Hooke's law is an equation that describes the nature of certain spring-mass systems. Appx1928; Appx1603. A spring-mass system having a single degree-of-freedom, e.g., displacement up and down, is reproduced below in the following demonstrative:



See Appx1928; Appx1603. In this schematic, the force of gravity pulling down on the mass mg equals the force of the spring pulling back up on the mass F_k. *Id*.

The nature of the spring force F_k may be determined by successively adding more mass to the spring, which causes the spring to incrementally stretch by successive displacements x (not illustrated). *Id*. Hooke's law simply describes how the spring force F_k applied to the mass is proportional to the displacement x of the spring by a linear spring constant or stiffness k:

$$F_k = kx$$

Appx1928; Appx1603.

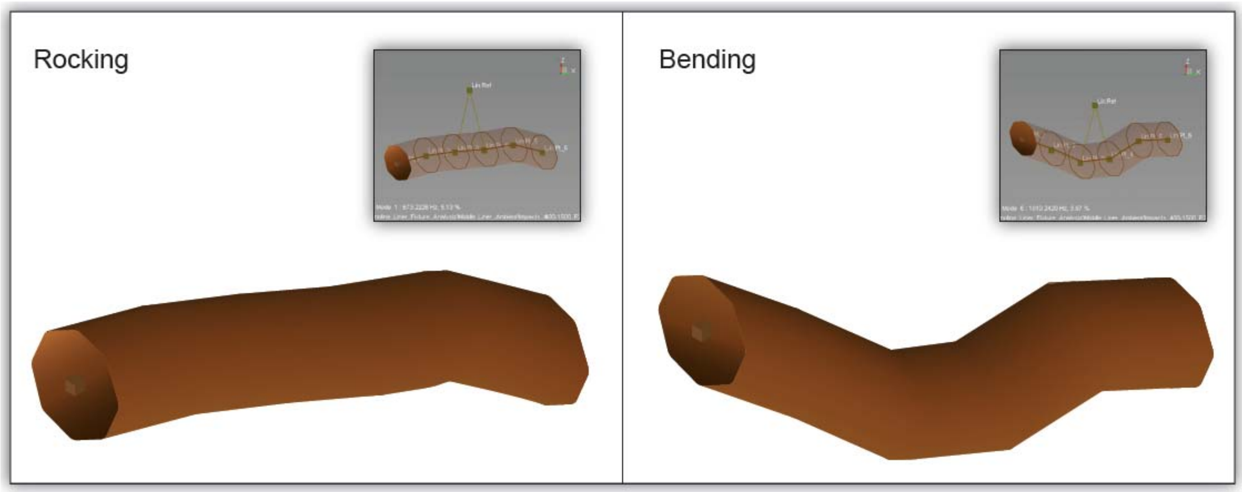
Variants of Hooke's law may also be used to understand the response of the spring-mass system when the mass is oscillating in periodic motion. Appx1603. For example, the natural frequency ω of the spring-mass system, i.e., the frequency at which the periodic motion repeats itself, may be represented by the following variant:

$$\omega = \sqrt{k/m}$$

Id.

Complicated objects—such as propshaft liners—cannot be simplified to a single degree-of-freedom mass-spring damper such that their behavior is governed simply by Hooke's law. Appx1752; Appx1928 (Liner "is a complex, distributed object with different stiffnesses in different directions (e.g., shell and bending).");

Appx2505. As shown in the demonstrative below, liners vibrate in varied and complicated shapes.



See Appx3157-3158.

On the other hand, sophisticated computer models, often called finite element analysis ("FEA") models, may employ Hooke's law to model vibration. Appx1752, Appx1772-1773; Appx1608-1609. Dr. Zhaohui Sun, a Senior Manager of NVH engineering at American Axle and inventor of the '911 patent, explained that liners cannot be simplified as single degree of freedom mass-spring dampers and, because of that, American Axle uses "very sophisticated FEA models." Appx1752.

FEA models have shortcomings, however. Neapco's technical expert, Mr. Steven Becker, acknowledged that FEA models do not precisely predict real-world behavior: "[O]ne typically does not get the same results from FRF testing and FEA modelling." Appx1609. Mr. Becker confirmed those differences by comparing his results of FEA modelling and physical testing of a prior art 2003 Ford Econoline propshaft, which "show[ed] different results for modal frequencies." *Id*.

Accordingly, as described *supra* Statement of Facts I.E., experimental modal analysis is used to measure the actual behavior of complex structures such as liners. Appx1770; *see also* Appx1771, Appx1780; Appx7061; Appx1943; Appx6095. Neapco also performs experimental modal analysis to test for and determine liner natural frequencies. Appx6016; Appx7075-7090. Engineers at Neapco, for example, were instructed "to run some FRF's with various liners … and try to capture 'empirical data' to really understand which damper designs absorb shell mode energy best for certain frequency ranges." Appx5944.

Even the variant of Hooke's law, $\boldsymbol{\omega = \sqrt{k/m}}$, is independent of vibration damping. Rather, Hooke's law and variants thereof are simply equations that inform the linear relationship between the natural frequency $\boldsymbol{\omega}$ of a mass $\boldsymbol{m}$ attached to a spring with stiffness $\boldsymbol{k}$ when the spring-mass system is oscillating in periodic motion. Appx1928; Appx1603. Simply put, Hooke's law is "unrelated to 'attenuating shell mode vibrations' and 'attenuating bending mode vibrations' of propshafts in driveline systems." Appx1929.

Neapco's own testing of the Econoline propshaft demonstrates that liners having a frequency that allegedly matches a relevant propshaft bending mode frequency may actually *amplify* vibration at that frequency, rather than dampen it.

Appx5217-5218; Appx1887-1891; Appx3417; Appx2822-2823, Appx2828; Appx1659; Appx6223-6224; Appx3051, Appx3060, Appx3088, Appx3096.

Neapco does not dispute that Hooke's law is also independent of shell mode damping. Mr. Becker, for example, never opined that Hooke's law related to claim limitations reciting damping shell mode vibrations. Appx1604-1605. Rather, Mr. Becker alleged that a different natural law applied to those limitations—friction damping. *Id.*; Appx4036-4037; Appx5218; Appx5944.

B. Friction Damping

Friction damping is as it sounds—damping that "occur[s] due to the resistive friction and interaction of two surfaces that press against each other as a source of energy dissipation." Appx1604-1605; Appx1929-1931. Neapco does not dispute that friction damping is different from reactive damping, where an absorber such as a liner oscillates in opposition to propshaft to cancel out a portion of the propshaft vibration energy. Appx1604-1605; Appx1248-1251. Mr. Becker, for example, never opined that friction damping related to claim limitations reciting damping bending mode vibrations. Appx1604-1605; Appx1248-1251. Rather, Mr. Becker alleged that a different natural law applied to those limitations—Hooke's law. *Id*.

Friction damping is also independent of the frequency of vibration of objects, including their natural frequencies of vibration. *See id.*; Appx1929-1931. Mr. Becker explains in the context of propshaft liners, for example, friction damping is simply "the interaction between material properties of the liner and [shaft] consisting of a viscous force coefficient and a Coulomb friction coefficient." Appx1605; Appx1250-1251. Simply put, friction damping is unrelated to "tuning" liners, "matching" a liner frequency to a relevant propshaft frequency, and reactive damping.

VI. PROCEDURAL HISTORY AT THE DISTRICT COURT

A. American Axle's and Neapco's Cross-Motions for Summary Judgment as to Patent-Eligible Subject Matter

Neapco and American Axle both moved for summary judgment relating to patent eligibility. *See* Appx1230-1231, 1248-1253; Appx4597-4605; Appx6139-6140; Appx6587-6589; Appx7119; Appx4330-4335; Appx5236-5237; Appx6094-6096; Appx6194; Appx7049. Neapco argued that the asserted claims "attempt to monopolize well-known laws of physics." Appx1249. First, Neapco argued in order to tune a liner "one merely applies the law of nature known as Hooke's law." *Id*. Neapco's argument assumed that "once the liner is 'tuned'" it necessarily acts as a reactive absorber and damps the relevant bending mode vibration. Appx1249-1250. Second, Neapco argued that tuning a liner to attenuate shell mode claimed multiple laws of nature combined together, namely tuning the frequency using Hooke's law and "the law of nature or natural phenomenon for friction damping." Appx1249-1251. Finally, Neapco merely argued that the other claims are patent ineligible for the same reasons. Appx1251-1253.

American Axle argued that the asserted claims were eligible under the *Mayo*/*Alice* two-part test because they are not directed to either Hooke's law or friction damping and contain several inventive concepts. Appx4330-4335; Appx5236-5237; Appx6094-6096; Appx6194; Appx7049. With regard to step one of *Mayo*/*Alice*, American Axle argued that, "[b]y their very nature, the Asserted Claims are … directed to industrial processes for manufacturing automotive components, e.g., 'large parts of cars'—not a patent-ineligible 'law of nature' or 'natural phenomenon'. Appx4331 (citations omitted).

With regard to step two of *Mayo*/*Alice*, American Axle argued that the asserted claims contain several inventive concepts. Appx4334; Appx4335 (collecting evidence that Neapco's engineers acknowledged the '911 patent as inventive); Appx6096-6097.

American Axle also argued, as to both steps one and two of *Mayo*/*Alice*, that the asserted claims do not preempt either Hooke's law or friction damping. Appx4331, Appx4333-4334; Appx6094.

Finally, American Axle argued that the machine-or-transformation test confirms that the asserted claims are patent eligible. Appx4335-4336.

B. The District Court's Summary Judgment Order

The District Court "agree[d] with Neapco" and granted Neapco's motion. Appx11. With regard to step one, the court found that there "is no dispute that adjusting the mass and stiffness of the liner will change the amount of damping of a certain frequency." *Id.* The court also found that the "claimed methods are applications of Hooke's law with the result of friction damping." The court found the claims do not disclose a method for manufacturing a propshaft and "fail to instruct how to design the tuned liners or manufacture the driveline system to attenuate vibrations." Appx11-12.

With regard to step two, the district court found that: (1) the "tuning limitations are non-inventive applications of Hooke's law"; (2) tuned liners were conventional and routine; (3) controlling the characteristics of a liner to match a relevant frequency "is just an inherent part of any design process"; (4) that dual tuned liners for multiple propshaft vibration modes is the "result that is achieved from performing the method rather than an active step in the method"; and (5) that the claims did not provide a "discrete" liner design. Appx14-17. The district court concluded that there was no "genuine dispute of material fact that the tuning limitations are non-inventive applications of Hooke's law." Appx14.

SUMMARY OF ARGUMENT

American Axle's claims recite patent eligible methods for manufacturing improved propshafts. Prior to American Axle's inventions, the automotive industry used various dampers and absorbers to attenuate a single type of propshaft vibration. American Axle conceived of the novel and unconventional concept of "tuning" a liner to match and damp specific and multiple propshaft vibration modes and reducing vibration at those modes resulting in a significantly improved propshaft.

The asserted claims, like "thousands of others that recite processes to achieve a desired outcome, e.g., methods of producing things" are directed to patent eligible subject matter. *See Rapid Litig. Mgmt. Ltd. v. CellzDirect, Inc.*, 827 F.3d 1042, 1048 (Fed. Cir. 2016). In addition, the claims include previously unknown and inventive tuned liners that are far from well-understood, routine, and conventional. *See Exergen Corp. v. Kaz USA, Inc.*, 725 F. App'x 959, No. 2016-2315, 2018 WL 1193529, at *3-4 (Fed. Cir. Mar. 8, 2018) (nonprecedential), Appx7249-7250. The asserted claims are therefore patent eligible and the district court's finding otherwise should be reversed.

At step one of the *Mayo/Alice* inquiry, the district court erroneously concluded that the asserted claims are directed to an application of Hooke's law with the result of friction damping. Appx11. But not even Neapco argued that an application of Hooke's law results in friction damping. In addition, the district court fundamentally misunderstood and ignored the asserted claims in characterizing them as applications of Hooke's law. Hooke's law is irrelevant to propshaft vibration modes, controlling liner characteristics, matching propshaft and liner frequencies, and attenuating vibration, all of which are required by the asserted claims as construed by the district court. The district court's finding that the claims are directed to Hooke's law is therefore clearly erroneous. *See CellzDirect*, 827 F.3d at 1049; *Vanda Pharm. Inc. v. W.-Ward Pharm. Int'l Ltd.*, 887 F.3d 1117, 1134 (Fed. Cir. 2018). Finally, the district court erred by injecting Section 112 into its Section 101 analysis and faulting the asserted claims for failing to instruct "how" to tune liners.

The district court's analysis at step two is similarly erroneous. American Axle's claimed invention—in particular liners that are specifically tuned to match and damp multiple vibration modes and are utilized to manufacture improved propshafts—was entirely new and far from well-understood, routine, and conventional. *See Exergen*, 2018 WL 1193529, at *3-4, Appx7249-7250. Neapco admitted the inventive concept of the asserted claims when it studied American Axle's patents and products, explicitly stating that "[o]bviously knowingly or unknowingly, [American Axle had] solved the issue with an extremely low cost solution [tuned liners]." Appx3513; Appx1921; Appx3510; Appx4335; Appx6096-6097. Neapco further admitted that it was "not aware" of anyone even "attempting" to tune liners prior to the invention of the asserted claims. Appx1309, Appx1327. The claims are therefore patent eligible for this reason as well. *Exergen*, 2018 WL 1193529, at *3-4, Appx7249-7250. To the extent this issue is disputed, the district court erred in dismissing numerous factual issues in a footnote and erroneously concluding that there was no dispute that the tuning limitations are "non-inventive applications of Hooke's law." Appx14; s*ee* *Berkheimer v. HP Inc.*, 881 F.3d 1360, 1368 (Fed. Cir. 2018).

Accordingly, because the asserted claims are patent eligible under Section 101, this Court should reverse the district court's decision and remand for further proceedings.

ARGUMENT

I. STANDARD OF REVIEW

This Court reviews the grant of summary judgment under regional circuit law, which is the Third Circuit in the present case. *Teva Pharm. Indus. Ltd. v. AstraZeneca Pharm. LP*, 661 F.3d 1378, 1381 (Fed. Cir. 2011). Under Third Circuit law, summary judgment rulings are reviewed de novo. *Nicini v. Morra*, 212 F.3d 798, 805 (3d Cir. 2000). The record is reviewed in the light most favorable to and all reasonable inferences are drawn in favor of the non-movant. *Id*. at 805-6. In addition, this Court reviews de novo patent eligibility decisions under Section 101. *In re BRCA1- & BRCA2-Based Hereditary Cancer Test Patent Litig.*, 774 F.3d 755, 759 (Fed. Cir. 2014). Under Section 282, patents are presumed valid, absent clear and convincing evidence to the contrary. *See, e.g.*, *CLS Bank Int'l v. Alice Corp. Pty. Ltd.*, 717 F.3d 1269, 1284, 1304-05 (Fed. Cir. 2013), *aff'd*, 134 S. Ct. 2347 (2014).

II. THE ASSERTED METHOD FOR MANUFACTURING CLAIMS ARE PATENT ELIGIBLE UNDER THE SUPREME COURT'S TWO-PART TEST

A. The Two-Part Test For Patent Eligibility

Section 101 of the Patent Act broadly defines patent eligible subject matter:

> Whoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title.

35 U.S.C. § 101. The Supreme Court has long-held that three specific patent-ineligible categories are implicit exceptions to Section 101: laws of nature, natural phenomena, and abstract ideas. *E.g.*, *Mayo Collaborative Servs. v. Prometheus Labs., Inc.*, 566 U.S. 66, 70 (2012).

But long-standing precedent and numerous decisions strongly caution against a broad application of these exclusionary categories for fear of "eviscerat[ing] patent law." *Id*. at 71. These cases acknowledge that "all inventions at some level embody, use, reflect, rest upon, or apply laws of nature, natural phenomena, or abstract ideas." *Id*. Thus, "'a process is not unpatentable simply because it **contains** a law of nature or a mathematical algorithm'." *Id*. (quoting *Diamond v. Diehr*, 450 U.S. 175, 187 (1981)) (emphasis added).[1]

[1] All emphasis herein is added unless otherwise stated.

Ultimately, courts must "tread carefully in construing this exclusionary principle lest it swallow all of patent law." *Alice* , 134 S. Ct. at 2354 (2014).

Mayo and *Alice* set forth a two-step framework for determining patent eligibility. First, a court must "determine whether the claims at issue are directed to a patent-ineligible concept." *Alice*, 134 S. Ct. at 2355. If the claims are not directed to a patent-ineligible concept, the inquiry ends and the claims are patent eligible. *CellzDirect*, 827 F.3d 1042, 1047 (Fed. Cir. 2016). In the case of a claim allegedly involving a law of nature, the Supreme Court has explained that to be patent eligible, "one must do more than simply state the law of nature while adding the words 'apply it'." *Mayo*, 566 U.S. at 72.

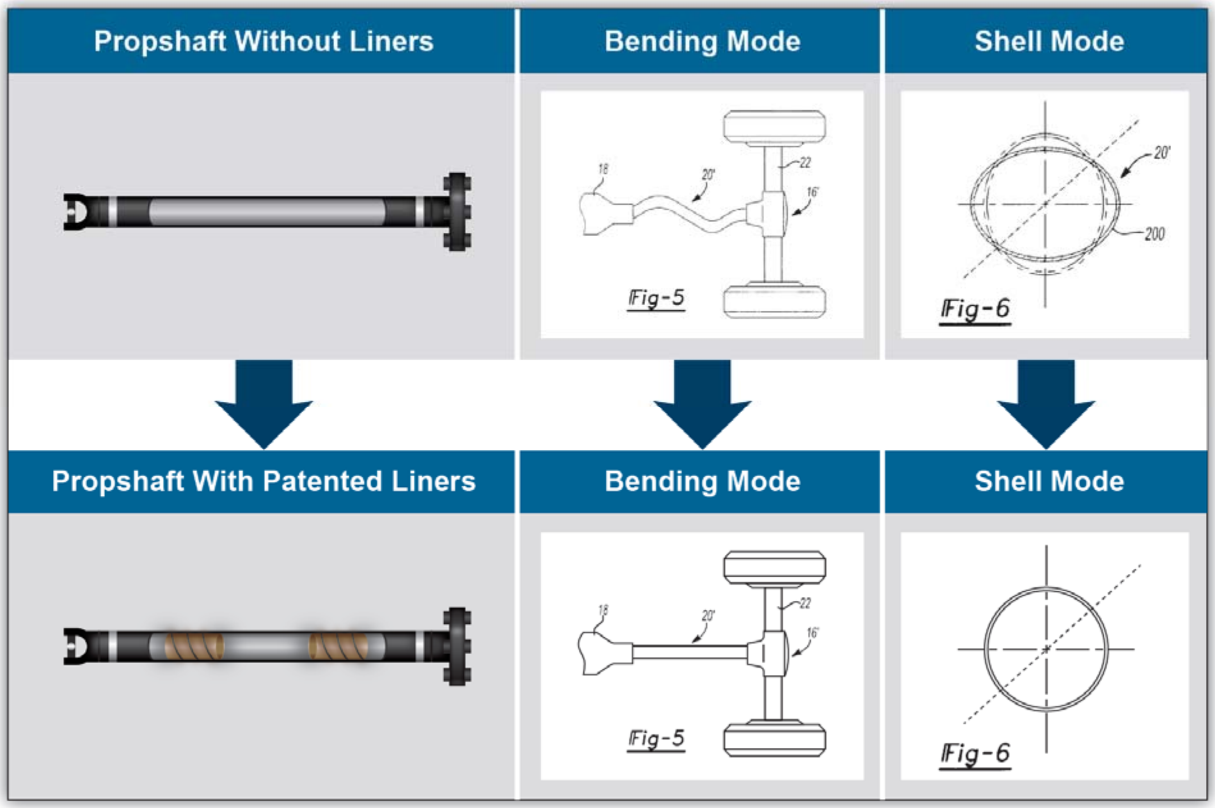
If the claims are directed to a patent ineligible concept, the inquiry proceeds to step two where a court asks whether considered both individually and as an ordered combination, "the additional elements 'transform the nature of the claim' into a patent-eligible application." *Alice*, 134 S.Ct. at 2354 (quoting *Mayo*, 566 U.S. at 78).

B. *Mayo/Alice* Step One: The Claims Are Directed To A Method For Manufacturing A Propshaft With Improved Vibration Performance, Not Any Law of Nature

The asserted claims are directed to methods for manufacturing propshafts with specifically designed tuned liners that improve real and measurable physical characteristics of the propshaft (i.e., reducing vibration). The district court erroneously concluded that "[t]he claimed methods are applications of Hooke's law with the result of friction damping." Appx11. As set forth in more detail below, the district court's conclusion was not even argued, much less supported, by Neapco; the claims are far removed from Hooke's law; the claims do not recite or merely apply Hooke's law; and the court ignored important claim limitations and its own claim construction. For all the reasons set forth herein, the asserted claims are patent eligible and the district court's decision should be reversed.

1. The Claims Are Directed To A Patent Eligible Method For Manufacturing Improved Propshafts

"Industrial processes . . . are the types which have historically been eligible to receive the protection of our patent laws." *Diehr*, 450 U.S. at 184. The asserted claims at issue here are no different. They are methods for manufacturing large, metal propshafts that use specifically designed liners to reduce the amount of vibration of multiple different types of vibration in the propshaft. As shown below, the first figure is a propshaft without liners having multiple different types of vibration. The other figure shows the propshaft with the patented tuned liners added to specifically reduce multiple different propshaft vibrations.



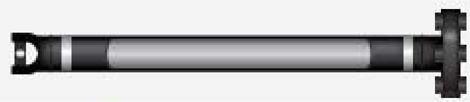
American Axle is unaware of a single Federal Circuit or Supreme Court decision finding claims reciting a "method for manufacturing" or "method of producing" patent ineligible. Courts addressing methods for manufacturing physical devices have instead upheld such claims as patent eligible. *See CellzDirect*, 827 F.3d at 1048 (Claimed "method of producing" was eligible and like "thousands of others that recite processes to achieve a desired outcome, e.g., methods of producing things."); *Hitkansut LLC v. United States*, 130 Fed. Cl. 353, 380 (2017), aff'd, 721 F. App'x 992 (Fed. Cir. 2018), Appx7259 (Claimed "method[s] of changing a physical property of a structure" were eligible (despite specifically referencing a mathematical relationship) as they were "directed to a new and more efficient method for treating metal parts to change their physical properties."); *Zircore, LLC v. Straumann Mfg., Inc.*, No. 2:15-cv-01557, 2017 WL 2901703, at *2 (E.D. Tex. Jan. 20, 2017) (Claimed "method of manufacturing" was eligible as it was "directed to a method of manufacturing *physical* crown copings for prosthodontics.") (emphasis in original).

The claimed features are summarized in the demonstrative below.

Claim 1

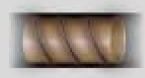
1[a]: A method for manufacturing a shaft assembly of a driveline system, the driveline system further including a first driveline component and a second driveline component, the shaft assembly being adapted to transmit torque between the first driveline component and the second driveline component, the method comprising:

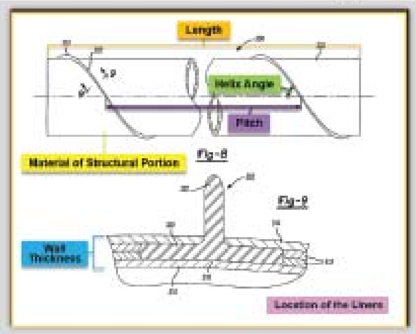
1[b]: providing a hollow shaft member;



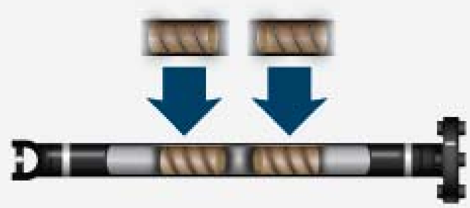
1[c]: tuning at least one liner to attenuate at least two types of vibration transmitted through the shaft member; and

[M]ass, length and outer diameter of the liner **204**, diameter and wall thickness of the structural portion **300**, material of which the structural portion **300** was fabricated, the quantity of the resilient members **302**, the material of which the resilient members **302** was fabricated, the helix angle **330** and pitch **332** with which the resilient members **302** are fixed to the structural portion **300**, the configuration of the lip member(s) **322** of the resilient member **302**, and the location of the liners **204** within the shaft member **200**.

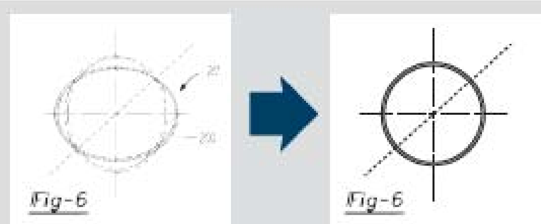




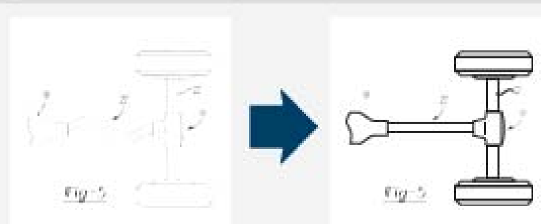
1[d]: positioning the at least one liner within the shaft member



1[e]: such that the at least one liner is configured to damp shell mode vibrations in the shaft member by an amount that is greater than or equal to about 2%,



1[f]: and the at least one liner is also configured to damp bending mode vibrations in the shaft member, the at least one liner being tuned to within about ±20% of a bending mode natural frequency of the shaft assembly as installed in the driveline system.



The district court construed the tuning limitations to require (1) controlling characteristics of a liner, (2) "matching" of a liner frequency to a relevant frequency or frequencies, and (3) reducing at least two types of vibration, e.g., bending and shell mode vibrations. Appx1046-1048. Thus, the claims are directed to manufacturing propshafts with specifically designed liners that not only match the relevant propshaft vibration mode frequencies, but also damp multiple different types of vibration. Appx33-35.

The specification of the '911 patent confirms that the asserted claims are directed to improved propshafts. The specification explains that prior art untuned liners "appear to disclose a resistive means for attenuating shell mode vibration" and "do not appear to be suitable for attenuating bending mode vibrations" of a propshaft. Appx30. The specification goes on to conclude:

> In view of the foregoing, **there remains a need in the art for an improved method** for damping various types of vibrations in a hollow shaft. **This method facilitates the damping of shell mode vibration as well as the damping of bending mode vibration**.

Appx30.

In addition, the '911 patent teaches in order to match the relevant frequency the liner should be within about 20% of the propshaft mode frequency. Appx33-34. The '911 patent also teaches that the liner characteristics have to be controlled to damp the relevant propshaft vibration modes, including the interference fit between the liner and the propshaft, the location of the liner within the propshaft, and other design characteristics:

> It will also be appreciated from this disclosure that various characteristics of the liner **204** can be controlled to tune its damping properties in the shell mode and in one or both of the bending mode and the torsion mode. In the particular example provided, the following variables were controlled: mass, length and outer diameter of the liner **204**, diameter and wall thickness of the structural portion **300**, material of which the structural portion **300** was fabricated, the quantity of the resilient members **302**, the material of which the resilient members **302** was fabricated, the helix angle **330** and pitch **332** with which the resilient members **302** are fixed to the structural portion **300**, the configuration of the lip member(s) **322** of the resilient member **302**, and the location of the liners **204** within the shaft member **200**. In the particular example provided:

Appx33. The claims are therefore directed to improved propshafts, i.e., propshafts having tuned liners that reduce multiple vibration modes by controlling characteristics of the liner to not only match but also damp those vibration modes. Such methods for manufacturing physical devices (propshafts) with improved physical characteristics (reduced vibration) are patent eligible subject matter. *See Diehr*, 450 U.S. at 184 ("[A] physical and chemical process for molding precision synthetic rubber products" was patent eligible despite a recitation of the Arrhenius equation.); *see also CellzDirect*, 827 F.3d at 1048; *Enfish, LLC v. Microsoft Corp.*, 822 F.3d 1327, 1337 (Fed. Cir. 2016) ("[S]pecification's teachings that the claimed invention achieves other benefits over" prior technologies supported and bolstered the conclusion that the claims were directed to an improved technology and not ineligible.).

2. The District Court Erroneously Found The Claims Were Directed To Hooke's Law With The Result Being Friction Damping

The district court erroneously found that the claims were directed to "applications of Hooke's law with the result of friction damping." Appx11. This conclusion is a fundamental error that is unsupported and contradicted by the underlying record. The district court also erroneously found that the claims "do not disclose" a method for manufacturing and "fail to instruct ***how*** to design the tuned liners or manufacture the driveline system to attenuate vibration." Appx11-12 (emphasis in original). Finding the claims ineligible on that basis is an application of a non-existent and erroneous legal standard.

a. The District Court's Conclusions Were Not Even Presented By Neapco And Are Wholly Unsupported

The district court erroneously concluded that the "claimed methods are applications of Hooke's law with the result of friction damping." Appx11. But not even Neapco advanced such a position.

Neapco argued that the claims were directed to multiple different laws of nature—(1) Hooke's law for tuning and attenuating bending modes and (2) friction damping as to shell modes. Appx1248-1251; Appx1604-1605. The record is simply devoid of any evidence to support the court's conclusion that "Hooke's law [results in] friction damping." Appx11. The court erroneously misunderstood and misapplied even Neapco's strained arguments. The district court's finding is therefore unsupported, erroneous, and should be reversed for this reason alone.

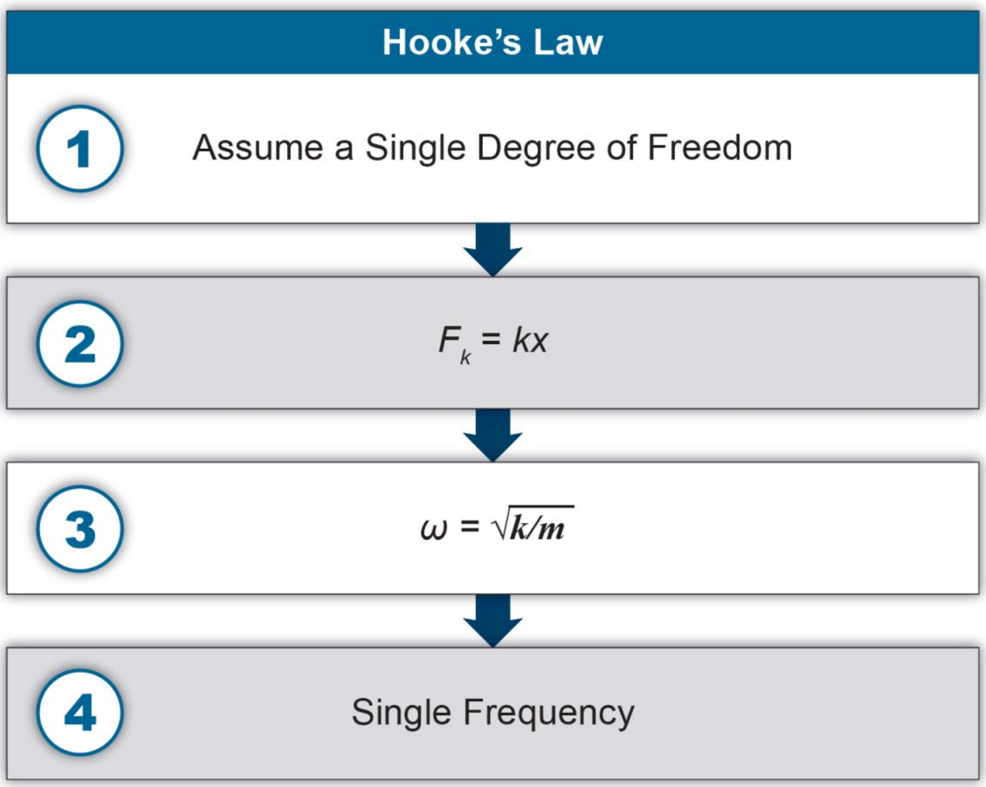
Furthermore, "the Federal Rules do not contemplate that a court may dispose of a cause by summary judgment, when the basis for the judgment was not raised by the movant with sufficient precision for the nonmovant to respond." *Cooper v. Ford Motor Co.*, 748 F.2d 677, 680 (Fed. Cir. 1984). Rather, a district court may only enter judgment *sua sponte* "if the parties have had an adequate opportunity to argue and present evidence on that point and summary judgment is otherwise appropriate." 10A Wright & Miller, Federal Practice and Procedure § 2719 (3d. ed. 1998); *see also* Fed. R. Civ. P. 56(f) (requiring "notice and a reasonable time to respond"). Accordingly, appellate courts routinely reverse or vacate summary judgment when, as here, the basis of the judgment was not raised by the movant. *See, e.g.*, *KangaROOS U.S.A., Inc. v. Caldor, Inc.*, 778 F.2d 1571, 1578 (Fed. Cir. 1985); *Armour v. Cty. of Beaver, PA*, 271 F.3d 417, 434 (3d Cir. 2001).

Neapco never argued, let alone with "sufficient precision," that the claims were directed to Hooke's law with the result being friction damping. By concluding as much, the district court unfairly deprived American Axle of the opportunity to respond and present evidence to the contrary. This Court should reverse or, at a minimum, vacate the district court's order as improper under Rule 56(f).

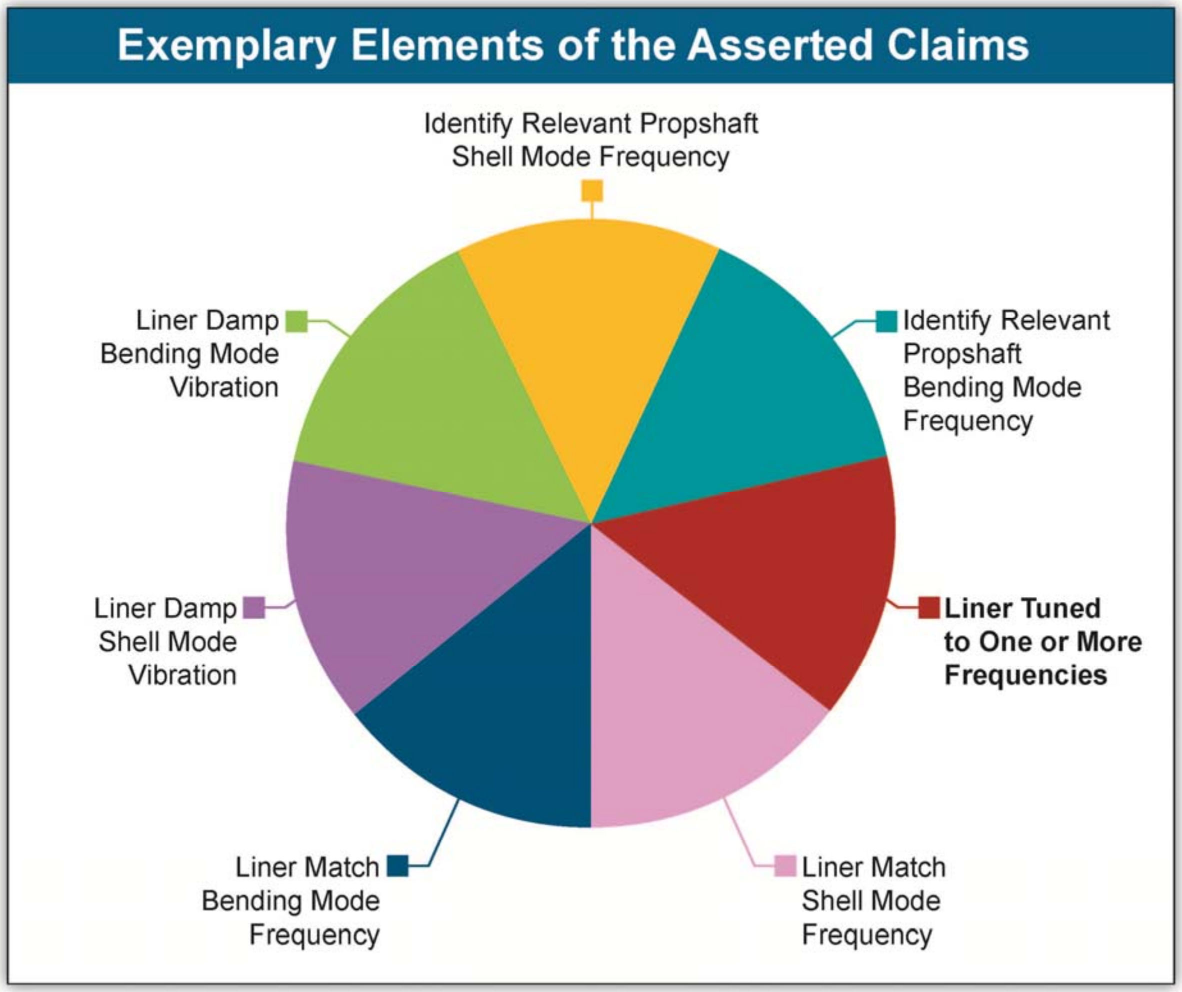
b. The District Court's Conclusion That The Claims Are Directed To Hooke's Law Is Erroneous

i. Hooke's Law Is Far Removed From the Claims And Is Irrelevant To Critical Elements of the Claims

Hooke's law relates to determining the frequency of a simple mass-spring system and, as shown below, is far removed from even determining the frequency of a liner.



Even if Hooke's law could determine a single liner frequency, the claims include many other elements. *See, e.g.*, Appx34-35; Appx1046-1047 (claim 22 requiring "matching," "attenuating shell mode vibrations" and "attenuating bending mode vibrations"; claim 1 requiring "liner . . . configure[d] . . . to match," "damp shell mode vibrations in the shaft member by an amount that is greater than or equal to about 2%" and "configured to damp bending mode vibrations"). This is shown in the demonstrative below.



Hooke's law simply has nothing to do with matching frequencies between multiple different objects (e.g., between a liner and a propshaft), how a liner attenuates different types of vibration (e.g., reactive and resistive attenuation), or damping vibration.

The district court's determination that "[t]here is no dispute that adjusting the mass and stiffness of the liner will change the amount of damping of a certain frequency" is unsupported and demonstrably incorrect. Appx11.[2] Neapco's testing of the Econoline propshaft showed that liners having a frequency that allegedly "matched" a relevant propshaft bending mode frequency *amplified* vibration at that frequency, rather than dampen it. Appx1890-1891; *compare* Appx3096 *and* Appx3088 (addition of liners caused damping at second and third bending modes to decrease (from 0.88% to 0.76% and 1.25% to 1.00%, respectively), which means the liners increased vibration); Appx5217-5218; Appx1887-1888; Appx3417; Appx2822-2823, Appx2828; Appx1659; Appx6223-

[2] The evidence cited by the district court was taken out of context and contradicts its conclusion. Appx11. Specifically, the '911 patent inventor, Dr. Sun, explained that tuning a liner involves "adjusting the controlling variables . . . to get the tuning that is needed." Appx1757. Similarly, American Axle's executive director explained that a liner is tuned "by selection of its physical properties." Appx2547. American Axle's expert, Dr. Rahn, explained that "friction damping is a property of physics experienced by any two surfaces in contact," but nowhere did he suggest that friction damping results from an application of Hooke's law as erroneously concluded by the district court. Appx1930-1931. To the contrary, Dr. Rahn explained that friction damping is unrelated to "tuning a mass and stiffness of at least one liner" and "a liner having characteristics configured to match a relevant frequency." Appx1930.

6224; Appx3051, Appx3060; *supra* Statement of Facts V.A. Thus, even assuming that Hooke's law was used to determine the liner frequency and that it matched a propshaft bending mode, the liner does not necessarily damp the bending mode vibration.

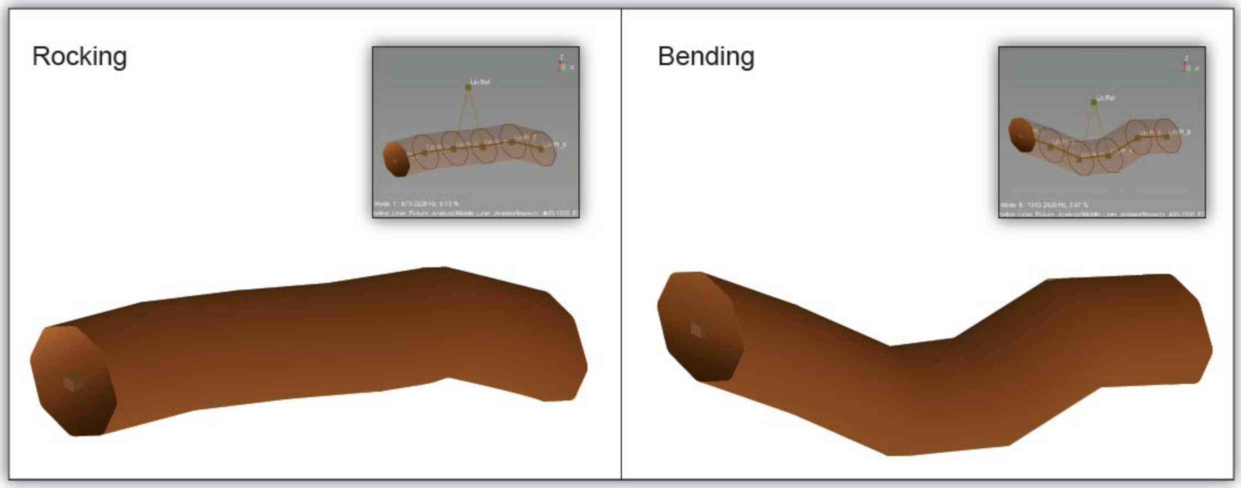
In addition, the specification of the '911 patent describes several "characteristics of the liner 204 [that] can be controlled to tune its damping properties." *Id*. One liner characteristic that can be controlled—"location of the liners 204 within the shaft member 200"—is independent of its structure, e.g., its mass and stiffness. Thus, even assuming *arguendo* that Hooke's law could determine the frequency of a liner, the damping properties of a liner also depend on other unrelated characteristics.

Because Hooke's law fails to explain matching, damping, and attenuation as required by the asserted claims, the district court's conclusion that the claims are "directed to" an "application[] of Hooke's law with the result of friction damping" was erroneous and should be reversed. Appx11.

ii. Neapco's Argument That Hooke's Law Applies Is Incorrect And Contrary To The Record

Neapco's patent eligibility argument is also based on the incorrect assumption that liners are simply single degree of freedom systems and that a single liner frequency can be calculated using Hooke's law. The district court erroneously concluded that "a liner with multiple degrees of freedom may be broken down mathematically into multiple, single degrees of freedom, and Hooke's law can then be applied to each individually." Appx12.

Hooke's law does not determine liner frequencies, because liners cannot be simplified as "[a] single degree of freedom mass spring damper system." Appx4332-4333 (citing Appx1603); Appx1419; Appx1928; Appx2505. Mr. Becker stated that liners are "multi-degree-of-freedom system[s]." Appx1419. Dr. Rahn confirmed his understanding. Appx1928 (explaining that "[t]he liner is not a spring with a single stiffness, it is a complex, distributed object"); Appx2505. When asked at his deposition, Dr. Rahn further explained that liners are "different" than "a single spring and mass" with "this one motion that they can do," and Hooke's law does not apply. Appx2505 (explaining that liners "can bounce, they can rock, they can deform . . . [t]hey can bend"). This is shown in the demonstrative below.



See Appx3157-3158.

The district court did not address Dr. Rahn's testimony and misapprehended the record when it mistakenly concluded that "[t]here is no genuine dispute of material fact that a liner with multiple degrees of freedom may be broken down mathematically into multiple, single degrees of freedom, and Hooke's law can then be applied to each individually." Appx12. Dr. Sun's cited testimony concerned the use of FEA analysis to simplify otherwise complex liners in an effort to model and predict their performance. Appx1767-1773; Appx3202 (comparing physical and FEA results). Indeed, the omitted remainder of Dr. Sun's testimony confirmed that he was discussing FEA modelling. Appx1773. When asked about mathematically simplifying tuned liners, Dr. Sun explained that "[a]ny continuous system" can be broken down or "discretized" into multiple single degrees of freedom, which is the first step in creating an FEA model. Appx1773; Appx1608.

Dr. Sun further testified that Hooke's law does not apply to tuned liners. For example, Dr. Sun testified that, while American Axle occasionally uses sophisticated FEA models during its design process, a liner is not governed simply by Hooke's law. Appx1752.

Neapco's argument that Hooke's law applies to tuned liners is also contradicted by the fact that, like American Axle, Neapco did not simply apply Hooke's law to design its tuned liners. Neapco used experimental modal analysis to measure liner frequencies and propshaft damping.[3] *Supra* Statement of Facts I.E., IV.B.i; Appx1773; Appx2013-2014; Appx2822-2823, Appx2828; Appx3156-3158, Appx3163-3165; Appx5207-5208, Appx5225-5233; Appx2785-2789; Appx2377, Appx2395-2399; Appx2404-2405; Appx7042-7049; Appx6015-6016; Appx6634, Appx6640-6641; Appx6439-6453.

Neapco took this approach because FEA models, which may oversimplify liners in order to employ Hooke's law at some level, do not precisely predict real-

[3] During Neapco's development of the 31XXN liners, for example, Neapco experimentally measured liner frequencies for each of its several prototypes and cataloged the results in a "Driveshaft Liner Tuning Log." Appx6013-6017; *see also* Appx3531; Appx3539. And when addressing shell modes, Neapco did not turn to Hooke's law at all—the engineers were instructed to experimentally test and run FRFs to understand varied liner designs. Appx5944. Neapco did so because it did not "have a good analytical model." *Id*.

world behavior. As Mr. Becker explained: the results from experimental FRF testing and FEA models are typically not the same. Appx1608-1609.

Accordingly, both Neapco and American Axle uses experimental modal analysis—not Hooke's law—to determine liner frequencies and propshaft damping. *Supra* Statement of Facts I.E, IV.B;; Appx1773; Appx2013-2014; Appx2822-2823, Appx2828; Appx3156-3158, Appx3163-3165; Appx5207-5208, Appx5225-5233; Appx2785-2789; Appx2377, Appx2395-2399; Appx2404-2405; Appx7042-7049; Appx6015-6016; Appx6634, Appx6640-6641; Appx6439-6453.

Neapco's testing demonstrably shows that liners are not simple single degree of freedom systems, but rather are complex systems that bend, deform, and have different types of many different natural frequencies. Appx6013-6019; Appx6651-6652; Appx3156-3158, Appx3163-3165. For example, Neapco's internal and external testing shows liners deforming in many different ways and having numerous frequencies in varied and complex shapes, not a single spring-mass frequency like Hooke's law. *Id.*; *supra* Statement of Facts I.D, I.E, IV.B, V.B.

Thus, the district court erred in concluding that Hooke's law applies to the complex multi-tuned liners claimed here.

c. The Plain Language Of The Claims Is Not Directed To Hooke's Law

The district court erred in not considering the claim language and instead "describe[d] the claims at such a high level of abstraction [] untethered from the language of the claims." *Enfish*, 822 F.3d at 1337. In *Enfish*, this Court reversed a district court finding that the claims at issue were directed to an abstract idea for this very reason. Failing to consider the language of the claims themselves is exactly what the Supreme Court cautioned against in the § 101 inquiry. *See e.g.*, *Mayo*, 566 U.S. at 71 (acknowledging that "all inventions at some level embody, use, reflect, rest upon, or apply laws of nature, natural phenomena, or abstract ideas" and strongly cautioning against broadly applying § 101 and "eviscerat[ing] patent law"); *Alice*, 134 S. Ct. at 2354 ("[W]e tread carefully in construing this exclusionary principle lest it swallow all of patent law.").

The plain language of the claims makes clear that the asserted claims are not directed to laws of nature. The claims do not recite or otherwise purport to apply Hooke's law, $\boldsymbol{F_k = kx}$. Appx34-35. A failure to recite the alleged patent-ineligible concept in "the plain claim language" supports a conclusion of patent eligibility. *See CellzDirect*, 827 F.3d at 1050 ("At step one, therefore, it is not enough to merely identify a patent-ineligible concept underlying the claim; we must determine what the claim is 'directed to.'"). In contrast, decisions finding claims directed to patent ineligible laws of nature at step one have involved a recitation of the law of nature itself. *See Mayo*, 566 U.S. at 75-79 (explaining that the claims stated the correlations alleged as laws of nature and providing exemplary claim language as to those correlations).[4]

The district court's opinion erroneously begins with Hooke's law and is devoid of explanation as to how the claim language itself relates to Hooke's law. Appx10-12. Even assuming *arguendo* that Hooke's law is involved at some level in determining liner frequencies, Hooke's law simply does not explain matching, damping, and different types of attenuation, which are required by the claims. *See supra* Argument II.B.2.i; Statement of Facts V.A.. The court fails to mention or discuss these claim requirements. The court's conclusion is therefore at a high level of abstraction that is "untethered from the language of the claims" and should be reversed. *Enfish*, 822 F.3d at 1337.

d. The Claims Do Not Merely Apply Hooke's Law

In addition to not reciting Hooke's law, the claims do not simply apply Hooke's law. At best, applying Hooke's law would determine the frequency of an

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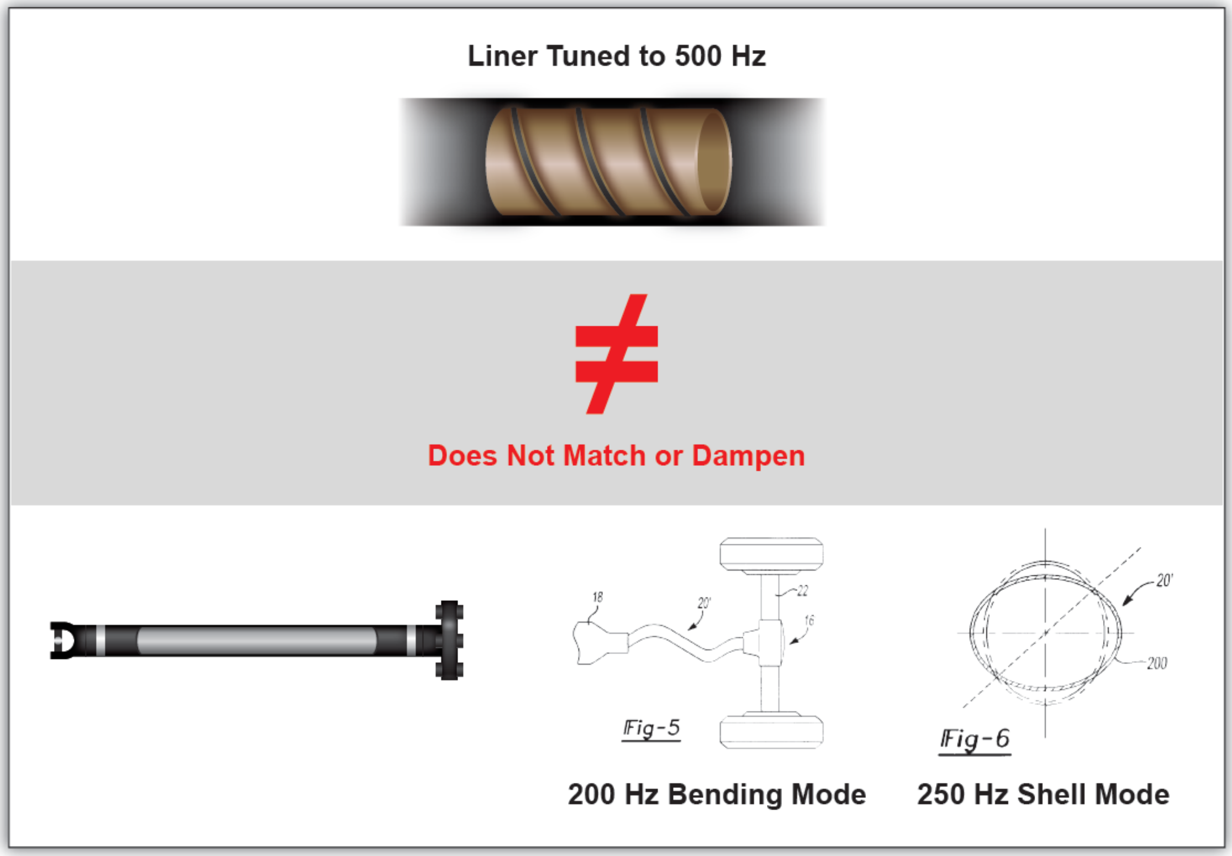
[4] *See also Ariosa Diagnostics, Inc. v. Sequenom, Inc.*, 788 F.3d 1371, 1376 (Fed. Cir. 2015) (claims recited the existence of cffDNA, the alleged natural phenomenon); *Exergen*, 2018 WL 1193529, at *3-4, Appx7249-7250 (claims recited calculating temperature, the alleged natural phenomena); *Genetic Techs. Ltd. v. Merial L.L.C.*, 818 F.3d 1369, 1372 (Fed. Cir. 2016) (claims recited law of linkage disequilibrium as to cDNA sequences); *The Cleveland Clinic Foundation v. True Health Diagnostics LLC*, 359 F.3d 1352, 1356-1358 (Fed. Cir. 2017) (claims recited the existence of MPO enzyme and its correlation to cardiovascular disease).

object. The claims do not merely observe or calculate the frequencies of a liner using Hooke's law.

The asserted claims go much further and are much narrower—they are directed to the use of liners designed to not only match but also damp both propshaft bending and shell mode vibrations. *See supra* Argument II.B.1 (demonstrative figure). As shown below, even assuming a liner were tuned to a particular frequency via an application of Hooke's law, that does not mean that liner will match or damp any relevant propshaft vibration mode.



As shown above, the district court's rationale that Hooke's law can be used to determine a liner frequency does not mean that the liner will match the bending or shell mode of the propshaft (e.g., the liner frequency of 500 Hz does not match the propshaft bending mode at 200 Hz or shell mode at 250 Hz). Even if the liner had a frequency that matched the propshaft vibration modes, such frequency matching is independent of, and does not necessarily result in, propshaft damping. *Supra* Argument II.B.2.i; Statement of Facts V.A. Thus, merely applying Hooke's law to a liner (even assuming tuning were merely an application of Hooke's law) fails to reach the asserted claims.

The asserted claims in this case are therefore very different than in *Mayo*, where the claims at issue recited "steps that must be taken in order to apply the laws in question" and accordingly "the effect is simply to tell doctors to apply the law somehow when treating their patients." *Mayo*, 132 S.Ct. at 1299-1300. The claims at issue here "do more than merely report" or apply a natural law. *See Pernix Ireland Pain DAC v. Alvogen Malta Operations Ltd.*, No. CV 16-139-WCB, 2018 WL 2225113, at *23 (D. Del. May 15, 2018); *see also Vanda*, 887 F.3d, at 1134 (Claims found eligible where they were not "akin to a limitation that tells engineers to apply a known natural relationship or to apply an abstract idea with computers."). American Axle's claims do much more and are directed to methods for manufacturing improved propshafts via specific improved liners for specific improved performance, and are therefore patent eligible.

Even if Hooke's law somehow related to determining a liner frequency, the claims at issue are patent eligible. In *CellzDirect*, this court addressed the eligibility of claims allegedly directed to a law of nature, specifically an ability of hepatocytes to survive multiple freeze-thaw cycles. 827 F.3d at 1048. This Court found that the claims were not directed to that ability. *Id*. (The "end result" of the "method of producing" was "a new and improved way of preserving hepatocyte cells for later use" even if that method did employ a law of nature to create such a result.). This Court further cautioned against finding ineligibility as to claims of this type:

> The '929 patent claims are like thousands of others that recite processes to achieve a desired outcome, e.g., methods of producing things, or methods of treating disease. **That one way of describing the process is to describe the natural ability of the subject matter to undergo the process does not make the claim "directed to" that natural ability.**

Id. at 1047-48. The claims here are a methods for manufacturing that result in a new and improved propshafts with vibration reduction and do so in a new and improved way. Thus even assuming, *arguendo*, that the claims "employ [a] natural discovery" (allegedly tuning liners using Hooke's law) the asserted claims are patent eligible. *Id.* at 1048.

The Supreme Court cautioned that "all inventions at some level embody, use, reflect, rest upon, or apply laws of nature, natural phenomena, or abstract ideas." *Mayo*, 566 U.S. at 71; *Fromson v. Advance Offset Plate, Inc.*, 755 F.2d 1549, 1556 n.3 (Fed. Cir. 1985) ("Only God works from nothing. Men must work with old elements."). The district court's decision disregarded this caution and concluded that claims having an element with some purported relation to a mathematical formula are invalid as patent ineligible. Here, reversal of the district court's decision is required to avoid an unwarranted and dangerous expansion of § 101 to inventions that "have historically been eligible to receive the protection of our patent laws." *Diehr*, 450 U.S. at 184 ("[A] physical and chemical process for molding precision synthetic rubber products falls within the § 101 categories of possibly patentable subject matter."); *Alice*, 134 S. Ct. at 2354 ("[W]e tread carefully in construing this exclusionary principle lest it swallow all of patent law.").

e. The District Court's Conclusions Are Erroneous In View of Its Own Claim Construction

The district court's conclusions are also contradicted by the court's own claim construction order. For example, the court construed tuned reactive absorber to mean:

> a liner having characteristics configured to match a relevant frequency or frequencies to **oscillate in opposition** to vibration energy to cancel out a portion of the vibration energy **to dampen bending mode vibrations**

Appx1047. The claims specifically require that the tuned liner damp bending mode vibration by oscillating in opposition to the propshaft vibration, not by "friction damping." *Compare id.* ("tuned reactive absorber for attenuating bending mode vibrations" *and* ("tuned resistive absorber for attenuating shell mode vibrations"); Appx1604-1605; Appx1250-1251; Appx4661.

In addition to friction damping being irrelevant to this claim element, Hooke's law provides no information regarding whether a liner is oscillating as required by the court's claim construction. *Supra* Statement of Facts I.D, V.A; Argument II.B.2.b.; Appx3156-3158, Appx3163-3165; Appx6013-6019; Appx6651; Appx2076-2077; Appx4036; Appx5218. In order to oscillate in opposition to dampen bending mode vibrations the liner must, for example, involve translation of the liner to effectively couple with the propshaft bending mode. *Id*. Even if Hooke's law somehow was used to determine a liner frequency, it is wholly unrelated and irrelevant to determining the type of liner natural frequency and making sure that the liner not only matches a bending mode frequency but is oscillating in such a way to cancel out a specific bending mode vibration.

Thus, the district court's conclusion that the claims are "directed to" an "application[] of Hooke's law with the result of friction damping" was in error and should be reversed. *Id.*

f. The District Court Applied An Erroneous Legal Standard

The district court also applied an erroneous legal standard finding that the asserted claims did not "disclose" or "instruct how" to design tuned liners. Appx11. There is no such standard, even under § 112, requiring the *claims* of the '911 patent to "instruct ***how*** to design the tuned liners or manufacture the driveline system to attenuate vibrations." *Id*. (emphasis in original). In any event, the Supreme Court has repeatedly cautioned that inquiries under § 112 (or §§ 102 or 103) are not relevant to the § 101 inquiry. *See, e.g., Mayo*, 566 U.S. at 91 ("declining" to "substitute §§ 102, 103, and 112 inquiries for the better established inquiry under § 101").

The case law relied upon by the district court is misplaced and contrary to the Supreme Court's cautions and makes no mention of a requirement that the claims disclose "how" the alleged improvement is achieved at step one of the *Mayo/Alice* inquiry. At most, "how the desired result is achieved" is addressed in analyzing step two, and only in the context of determining the extent to which the claims at issue invoked nonconventional machines to perform the abstract processes. *Electric Power Grp., LLC v. Alston S.A.*, 830 F.3d 1350, 1355 (Fed. Cir. 2016). In analyzing step one, the *Electric Power* court found that "[t]he advance" that the claims purported to make was an abstract idea. *Id*. at 1354.

Even if such a standard were legally proper, the district court ignored that its claim construction includes "how" to tune a liner. The claims as construed require "controlling characteristics," which the specification describes in detail. Appx1046-1047; Appx33-35. Thus, even if the claims must disclose "how" to tune liners or attenuate vibration, the controlling characteristics requirement of the claims as construed meets such a standard.

3. At A Minimum, The District Court Erroneously Ignored Disputed Facts As To Whether the Claims Are Directed to a Law of Nature

To the extent any question exists with regard to step one, American Axle submits that a factual dispute exists regarding the district court's characterization of the asserted claims as applications of a law of nature. Specifically, whether and to what extent the asserted claims are an application of Hooke's law and/or other laws of nature is, at the very least, a disputed question of fact rendering summary judgment improper.

This court has recognized that "[l]ike indefiniteness, enablement, or obviousness, whether a claim recites patent eligible subject matter is a question of law which may contain underlying facts." *Berkheimer v. HP Inc.*, 881 F.3d 1360, 1368 (Fed. Cir. 2018); *see also Aatrix Software, Inc. v. Green Shades Software, Inc.*, 882 F.3d 1121, 1126 (Fed. Cir. 2018). While this Court's decisions in *Berkheimer* and *Aatrix* concerned step two of the *Mayo*/*Alice* inquiry, whether a claim is directed to a patent ineligible natural law under step one may also raise questions of fact. *See, e.g.*, *Berkheimer v. HP Inc.*, 890 F.3d 1369, 1380 (Fed. Cir. 2018) (Reyna, J., dissenting) ("And given our adoption of *Aatrix* and *Berkheimer*, I see no principled reason that would restrain extending a factual inquiry to step one of *Alice*."). This is particularly true given the "considerable overlap between step one and step two." *Amdocs (Israel) Ltd. v. Openet Telecom, Inc.*, 841 F.3d 1288, 1294 (Fed. Cir. 2016); *see also Electric Power*, 830 F.3d at 1353 ("[T]he two stages involve overlapping scrutiny of the content of the claims.").

In this case, genuine issues of material fact exist as to whether and to what extent the claims involve Hooke's law and friction damping. American Axle presented substantial record evidence that the claims are not so directed. Appx4330-4336; Appx6094-6096; Appx6194; Appx7049; Appx1907-1939; Appx6360-6363; *supra* Argument II.B.1-2.; Statement of Facts I.D.

As one example (in addition to the record evidence set forth above), American Axle set forth testimony from both Mr. Becker and Dr. Rahn explaining that Hooke's law did not apply because tuned liners may not be simplified as "[a] single degree of freedom mass spring damper system." Appx4332-4333 (citing Appx1603; Appx1419). Mr. Becker stated that tuned liners are "multi-degree-of-freedom system[s]." Appx1419. Dr. Rahn confirmed his understanding. Appx1928; Appx2505. There were also genuine issues of disputed fact that adjusting the mass and stiffness of a liner will change the damping of a certain frequency. The district court, however, did not address this evidence which, at a minimum, raises disputed facts concerning whether the claims are directed to a natural law. Appx10-12. The district court's determination was therefore in error.

C. *Mayo/Alice* Step Two: The Claims Include Several Inventive Concepts That Were Not Previously Known, Much Less Conventional And Routine

The district court also committed legal error and improperly decided genuine issues of fact with respect to step two of the *Mayo/Alice* test.

1. The Claims Contain Inventive Concepts And Are Not Conventional Or Routine

The asserted claims include inventive concepts that were significant advances in reducing noise and vibration in the propshaft industry, and those inventive concepts were repeatedly acknowledged by Neapco and its engineers. In particular, the asserted claims include at least the following inventive concepts:

- using a cardboard liner to reduce bending mode vibrations;
- using a cardboard liner to reduce bending and shell mode vibrations;
- tuning a cardboard liner by controlling its characteristics;
- controlling the characteristics of a cardboard liner such that it matches and damps bending mode vibrations;

- controlling the characteristics of a cardboard liner such that it damps bending mode vibrations by oscillating in opposition to a specific propshaft bending mode frequency; and
- controlling the characteristics of a cardboard liner such that it matches and damps vibration of multiple different types of propshaft vibration, e.g., both bending and shell mode vibrations.

As set forth in more detail below, the asserted claims are patent eligible because these inventive concepts were neither routine nor common in the industry. *See Exergen*, 2018 WL 1193529, at *3-4, Appx7249-7250 (Inventive concepts existed where the elements were "not conventional, routine, and well-understood" and "simply being known in the art did not suffice to establish that the subject matter was not eligible for patenting."); *Hitkansut*, 130 Fed. Cl. at 382 (Inventive concepts existed even where the claims "rely on [a mathematical formula] in an inventive manner to process materials more efficiently."); *CellzDirect*, 827 F.3d at 1050 (Inventive concepts existed where the claims "recite an improved process" and "the benefits of the improved process over the prior art methods are significant.").

Neapco admitted that tuning liners to attenuate bending mode vibrations, as well as tuning liners generally, was **unknown** (much less routine or conventional) prior to American Axle's patented invention. Appx1327; Appx1309; Appx23.

Throughout Neapco's design and the development of tuned liners, Neapco engineers repeatedly recognized the inventiveness of tuning liners. For example, instead of looking to the prior art, Neapco turned to American Axle's patent in attempting to provide the tuned liners requested by GM. Appx825; Appx3281; Appx3510-3511; Appx780; Appx4203; Appx1918-1922; *supra* Statement of Facts IV.B. At that time, Neapco admitted that it did not already know how to tune liners. Appx1913-1918; Appx1327; Appx1309. Neapco also admitted that American Axle's tuned liners were inventive and solved how to damp both bending and shell mode vibrations. Appx3513; Appx3510-3511.

In addition to this overwhelming evidence from Neapco, there is significant other evidence that the asserted claims include inventive concepts. For example, untuned liners were previously used to provide general broadband damping of shell mode vibrations, but were ineffective at reducing and, in some instances, may even *amplify* bending mode vibrations. Appx30; Appx3500-3502; Appx5217-5218; Appx1887-1891; Appx3417; Appx2822-2823, Appx2828; *supra* Statement of Facts II. "Slip yoke dampers," "internal tuned dampers," and plugs were previously used to damp bending mode vibrations or torsion mode vibrations, but each were ineffective at reducing shell mode vibrations. Appx30; Appx3504-3505; Appx3417-3422; Appx1967-1968; *supra* Statement of Facts II. The prior art therefore fails to establish and teaches away from inventive concepts of the '911 patent, for example, using liners for bending modes, tuning liners to bending modes, and tuning liners to multiple different vibration modes, all of which were not known, much less conventional, in the art.

Thus, the asserted claims contain patent eligible inventive concepts that were not known in the art, let alone "conventional, routine, and well-understood" and reduce propshaft vibration "in a novel manner to engender more efficient results." *See Exergen*, 2018 WL 1193529, at *3-4, Appx7249-7250; *Hitkansut*, 130 Fed. Cl. at 382; *see also CellzDirect*, 827 F.3d at 1050-51.

2. The District Court Erroneously Found That Tuned Liners Are Conventional and Routine

The district court's determination that tuned liners are conventional and routine was clear error. Appx14-17.

a. The District Court Erroneously Found That Tuning Limitations Are Merely Applications of Hooke's Law

First, the district court erroneously found that the tuning limitations did not contain inventive concepts because they were "just the application of Hooke's law." Appx15. The district court also erred in finding that those limitations do nothing more than suggest to an engineer to "consider that law of nature when designing propshaft liners to attenuate driveline vibrations." Appx15.

Hooke's law has nothing to do with liners, propshafts, matching frequencies of any two objects, or attenuating vibration. *Supra* Argument II.B.2.b. The claimed "tuning limitations" are ***inventive*** and are not merely applications of Hooke's law. *Id.* At most, Hooke's law relates to the frequency of a mass-spring system. *Id*.

Moreover, there is no evidence that the prior art used or considered Hooke's law to tune liners and the claims are patent eligible on that basis. *See Bascom Glob. Internet Servs., Inc. v. AT&T Mobility LLC*, 827 F.3d 1341, 1350 (Fed. Cir. 2016) ("The inventive concept inquiry requires more than recognizing that each claim element, by itself, was known in the art."); *Exergen*, 2018 WL 1193529, at *3-4, Appx7249-7250 (requiring the claim limitations to be known as well as conventional and routine to negate existence of inventive concepts). Even if the claims are considered to apply Hooke's law at some level, the district court erroneously used the asserted claims in hindsight to find that the new and improved limitations were routine and conventional. *See Diehr*, 450 U.S. at 192 (finding claims applying a mathematical formula are patent eligible where they "transform[] . . . an article to a different state or thing"); *CellzDirect*, 827 F.3d at 1050-51 (finding claims patent eligible at step two where application of a natural law was used to "improve existing methods"); *Hitkansut*, 130 Fed. Cl. at 382, (finding claims patent eligible where they "rely on [a mathematical formula] in an inventive manner to process materials more efficiently").

b. The District Court Erred In Finding Ineligibility Despite Neapco's Failure To Argue Or Establish That The Claims Were Conventional And Routine

Second, Neapco did not specifically allege that tuned liners were conventional or routine, but rather argued only that: (1) the tuning limitations are merely applications of natural laws; and (2) "each of the limitations separately and as a whole are taught by the prior art." *See* Appx1602-1606; Appx2707; Appx6208. Neapco's argument that the tuning limitations are merely applications of natural laws fails for the reasons set forth above and its argument that the claim limitations (separately and as a whole) are taught by the prior art also fails.

As set forth above, the claimed tuned liners were unknown prior to the '911 patent. *Supra* Statement of Facts II-IV; Argument II.C.1. Moreover, the mere existence in the prior art (even if true) does not rise to the level of conventional or routine for the purpose of determining whether the claims contain an inventive concept. *Bascom*, 827 F.3d at 1350; *Exergen*, 2018 WL 1193529, at *3-4, Appx7249-7250. Because none of the prior art discloses or discusses tuning liners, much less shows that tuning liners to multiple different propshaft vibration modes was conventional and routine, Neapco failed to establish that tuned liners were conventional or routine as a matter of law. *See CellzDirect*, 827 F.3d at 1051 (Although individual claim steps "were well known," repeating a step where the prior art taught away from doing so was an inventive concept.).

Thus, the district court erred in finding ineligibility in absence of any evidence supporting Neapco's burden to establish that the claims were well-understood, conventional, or routine. 35 U.S.C. § 282; *see also Alice*, 717 F.3d at 1284, 1304-05.

c. The District Court Erroneously Found That Tuning Liners Was An Inherent Part Of Any Design Process

Third, the district court erred finding that tuning liners to multiple different vibration modes was an inherent part of any design process. Appx15. While controlling characteristics of *untuned* liners may have been "an inherent part of any design process," the concept of controlling characteristics of a liner to **match and damp** multiple different vibration modes was not known or part of any design process prior to the invention of the '911 patent. *Supra* Statement of Facts II-IV; Argument II.C.1, II.C.2.b. Neapco admitted that tuning was new and that it had never tuned liners before the accused products in this case. Appx1327; Appx1309.

In *CellzDirect*, this Court addressed and found eligible a claimed process where "[t]he individual steps of freezing and thawing were well known, but a process of preserving hepatocytes by repeating those steps was far from routine." 827 F.3d at 1051. Here, there is simply no evidence that anyone ever controlled the characteristics of a liner to match and damp bending modes, let alone multiple different propshaft vibration modes, prior to the '911 patent. The district court's finding that this was inherent in the design process of all liners is therefore unsupported and erroneous, and the claims are patent eligible.

d. The District Court Erroneously Found That Dual Tuned Liners Are A Result Rather Than An Active Step In the Claimed Method For Manufacturing

Fourth, the district court erred in finding that specifically controlling the characteristics of a liner to match and damp multiple different vibration modes is somehow a result instead of steps of the method for manufacturing. Appx15-16. Claim 1, however, expressly requires the step of "tuning at least one liner to attenuate at least two types of vibration," which, as construed, requires specifically designing the liner by controlling its characteristics (e.g., length, width, interference fit, location, etc.). *Supra* Statement of Facts III; Argument II.B.1. Controlling characteristics of a liner is an active step in the claimed method rather than merely a result. The claims therefore include inventive concepts and are patent eligible. *See Diehr*, 450 U.S. at 191; *CellzDirect*, 827 F.3d at 1050-51; *Hitkansut*, 130 Fed. Cl. at 382.

e. The District Court Erroneously Found The Claims Do Not Disclose a Discrete Liner Design

Finally, the district court erred in finding that the claims were patent ineligible because they allegedly did not disclose a specific discrete liner design. Appx16-17. The '911 patent specifically teaches how to control the characteristics of a liner to not only match but damp relevant propshaft vibrations, including the thickness of the liner, the interference fit, the location of the liner, and numerous others. Appx33. But every propshaft is different and has different vibration mode frequencies. *Supra* Statement of Facts I.B-E; IV.B; Argument II.B.2.i-ii. Requiring one specific "discrete" liner design to apply to all propshafts is impossible and improper as a matter of law.

The district court's reliance on *Electric Power*, which addresses data analysis and detection methods, is misplaced and far removed from the methods for manufacturing at issue here. 830 F.3d at 1351.[5, 6] Moreover, the claims at issue here do specify how the claimed result is achieved—designing liners that are tuned to match and damp both bending and shell modes are required to achieve the claimed bending and shell mode vibration reductions. *See id.* at 1355 (claims

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[5] *Electric Power* was distinguished on exactly these grounds in *Trading Tech. Int'l, Inc. v. CQG, INC.*, where this Court characterized *Electric Power* as addressing ineligible claims that "generally lack steps or limitations specific to a solution of a problem, or improvement in the functioning of technology." 675 Fed. Appx. 1001, 1005 (Fed. Cir. 2017) (nonprecedential); Appx7260-7264. By contrast, "specific technologic modifications to solve a problem or improve the functioning of a known system generally produce patent-eligible subject matter" (e.g., using tuned liners to reduce bending mode vibrations) and constitute inventive concepts. *See id*. at 1004-1005.

[6] *McRO, Inc. v. Bandai Namco Games Am. Inc.*, also relied on by the district court, does not address step two and supports a finding of patent eligibility here. 837 F.3d 1299, 1314 (Fed. Cir. 2016) (Claims ineligible only where they are "directed to a result … that itself is the abstract idea."). Unlike *McRO*, the specific and improved result claimed here is not a law of nature but rather the reduction of multiple types of propshaft vibration. *See* Argument II.B.

merely required "selection and manipulation of information" without requiring an "arguably inventive set of components or methods, such as measurement devices or techniques").

3. At A Minimum, The District Court Erroneously Ignored Disputed Facts

American Axle submits that the asserted claims include inventive concepts, but at a minimum, factual disputes exist regarding the district court's characterization of the asserted claims as well-understood, conventional, and routine. *See Berkheimer*, 881 F.3d at 1368; *Aatrix*, 882 F.3d at 1128.

The district court summarily concluded in a footnote without any support that there were no disputed facts that "the tuning limitations are non-inventive applications of Hooke's law." Appx14. There are, however, genuine issues of material fact as to whether the asserted claims are well-understood, conventional, or routine and whether the claims are non-inventive applications of Hooke's law. American Axle presented substantial record evidence that the claims are not. *E.g.*, Appx4334-4335; Appx1910-1925, Appx1931-1939; *supra* Argument II.C.1-2. For example, American Axle presented testimony and evidence from Neapco characterizing tuned liners as new and inventive. Appx1327, Appx1309; Appx3513; Appx3510; Appx4335. In addition, American Axle's expert, Dr. Rahn, provided expert opinion and supporting evidence that the asserted claims include inventive concepts. Appx1907-1939; Appx6432-6435.

Nowhere in its step two opinion does the court address any of this underlying evidence, which, at a minimum, raises disputed facts concerning whether the claims are well-understood, routine, and conventional. *See Graham v. John Deere Co. of Kansas City*, 383 U.S. 1, 17 (1966) (describing the "basic factual inquiries" underlying an obviousness determination); *Mayo*, 566 U.S. at 90 ("We recognize that, in evaluating the significance of additional steps, the § 101 patent-eligibility inquiry and, say, the § 102 novelty inquiry might sometimes overlap."). There are therefore, at a minimum, disputed issues of fact and the case should at the very least be remanded for further proceeding.

D. THE DISTRICT COURT ERRED IN IGNORING LACK OF PREEMPTION ARGUMENTS SUPPORTING PATENT ELIGIBILITY

American Axle presented significant evidence that the asserted claims present minimal risk of preemption, much less preempting Hooke's law or friction damping in their entirety. For example, American Axle's expert, Dr. Rahn, opined that there are "myriad applications" of Hooke's law and friction damping not covered by the asserted claims. Appx1928-1929. Neapco agreed—its expert, Mr. Becker admitted that Hooke's law applies to many different devices that were not covered by the asserted claims. Appx1603-1604; Appx4660-4661; Appx1928.

The district court did not consider and disregarded these preemption arguments as moot, relying on *Ariosa*. Appx17. This was erroneous in view of the arguments *supra*—including that the claims do not apply Hooke's law, but rather are directed to methods of manufacturing improved propshafts and include inventive concepts.

In addition, *Ariosa*—where the claims at issue were "directed to an application that **starts and ends** with a naturally occurring phenomenon," 788 F.3d at 1378—cannot be read to sanction side-stepping the preemption analysis as the district court did here. The Supreme Court has repeatedly "described the concern that drives the exclusionary principle" of § 101 as "one of pre-emption." *Alice*, 134 S. Ct. at 2354; *id*. at 2355, 2358; *Mayo*, 132 S. Ct. at 1294; *Bilski*, 130 S. Ct. at 3218; *Diehr*, 101 S.Ct. at 1057. In *Diehr*, for example, the Supreme Court distinguished a prior case, *Parker v. Flook*, on preemption grounds:

> In contrast, the respondents here do not seek to patent a mathematical formula. Instead, they seek patent protection for a process of curing synthetic rubber. Their process admittedly employs a well-known mathematical equation, but **they do not seek to pre-empt the use of that equation**. Rather, they seek only to foreclose from others the use of that equation in conjunction with all of the other steps in their claimed process.

101 S.Ct. at 1057.

In the present case, American Axle's substantial evidence of a lack of preemption supports the conclusion that the asserted claims are not directed to a law of nature and contain inventive concepts. Unlike *Ariosa*, the asserted claims in the present case do not begin and end with Hooke's law or friction damping. And unlike *Flook*, American Axle does not "seek to patent a mathematical formula" such as Hooke's law. *Diehr*, 101 S.Ct. at 1057.

Instead, the present claims are akin to those found eligible in *Diehr* and present an even stronger case for eligibility. The present claims involve a specific technology improvement to methods for manufacturing physical devices (propshafts) with improved physical characteristics (reduced vibration) and do not purport to apply Hooke's law. *See supra* Argument II.B.1. To the extent Hooke's law and friction damping apply at all, the present claims do not broadly relate to those natural laws and American Axle "seek[s] only to foreclose from others the use of [those natural laws] in conjunction with all of the other steps in their claimed process." *Id*.

The district court erred when it disregarded of "the pre-emption concern that undergirds [] § 101 jurisprudence." *Alice*, 134 S. Ct. at 2358. The claims are patent eligible.

CONCLUSION AND STATEMENT OF RELIEF SOUGHT

The district court erred in granting summary judgment of invalidity under Section 101. Judgment should be reversed and the case remanded for further proceedings.

June 29, 2018

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ADDENDUM

ADDENDUM

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IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

AMERICAN AXLE & MANUFACTURING, INC.,	:	
Plaintiff,	:	
v.	:	C.A. No. 15-1168-LPS
NEAPCO HOLDINGS LLC and NEAPCO DRIVELINES LLC,	:	
Defendants.	:	

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MEMORANDUM OPINION

February 27, 2018
Wilmington, Delaware

STARK, U.S. District Judge:

Pending before the Court in this patent infringement action are the following motions:

(i) Plaintiff American Axle & Manufacturing, Inc.'s ("AAM" or "Plaintiff") Motion for Summary Judgment of Infringement (D.I. 155; *see also* D.I. 206);

(ii) AAM's Motion for Summary Judgment of No Invalidity Pursuant to 35 U.S.C. §§ 101 and 102 (as to the Laskey Reference) (D.I. 159; *see also* D.I. 206);

(iii) AAM's Motion to Exclude Portions of the Testimony of Neapco's Technical Expert, Steven Becker, and Neapco's Damages Expert, Michael Chase (D.1. 157; *see also* D.I. 206);

(iv) Defendants Neapco Holdings LLC and Neapco Drivelines LLC's (collectively, "Neapco" or "Defendants") Motion for Summary Judgment of Invalidity and/or Non-Infringement (D.I. 149);

(v) Neapco's Supplemental Motion for Summary Judgment of Invalidity and/or Non-Infringement as to the New Claims (D.I. 207); and

(vi) Neapco's Motion to Preclude Certain Expert Testimony and Evidence (D.I. 208).

I. BACKGROUND

AAM filed suit against Neapco on December 18, 2015, alleging infringement of U.S. Patent Nos. 7,774,911 (the "'911 patent"), 8,176,613 (the "'613 patent"), and 8,528,180 (the "'180 patent"). (*See* D.I. 1) The pending motions are principally (if not entirely) addressed to the '911 patent.

The '911 patent "generally relates to shaft assemblies for transmitting rotary power in a driveline and more particularly to a method for attenuating driveline vibrations transmitted through a shaft assembly." ('911 patent col. 1:4-7) The reason for attenuating such vibrations is to reduce the tonal noise that can be heard by occupants in the vehicle as a result of the vibrations. (*See id.* col. 1:8-23) "Modern automotive propshafts are commonly formed of relatively thin-walled steel or aluminum tubing and as such, can be receptive to various driveline excitation sources," which "can typically cause the propshaft to vibrate in a bending (lateral) mode, a torsion mode and a shell mode." (*Id.* col. 1:39-44) Several techniques existed in the prior art "to attenuate vibrations in propshafts including the use of weights and liners." (*Id.* col. 1:53-54) However, many of the prior art liners only attenuate shell mode vibrations and not also bending or torsion mode vibrations. (*See id.* col. 2:34-38) The '911 patent purports to provide "an improved method for damping various types of vibrations in a hollow shaft," which facilitates the damping of shell mode vibration as well as bending mode vibration and/or torsion mode vibration. (*Id.* col. 2:40-43)

On April 7, 2017, the Court issued its Claim Construction Opinion (D.I. 113), which found certain claims of the '911 patent indefinite.

On August 11, 2017, the parties filed motions with respect to the claims that remained asserted after the Court's Claim Construction Opinion. In particular, the motions were directed to '911 patent claims 22-24, 26, 27, 31, and 34-36 (the "Original Claims"). (D.I. 149, 155, 157, 159) The parties completed briefing on their initial motions on September 15, 2017.

In the meantime, on September 6, 2017, the Court granted AAM's motion for reconsideration of the Claim Construction Opinion, finding that new evidence demonstrated that Defendants had failed to prove that any of the claims of the '911 patent were indefinite. (D.I. 180) The Court then ordered the parties to submit supplemental briefing to address how the pending motions might apply to the claims that had been initially invalidated as indefinite, but were now newly-revived in the case. In particular, the supplemental briefing relates to claims 1-6, 12, 13, and 19-21 of the '911 patent (the "New Claims," and collectively with the Original Claims, the "Asserted Claims"). (D.I. 188) The parties submitted supplemental briefs and motions on December 1, 2017 and responsive briefs on December 18, 2017.

Collectively, the parties filed a total of 287 pages of briefing in relation to their many motions. The Court heard oral argument on January 18, 2018. (D.I. 217 "("Tr."))

Independent claim 22 is representative of the Original Claims and reads:

> A method for manufacturing a shaft assembly of a driveline system, the driveline system further including a first driveline component and a second driveline component, the shaft assembly being adapted to transmit torque between the first driveline component and the second driveline component, the method comprising:
>
> providing a hollow shaft member;
>
> tuning a mass and a stiffness of at least one liner; and
>
> inserting the at least one liner into the shaft member;
>
> wherein the at least one liner is a tuned resistive absorber for attenuating shell mode vibrations and wherein the at least one liner is a tuned reactive absorber for attenuating bending mode vibrations.

Independent claim 1 is representative of the New Claims and reads:

> A method for manufacturing a shaft assembly of a driveline system, the driveline system further including a first driveline component and a second driveline component, the shaft assembly being adapted to transmit torque between the first driveline component and the second driveline component, the method comprising:

> providing a hollow shaft member;
>
> tuning at least one liner to attenuate at least two types of vibration transmitted through the shaft member; and
>
> positioning the at least one liner within the shaft member such that the at least one liner is configured to damp shell mode vibrations in the shaft member by an amount that is greater than or equal to about 2%, and the at least one liner is also configured to damp bending mode vibrations in the shaft member, the at least one liner being tuned to within about ±20% of a bending mode natural frequency of the shaft assembly as installed in the driveline system.

II. LEGAL STANDARDS

Under Rule 56(a) of the Federal Rules of Civil Procedure, "[t]he court shall grant summary judgment if the movant shows that there is no genuine dispute as to any material fact and the movant is entitled to judgment as a matter of law." The moving party bears the burden of demonstrating the absence of a genuine issue of material fact. *See Matsushita Elec. Indus. Co., Ltd. v. Zenith Radio Corp.*, 475 U.S. 574, 585-86 (1986). An assertion that a fact cannot be – or, alternatively, is – genuinely disputed must be supported either by "citing to particular parts of materials in the record, including depositions, documents, electronically stored information, affidavits or declarations, stipulations (including those made for purposes of the motion only), admissions, interrogatory answers, or other materials," or by "showing that the materials cited do not establish the absence or presence of a genuine dispute, or that an adverse party cannot produce admissible evidence to support the fact." Fed. R. Civ. P. 56(c)(1)(A) & (B). If the moving party has carried its burden, the nonmovant must then "come forward with specific facts showing that there is a genuine issue for trial." *Matsushita*, 475 U.S. at 587 (internal quotation marks omitted). The Court will "draw all reasonable inferences in favor of the nonmoving party, and it may not make credibility determinations or weigh the evidence." *Reeves v. Sanderson Plumbing Prods., Inc.*, 530 U.S. 133, 150 (2000).

To defeat a motion for summary judgment, the nonmoving party must "do more than simply show that there is some metaphysical doubt as to the material facts." *Matsushita*, 475 U.S. at 586; *see also Podobnik v. U.S. Postal Serv.*, 409 F.3d 584, 594 (3d Cir. 2005) (stating party opposing summary judgment "must present more than just bare assertions, conclusory allegations or suspicions to show the existence of a genuine issue") (internal quotation marks omitted). The "mere existence of some alleged factual dispute between the parties will not defeat an otherwise properly supported motion for summary judgment;" a factual dispute is genuine only where "the evidence is such that a reasonable jury could return a verdict for the nonmoving party." *Anderson v. Liberty Lobby, Inc.*, 477 U.S. 242, 247-48 (1986). "If the evidence is merely colorable, or is not significantly probative, summary judgment may be granted." *Id.* at 249-50 (internal citations omitted); *see also Celotex Corp. v. Catrett*, 477 U.S. 317, 322 (1986) (stating entry of summary judgment is mandated "against a party who fails to make a showing sufficient to establish the existence of an element essential to that party's case, and on which that party will bear the burden of proof at trial"). Thus, the "mere existence of a scintilla of evidence" in support of the nonmoving party's position is insufficient to defeat a motion for summary judgment; there must be "evidence on which the jury could reasonably find" for the nonmoving party. *Anderson*, 477 U.S. at 252.

III. DISCUSSION

As explained below, the Court has determined that the Asserted Claims are not directed to patentable subject matter. Therefore, the Court will rule only on the motions implicating 35

U.S.C. § 101. The Court will deny as moot all other motions that address only the '911 patent – the motions relating to infringement and invalidity of the Asserted Claims of the '911 patent – and will defer ruling on the remaining motions until after conferring with the parties on how the case should now proceed.[1]

A. Section 101: Applicable Law

The parties have filed cross-motions for summary judgment on the issue of patent eligibility under 35 U.S.C. § 101. (*See* D.I. 149, 159) The Court will address both motions together.

Under 35 U.S.C. § 101, "[w]hoever invents or discovers any new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof, may obtain a patent therefor, subject to the conditions and requirements of this title." There are three exceptions to § 101's broad patent-eligibility principles: "laws of nature, physical phenomena, and abstract ideas." *Diamond v. Chakrabarty*, 447 U.S. 303, 309 (1980). "Whether a claim recites patent eligible subject matter is a question of law which may contain disputes over underlying facts." *Berkheimer v. HP Inc.*, ___ F.3d ___, 2018 WL 774096, at *6 (Fed. Cir. Feb. 8, 2018).

In *Mayo Collaborative Services v. Prometheus Laboratories, Inc.*, 132 S. Ct. 1289 (2012), the Supreme Court set out a two-step "framework for distinguishing patents that claim

[1]At the hearing, Neapco advised the Court they did not think the Court would need to resolve infringement issues if it determined the patent is not eligible for patentability. (*See* Tr. at 54) While AAM stated it preferred the Court to rule on all the issues before it, AAM recognized that the Court could exercise its discretion on this matter. (*See id.* at 74) It appears that the only motion that may arguably remain ripe is AAM's motion to preclude Neapco's damages expert, Mr. Chase. (D.I. 157)

laws of nature, natural phenomena, and abstract ideas from those that claim patent-eligible applications of those concepts." *Alice Corp. Pty. Ltd. v. CLS Bank Int'l*, 134 S. Ct. 2347, 2355 (2014). First, courts must determine if the claims at issue are directed to a patent-ineligible concept ("step one"). *See id.* If so, the next step is to look for an "'inventive concept' – *i.e.*, an element or combination of elements that is sufficient to ensure that the patent in practice amounts to significantly more than a patent upon the [ineligible concept] itself" ("step two"). *Id.* The two steps are "plainly related" and "involve overlapping scrutiny of the content of the claims." *Elec. Power Grp., LLC v. Alstom S.A.*, 830 F.3d 1350, 1353 (Fed. Cir. 2016).

At step one, "the claims are considered in their entirety to ascertain whether their character ***as a whole*** is directed to excluded subject matter." *Internet Patents Corp. v. Active Network, Inc.*, 790 F.3d 1343, 1346 (Fed. Cir. 2015) (emphasis added); *see also Affinity Labs of Texas, LLC v. DIRECTV, LLC*, 838 F.3d 1253, 1257 (Fed. Cir. 2016) (stating first step "calls upon us to look at the 'focus of the claimed advance over the prior art' to determine if the claim's 'character as a whole' is directed to excluded subject matter").

Courts should not "oversimplif[y]" key inventive concepts or "downplay" an invention's benefits in conducting a step one analysis. *See Enfish, LLC v. Microsoft Corp.*, 822 F.3d 1327, 1337-38 (Fed. Cir. 2016); *see also McRO, Inc. v. Bandai Namco Games Am. Inc.*, 837 F.3d 1299, 1313 (Fed. Cir. Sept. 13, 2016) ("[C]ourts 'must be careful to avoid oversimplifying the claims' by looking at them generally and failing to account for the specific requirements of the claims.") (quoting *In re TLI Commc'ns LLC Patent Litig.*, 823 F.3d 607, 611 (Fed. Cir. 2016)). "Whether at step one or step two of the *Alice* test, in determining the patentability of a method, a court must look to the claims as an ordered combination, without ignoring the requirements of the individual steps." *McRO*, 837 F.3d at 1313.

At step two, courts must "look to both the claim as a whole and the individual claim elements to determine whether the claims contain an element or combination of elements that is sufficient to ensure that the patent in practice amounts to significantly more than a patent upon the ineligible concept itself." *Id.* at 1312 (internal brackets and quotation marks omitted). The "standard" step two inquiry includes consideration of whether claim elements "simply recite 'well-understood, routine, conventional activit[ies].'" *Bascom Glob. Internet Servs., Inc. v. AT&T Mobility LLC*, 827 F.3d 1341, 1350 (Fed. Cir. 2016) (quoting *Alice*, 134 S. Ct. at 2359). "Simply appending conventional steps, specified at a high level of generality, [is] not ***enough*** to supply an inventive concept." *Alice*, 134 S. Ct. at 2357 (internal quotation marks omitted) (emphasis in original).

However, "[t]he inventive concept inquiry requires more than recognizing that each claim element, by itself, was known in the art." *Bascom*, 827 F.3d at 1350. In *Bascom*, the Federal Circuit held that "the limitations of the claims, taken individually, recite generic computer, network and Internet components, none of which is inventive by itself," but nonetheless determined that an ***ordered combination*** of these limitations was patent-eligible under step two. *Id.* at 1349. The Federal Circuit has looked to the claims as well as the specification in performing the "inventive concept" inquiry. *See Affinity Labs of Texas, LLC v. Amazon.com Inc.*, 838 F.3d 1266, 1271 (Fed. Cir. 2016) ("[N]either the claim nor the specification reveals any concrete way of employing a customized user interface.").

The Federal Circuit recently elaborated on the step two standard, stating that "[t]he question of whether a claim element or combination of elements is well-understood, routine and conventional to a skilled artisan in the relevant field is a question of fact. Any fact, such as this one, that is pertinent to the invalidity conclusion must be proven by clear and convincing evidence." *Berkheimer*, 2018 WL 774096, at *5; *see also Aatrix Software, Inc. v. Green Shades Software, Inc.*, ___ F.3d ___, 2018 WL 843288, at *5 (Fed. Cir. Feb. 14, 2018) ("While the ultimate determination of eligibility under § 101 is a question of law, like many legal questions, there can be subsidiary fact questions which must be resolved en route to the ultimate legal determination."); *Automated Tracking Sols., LLC v. Coca-Cola Co.*, ___ Fed. Appx. ___, 2018 WL 935455, at *5 (Fed. Cir. Feb. 16, 2018) ("We have held that 'whether a claim element or combination of elements is well-understood, routine and conventional to a skilled artisan in the relevant field is a question of fact.'") (quoting *Berkheimer*, 2018 WL 774096, at *5). "Whether a particular technology is well-understood, routine, and conventional goes beyond what was simply known in the prior art. The mere fact that something is disclosed in a piece of prior art, for example, does not mean it was well-understood, routine, and conventional." *Berkheimer*, 2018 WL 774096, at *6. "When there is no genuine issue of material fact regarding whether the claim element or claimed combination is well-understood, routine, [and] conventional to a skilled artisan in the relevant field, this issue can be decided on summary judgment as a matter of law." *Id.*

B. Step One

With respect to step one, the issue presented is whether the Asserted Claims as a whole are directed to laws of nature: Hooke's law and friction damping. AAM does not dispute that Hooke's law is the linear relationship between force F and displacement x of a spring with stiffness k, specifically $F=kx$. (*See* D.I. 160 at 6; D.I. 160-4 at ¶ 389) AAM also does not dispute that the frequency is affected by a change in mass *m* or stiffness *k*. (*See* D.I. 150 at 29-30; D.I. 151 at 496 (inventor Sun testifying frequency is changed by adjusting mass and stiffness); D.I. 153 at 142 (AAM executive director testifying, "the natural frequency is strictly a function of stiffness and mass"); D.I. 160 at 6) Furthermore, AAM's expert stated that friction damping, or the reduction in friction, "is a property of physics experienced by any two surfaces in contact." (D.I. 172 at 6 (quoting D.I. 160-4 at ¶ 396); *see also* D.I. 150 at 30-31)

Neapco argues, "[t]he Asserted Claims do nothing more than use a prior art liner design (*e.g.*, cardboard having, for certain embodiments, elastomer winding) and apply (or just characterize) the physics behind 'tuning' and vibration attenuation or damping." (D.I. 150 at 28) Therefore, Neapco asserts, in order to "tune" the liner, one merely applies Hooke's law and then measures the amount of damping. (*See* D.I. 150 at 29; Tr. at 53)

The Court agrees with Neapco. There is no dispute that adjusting the mass and stiffness of the liner will change the amount of damping of a certain frequency. The claimed methods are applications of Hooke's law with the result of friction damping. (*See, e.g.*, D.I. 151 at 496 (inventor Sun testifying that "tuning" is "basic physics"))

AAM's arguments to the contrary are unavailing. AAM contends that the Asserted Claims are patent-eligible because they are directed to industrial processes for manufacturing very large automotive components, rather than any law of nature or natural phenomenon. (*See* D.I. 160 at 5; Tr. at 21 (arguing "[m]ethod of manufacturing a prop shaft is not some law of nature")) But the Asserted Claims do not disclose a method of manufacturing a propshaft; instead, considered as a whole, they are directed to the mere application of Hooke's law, and they fail to instruct ***how*** to design the tuned liners or manufacture the driveline system to attenuate vibrations. *See Elec. Power*, 830 F.3d at 1355-56 (discussed further in step two). AAM's other argument – that the tuned liners in the propshaft make up a complex system with multiple degrees of freedom, so Hooke's law, which relates to "a very simple spring and mass," does not apply (*see* D.I. 160 at 6; Tr. at 22) – also fails. There is no genuine dispute of material fact that a liner with multiple degrees of freedom may be broken down mathematically into multiple, single degrees of freedom, and Hooke's law can then be applied to each individually. (*See, e.g.*, D.I. 151 at 512 (inventor Sun testifying, "a tunable liner theoretically or mathematically can be simplified as just single degree[s] of freedom[] of mass spring systems," and if one breaks down each of the modes, "they're all a combination of [] single degree[s] of freedom[]"); D.I. 173-1 at 45 (Neapco's expert explaining if one has a multi-degree of freedom system, then "you're going to be applying Hooke's Law in a couple of axes"))

Looking at the "focus" of the claims and their "character as a whole," *Elec. Power*, 830 F.3d at 1353, Neapco has met its burden at step one.

C. Step Two

A claimed method "is not unpatentable simply because it contains a law of nature or a mathematical algorithm." *Diamond v. Diehr*, 450 U.S. 175, 187 (1981) (internal quotation marks omitted). In fact, it is "commonplace that an ***application*** of a law of nature or mathematical formula to a known structure or process may well be deserving of patent protection." *Id.* In the present case, then, it is necessary to proceed to step two, and consider "what the claim elements add," and specifically whether they identify an "inventive concept." *Elec. Power*, 830 F.3d at 1353.

In *Mayo*, 556 U.S. at 72, the claims covered "processes that help doctors who use thiopurine drugs to treat patients with autoimmune diseases determine whether a given dosage level is too low or too high" by "describing the relationships between the concentration in the blood of certain thiopurine metabolites and the likelihood that the drug dosage will be ineffective or induce harmful side-effects." The Supreme Court held that the claims there were not patent-eligible because they "inform a relevant audience about certain laws of nature; any additional steps consist of well-understood, routine, conventional activity already engaged in by the scientific community; and those steps, when viewed as a whole, add nothing significant beyond the sum of their parts taken separately." *Id.* at 79-80.

As in *Mayo*, the question before the Court is whether the process claimed in the '911 patent "has additional features that provide practical assurance that the process is more than a drafting effort designed to monopolize the law of nature itself." *Id.* at 77. Patentees should not obtain claims that "simply recite a law of nature and then add the instruction 'apply the law.'" *Id.* at 77-78.

Since claims must be considered as a whole, it is important to consider the "ordered combination" of the method's steps, *id.* at 79, because "a new combination of steps in a process may be patentable even though all the constituents of the combination were well known and in common use before the combination was made," *Diehr*, 450 U.S. at 188. For example, in *Diehr*, even though the "process used a known mathematical equation," the Supreme Court "found the overall process patent eligible because of the way the additional steps of the process integrated the equation into the process as a whole." *Mayo*, 566 U.S. at 80. The combination of steps was not "obvious, already in use, or purely conventional." *Id.* at 81; *see also Rapid Litig. Mgmt. Ltd. v. CellzDirect, Inc.*, 827 F.3d 1042, 1050-51 (Fed. Cir. 2016) (finding that new and improved claimed method of freezing and thawing hepatocytes twice, as result of discovered phenomenon that hepatocytes can survive multiple freeze-thaw cycles, was patent-eligible because, even though the individual steps were known in the art, repetition of the process was previously taught away from).

However, adding instructions to the claimed method that "add nothing specific to the laws of nature other than what is well-understood, routine, conventional activity, previously engaged in by those in the field," is insufficient to constitute an inventive concept. *Mayo*, 566 U.S. at 82. For example, in *Parker v. Flook*, 437 U.S. 584, 585-86 (1978), the claim was not patent-eligible because it simply applied a novel mathematical algorithm to the otherwise well-known steps of a method in a particular technological environment. *See also Mayo*, 566 U.S. at 81-82 (discussing *Flook*). Thus, "[t]he process itself, not merely the mathematical algorithm, must be new and useful." *Flook*, 437 U.S. at 591; *see also Ariosa Diagnostics, Inc. v. Sequenom, Inc.*, 788 F.3d 1371, 1377 (Fed. Cir. 2015) ("For process claims that encompass natural phenomenon, the process steps are the additional features that must be new and useful."). "[A]ppending routine, conventional steps to a natural phenomenon, specified at a high level of generality, is not enough to supply an inventive concept." *Ariosa*, 788 F.3d at 1378.

Here, as the '911 patent itself explains, the method of manufacturing a shaft assembly of a driveline system by inserting a liner into the propshaft was well-known in the prior art.[2] (*See,*

[2]Since the hearing on these motions, the Federal Circuit has expressly observed that the patent eligibility inquiry, which is a question of law, may involve issues of fact. *See Berkheimer*, 2018 WL 774096, at *6. But here the record reveals no genuine disputes of material fact. The parties here do not dispute that the non-tuning claim limitations are well-understood, routine, and conventional. Nor is there any genuine dispute of material fact that the tuning limitations are non-inventive applications of Hooke's law. Thus, "this issue can be decided on summary judgment as a matter of law." *Id.*

e.g., '911 patent col. 2:23-34) What AAM claims is new – for example, in independent claim 22 – are two claim elements. First is the claim limitation "tuning a mass and a stiffness of at least one liner," which the Court has construed as "controlling a mass and stiffness of at least one liner to configure the liner to match a relevant frequency or frequencies." (D.I. 113 at 6) But this claim limitation is just the application of Hooke's law.[3] AAM argues that this element makes the claim inventive because "[p]rior to this invention, people used untuned liners and just put them in the prop shaft in hopes of getting some general damping," whereas the claimed method requires one "to actually target certain frequencies and modes." (Tr. at 23) One's intentional act of controlling the characteristics of a liner is not inventive, because, as Neapco explained at oral argument, controlling the characteristics of a liner "is just an inherent part of any design process." (Tr. at 33) Since Hooke's law governs the relationship between mass, stiffness, and frequency, the "tuning" claim limitation does nothing more than suggest that a noise, vibration, and harshness ("NVH") engineer (D.I. 156 at 5) consider that law of nature when designing propshaft liners to attenuate driveline vibrations.

AAM argues that a second inventive concept is that the Asserted Claims cover a dual-tuned liner to absorb vibrations in both bending and shell modes (*see* Tr. at 22-24), as reflected in the claim limitation "wherein the at least one liner is a tuned resistive absorber for attenuating shell mode vibrations and wherein the at least one liner is a tuned reactive absorber for attenuating bending mode vibrations." In the Court's view, this claim limitation is, instead, the

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[3]The same result applies to claim 1, which has as a claim limitation "tuning at least one liner to attenuate at least two types of vibration transmitted through the shaft member," which the Court construed as "controlling characteristics of at least one liner to configure the liner to match a relevant frequency or frequencies to reduce at least two types of vibration transmitted through the shaft member." (D.I. 113 at 5)

result that is achieved from performing the method rather than an active step in the method.

In sum, as in *Mayo*, 566 U.S. at 79-80, the Asserted Claims "inform a relevant audience [NVH engineers] about certain laws of nature [Hooke's law and friction damping]; any additional steps consist of well-understood, routine, conventional activity already engaged in by the scientific community [inserting liners with certain characteristics into propshafts to attenuate driveline vibrations]; and those steps, when viewed as a whole, add nothing significant beyond the sum of their parts taken separately [having the same, but potentially slightly improved, effect of attenuating certain frequencies and modes of driveline vibrations]." Hence, as in *Mayo*, the Asserted Claims here are not patent-eligible.

The Court further agrees with Neapco that another obstacle to the Asserted Claims being patent-eligible is that they "are not directed to any specific, discrete liner design but rather a solution to the problem of attenuating shell and bending mode vibrations generally by applying physics." (D.I. 172 at 9) *Electric Power Group*, 830 F.3d at 1530, provides support for this conclusion. That case involved patents that "describe and claim systems and methods for performing real-time performance monitoring of an electric power grid by collecting data from multiple data sources, analyzing the data, and displaying the results." *Id.* at 1351. The Court searched for an inventive concept in "***how*** the desired result is achieved," and found that the claims did not include any requirement for performing the claimed functions with anything other than "off-the-shelf, conventional . . . technology." *Id.* at 1355. Then, pointing to "an important common-sense distinction . . . between desired results (functions) and particular ways of achieving (performing) them," the Court explained, "there is a critical difference between patenting a particular concrete solution to a problem and attempting to patent the abstract idea of a solution to the problem in general." *Id.* at 1356 (internal quotation marks omitted). "[C]laims, defining a desirable [] result and not limited to inventive means of achieving the result, fail under § 101." *Id.* at 1351; *see also McRO*, 837 F.3d at 1314 ("A patent may issue for the means or method of producing a certain result, or effect, and not for the result or effect produced.") (internal quotation marks omitted).

Here, the Asserted Claims simply instruct one to apply Hooke's law to achieve the desired result of attenuating certain vibration modes and frequencies. They provide no particular means of how to craft the liner and propshaft in order to do so. Thus, like the claims in *Electric Power Group*, the claims here are invalid under § 101.

D. Preemption

AAM further argues that "the Asserted Claims provide no risk of preempting Hooke's law in its entirety." (D.I. 160 at 7) However, "[w]here a patent's claims are deemed only to disclose patent ineligible subject matter under the *Mayo* framework, as they are in this case, preemption concerns are fully addressed and made moot." *Ariosa*, 788 F.3d at 1379.

E. Machine or Transformation Test

AAM also argues that the Asserted Claims are patent-eligible under the machine-or-transformation test. (*See* D.I. 160 at 9-10) This test provides that a process claim is patent-eligible if "(1) it is tied to a particular machine or apparatus, or (2) it transforms a particular article into a different state or thing." *Bilski v. Kappos*, 561 U.S. 593, 600 (2010). To satisfy the test, the use of a machine "must impose meaningful limits on the claim's scope." *In re Bilski*, 545 F.3d 943, 961 (Fed. Cir. 2008). "In other words, the machine must play a significant part in permitting the claimed method to be performed." *CyberSource Corp. v. Retail Decision, Inc.*, 654 F.3d 1366, 1375 (Fed. Cir. 2011) (internal quotation marks omitted).

Here, because the Asserted Claims are nothing more than applying a law of nature to a conventional method to achieve an abstract solution to a problem, the Asserted Claims fail to provide any meaningful limits on the scope of the claim. The machine or transformation test does not help AAM.

IV. CONCLUSION

The Asserted Claims of the '911 patent are invalid under § 101, as they are directed to nonpatentable subject matter. Thus, the Court will grant Neapco's motion for summary judgment with respect to § 101 and will deny AAM's cross-motion on the same issue. The other motions – with the exception of AAM's motion directed to striking testimony from Neapco's damages expert – will be denied as moot. An appropriate Order follows.

**IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE**

AMERICAN AXLE & MANUFACTURING, INC., Plaintiff,	:	
v.	:	C.A. No. 15-1168-LPS
NEAPCO HOLDINGS LLC and NEAPCO DRIVELINES LLC, Defendants.	:	

ORDER

At Wilmington, this **27th** day of **February, 2018**:

For the reasons set forth in the Memorandum Opinion issued this date,

IT IS HEREBY ORDERED that:

1. Plaintiff American Axle & Manufacturing, Inc.'s ("AAM") Motion for Summary Judgment of Infringement (D.I. 155) is **DENIED AS MOOT**.

2. AAM's Motion for Summary Judgment of No Invalidity Pursuant to 35 U.S.C. §§ 101 and 102 (as to the Laskey Reference) (D.I. 159) is **DENIED** as to § 101 and **DENIED AS MOOT** as to § 102.

3. AAM's Motion to Exclude Portions of the Testimony of Neapco's Technical Expert, Steven Becker, and Neapco's Damages Expert, Michael Chase (D.1. 157) is **DENIED AS MOOT** as to Mr. Becker and remains **PENDING** as to Mr. Chase.

4. Defendants Neapco Holdings LLC and Neapco Drivelines LLC's (collectively, "Neapco") Motion for Summary Judgment of Invalidity and/or Non-Infringement (D.I. 149) and Supplemental Motion (D.I. 207) are **GRANTED** as to § 101 and **DENIED AS MOOT** in all

other respects.

5. Neapco's Motion to Preclude Certain Expert Testimony and Evidence (D.I. 208) is **DENIED AS MOOT**.

IT IS FURTHER ORDERED that the parties shall meet and confer and, no later than **March 2, 2018**, submit a joint status report, including their proposal(s) for how this case should now proceed, including whether the Court should resolve the motion that remains pending. The due date for the final proposed pretrial order is **AMENDED** and is now **March 6, 2018**.

HON. LEONARD P. STARK
UNITED STATES DISTRICT JUDGE

IN THE UNITED STATES DISTRICT COURT

FOR THE DISTRICT OF DELAWARE

AMERICAN AXLE & MANUFACTURING, INC., Plaintiff,	)	
v.	)	C.A. No. 15-1168-LPS
NEAPCO HOLDINGS LLC and NEAPCO DRIVELINES LLC, Defendants.	)	

~~[PROPOSED]~~ FINAL JUDGMENT

WHEREAS the Court, by Order dated February 27, 2018 (D.I. 220), (1) granted Defendants Neapco Holdings LLC's and Neapco Drivelines LLC's Motion for Summary Judgment of Invalidity and/or Non-Infringement as to 35 U.S.C. § 101, and denied it as moot in all other respects, and (2) denied Plaintiff American Axle & Manufacturing, Inc.'s Motion for Summary Judgment of No Invalidity Pursuant to 35 U.S.C. §§ 101 and 102 as to 35 U.S.C. § 101, and denied it as moot in all other respects:

It IS HEREBY ORDERED, ADJUDGED AND DECREED that:

1. FINAL JUDGMENT of invalidity of claims 1-6, 12, 13, 19-24, 26, 27, 31, and 34-36 of U.S. Patent No. 7,774,911 under 35 U.S.C. § 101 is entered in favor of Defendants and against Plaintiff;

2. Any motion for an award of costs or attorneys' fees shall be filed within 30 days after the later of the date that the time for appeal of this Judgment has expired, or if there is an appeal from this Judgment, the date of issuance of the Mandate of the Court of Appeals, and no such motion shall be filed less than 20 days after the later of those two dates;

This is a final judgment and may be appealed.

March 2nd, 2018.

Chief United States District Judge

US007774911B2

(12) **United States Patent**
Sun et al.

(10) **Patent No.: US 7,774,911 B2**
(45) **Date of Patent: Aug. 17, 2010**

(54) **METHOD FOR ATTENUATING DRIVELINE VIBRATIONS**

(75) Inventors: **Zhaohui Sun**, Rochester Hills, MI (US); **David P Schankin**, Harper Woods, MI (US); **Dumitru F Patrascu**, West Bloomfield, MI (US); **Austin R Gerding**, Royal Oak, MI (US)

(73) Assignee: **American Axle & Manufacturing, Inc.**, Detroit, MI (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1208 days.

(21) Appl. No.: **11/363,143**

(22) Filed: **Feb. 27, 2006**

(65) **Prior Publication Data**

US 2007/0204453 A1 Sep. 6, 2007

(51) **Int. Cl.**
B23Q 17/00 (2006.01)
B23P 17/00 (2006.01)

(52) **U.S. Cl.** **29/407.07**; 29/896.93

(58) **Field of Classification Search** 29/407.07, 29/428, 888, 889.61, 896.93; 464/127, 180, 464/181, 183; 180/381, 380, 379, 378; 188/372, 188/379
See application file for complete search history.

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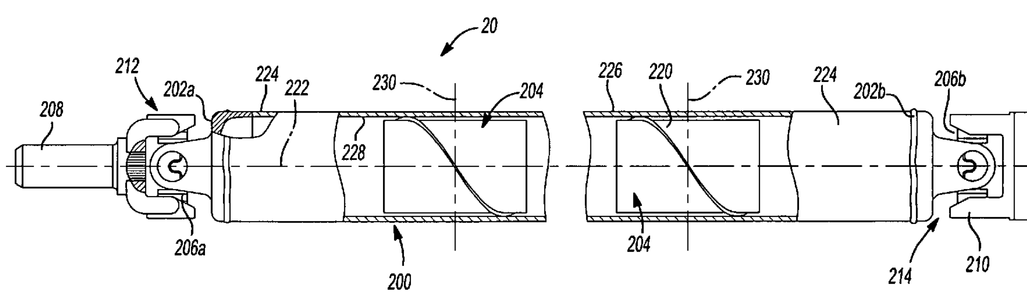
Primary Examiner—John C Hong
(74) *Attorney, Agent, or Firm*—Harness, Dickey & Pierce, P.L.C.

(57) **ABSTRACT**

A method for attenuating vibration in a driveline having a shaft assembly that transmits torque between first and second driveline components. The shaft assembly can have a hollow shaft member and at least one liner. The liner has a mass and a stiffness that are tuned such that the liner is a tuned resistive absorber for attenuating shell mode vibrations as well as at least one of a tuned reactive absorber for attenuating bending mode vibrations and a tuned reactive absorber for attenuating torsion mode vibrations. The tuned liner is inserted into the shaft member.

36 Claims, 6 Drawing Sheets



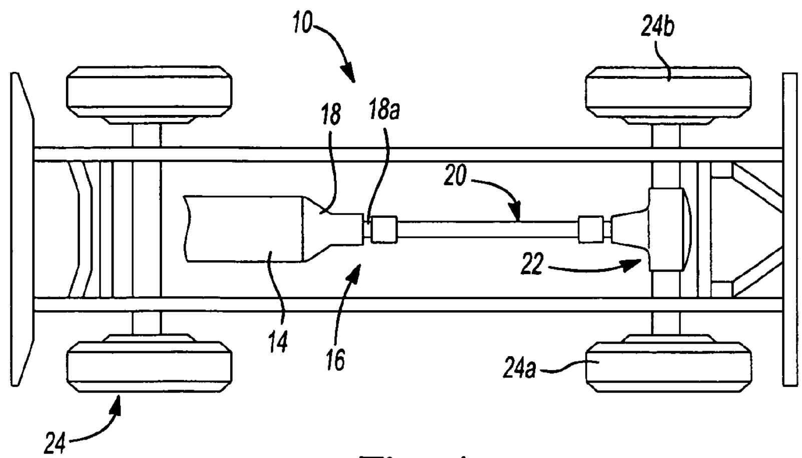

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Fig-1

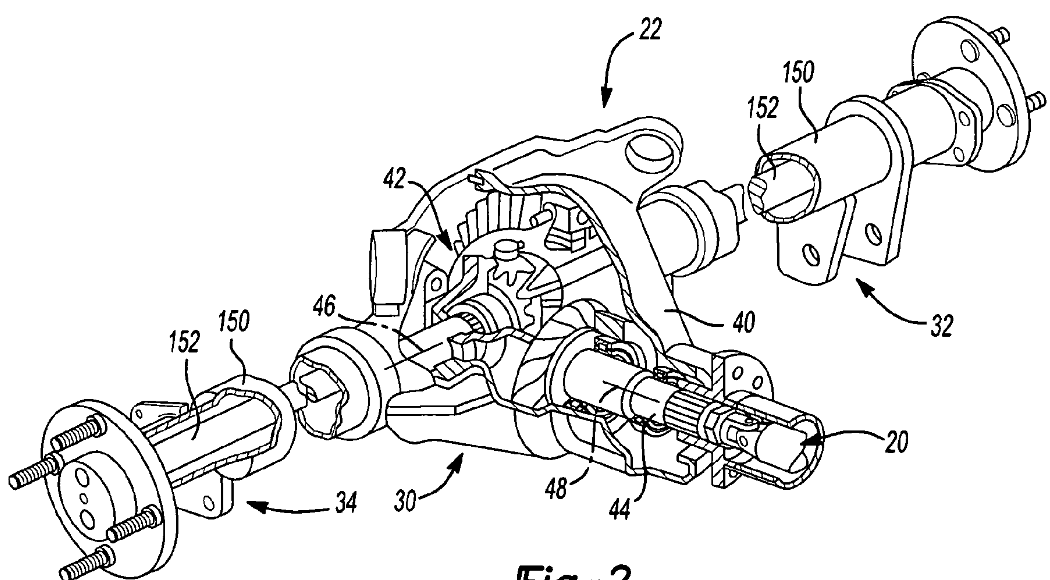
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Fig-2

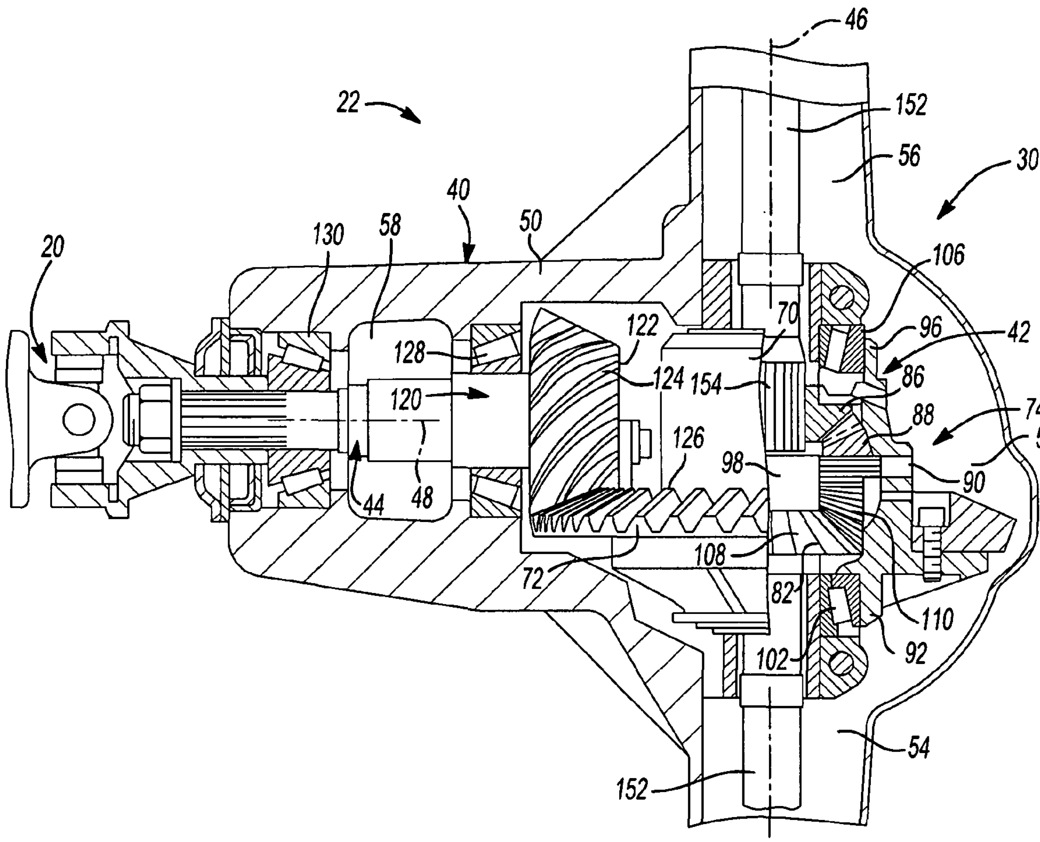
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Fig-3

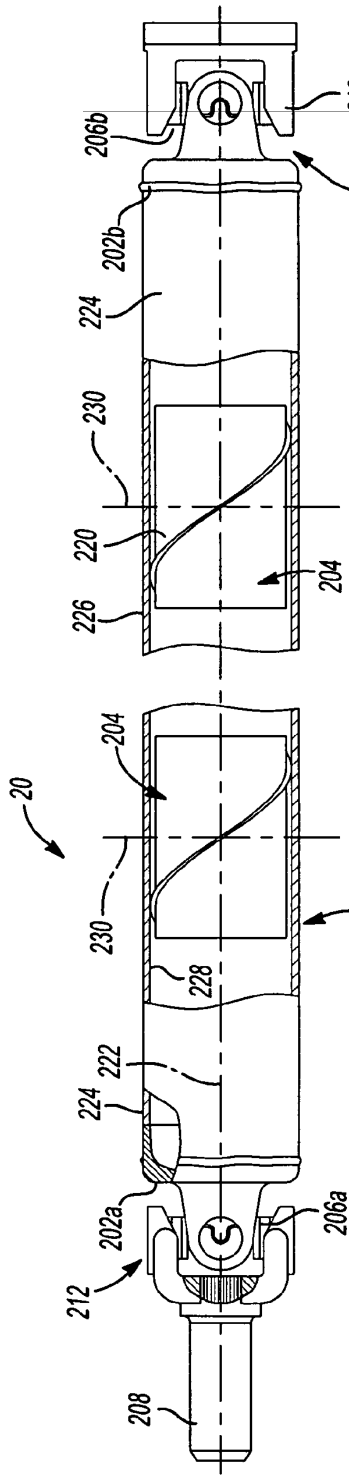

Fig-4

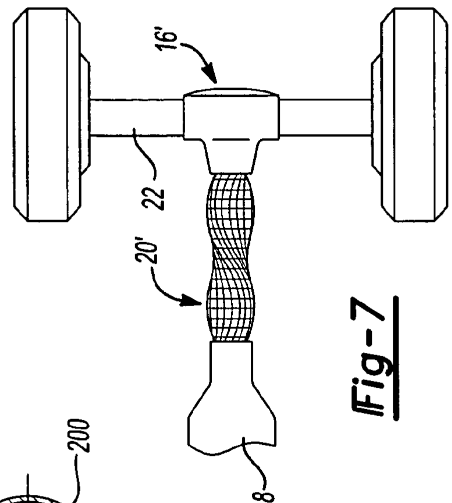

Fig-7

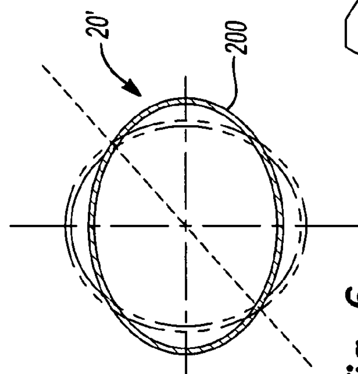

Fig-6

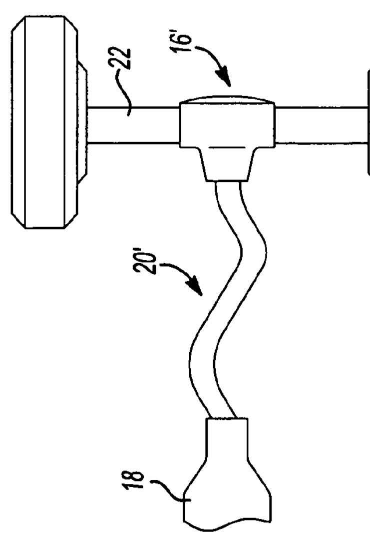

Fig-5

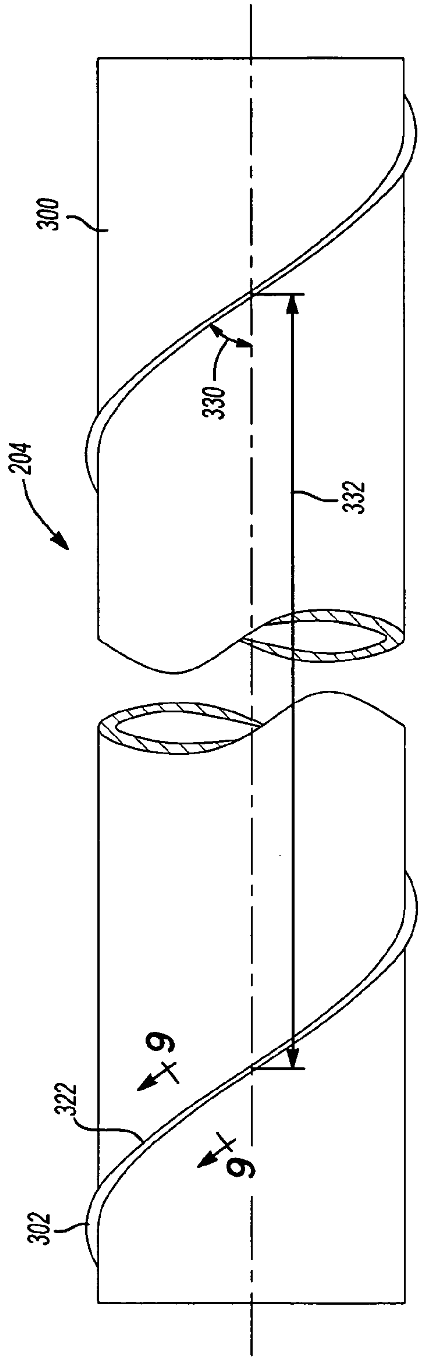

Fig-8

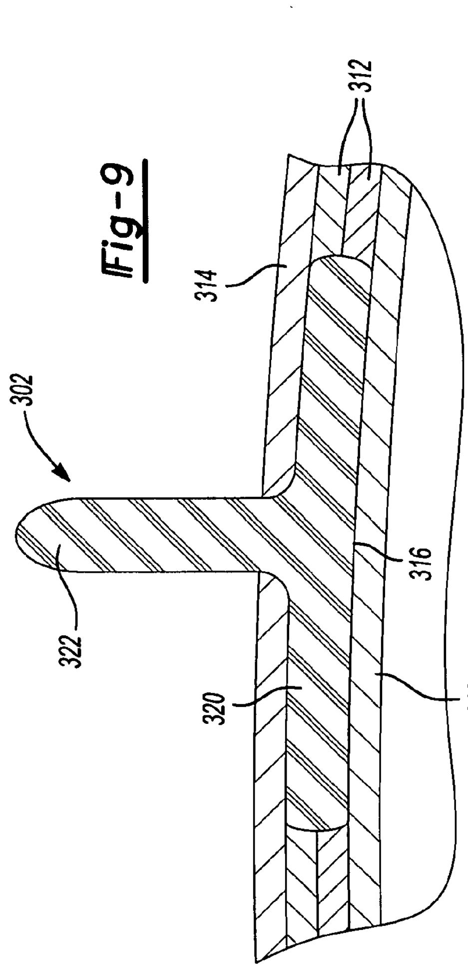

Fig-9

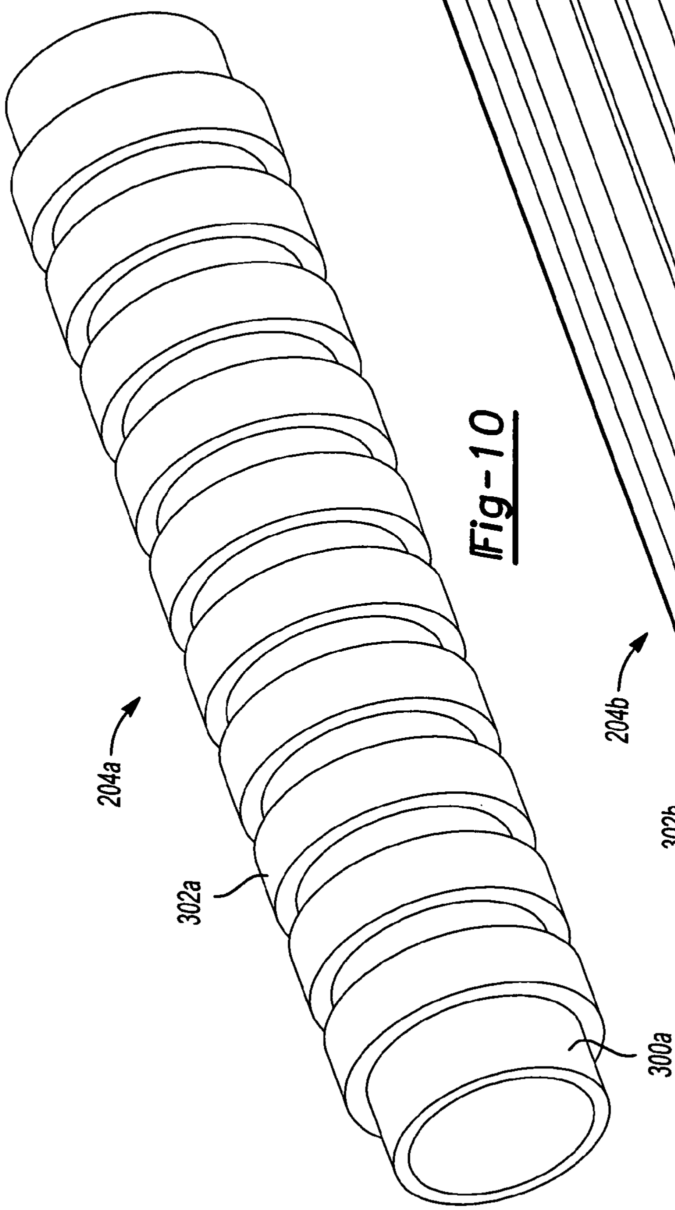

Fig-10

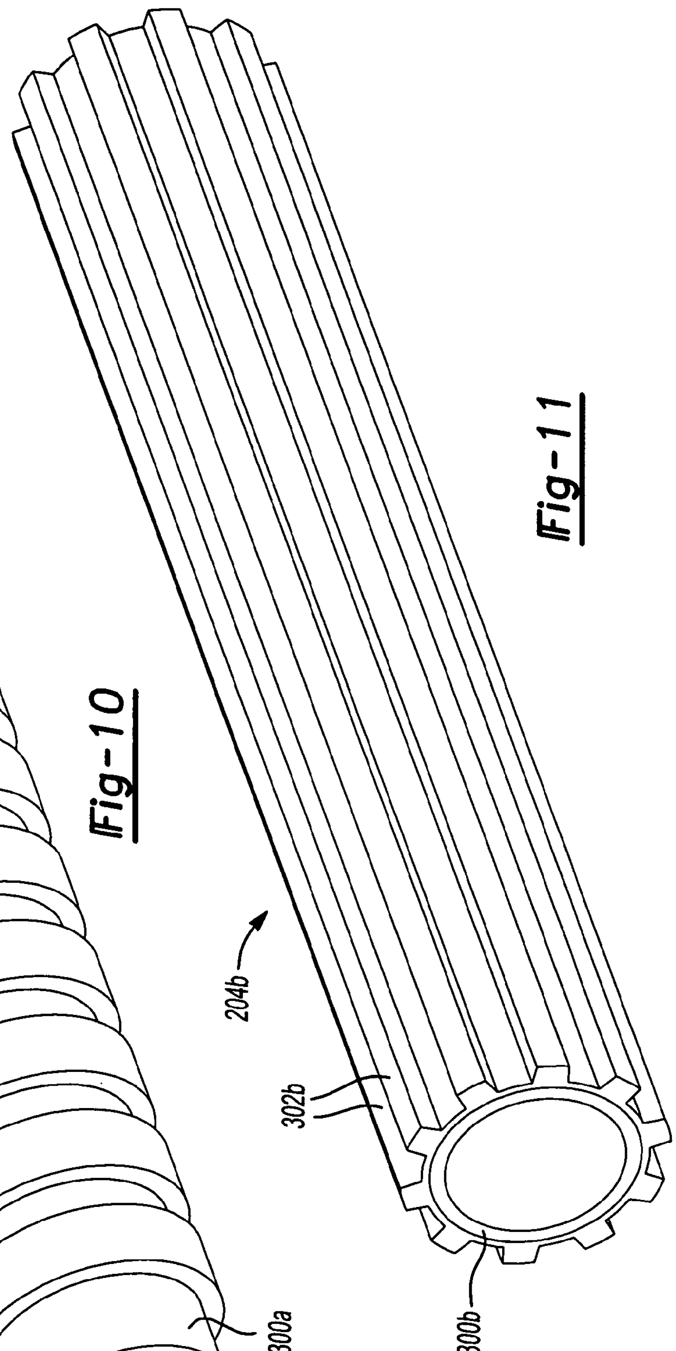

Fig-11

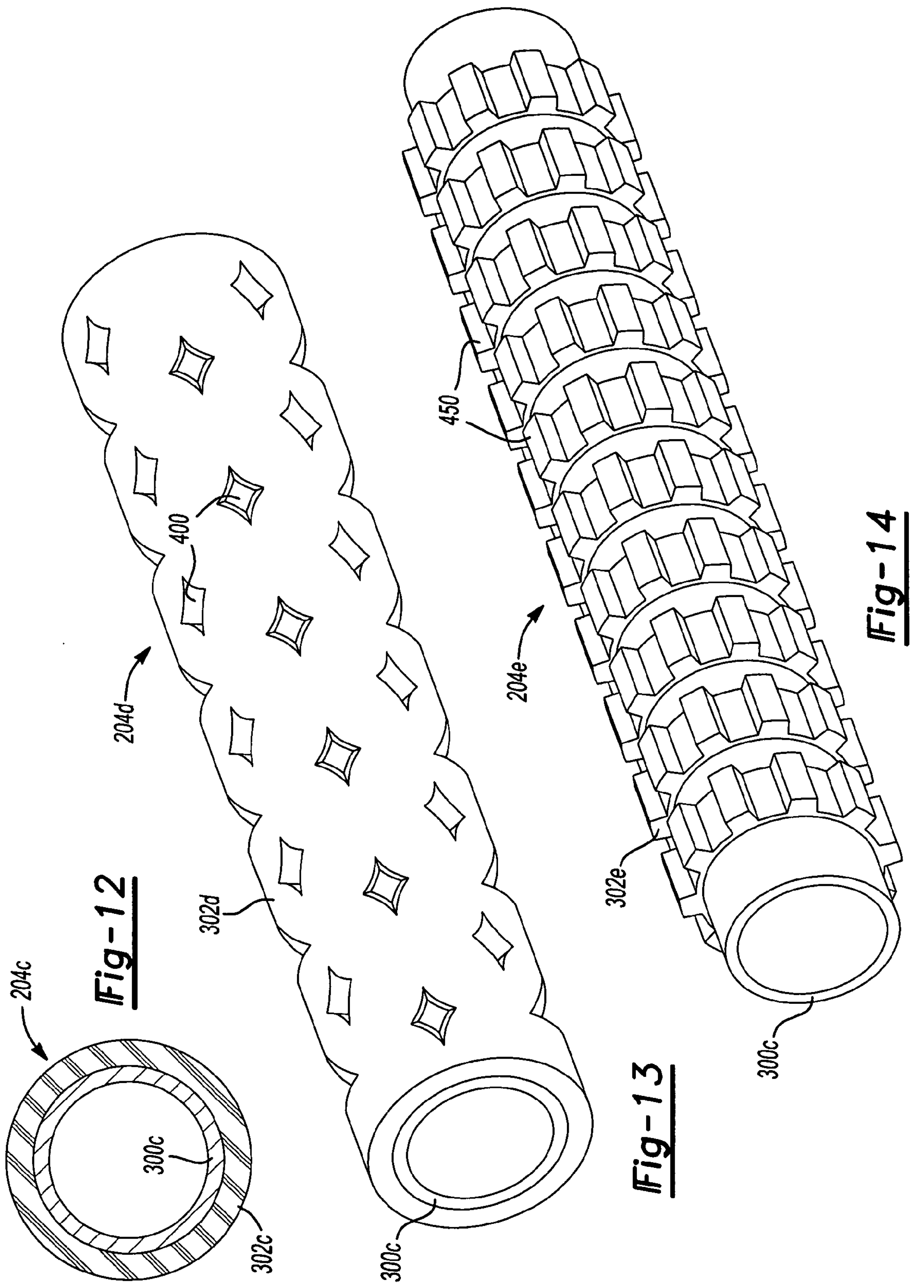

Fig-12

Fig-13

Fig-14

METHOD FOR ATTENUATING DRIVELINE VIBRATIONS

The present invention generally relates to shaft assemblies for transmitting rotary power in a driveline and more particularly to a method for attenuating driveline vibrations transmitted through a shaft assembly.

The consumers of modern automotive vehicles are increasingly influenced in their purchasing decisions and in their opinions of the quality of a vehicle by their satisfaction with the vehicle's sound quality. In this regard, consumers increasingly expect the interior of the vehicle to be quiet and free of noise from the power train and driveline. Consequently, vehicle manufacturers and their suppliers are under constant pressure to reduce noise to meet the increasingly stringent expectations of consumers.

Driveline components and their integration into a vehicle typically play a significant role in sound quality of a vehicle as they can provide the forcing function that excites specific driveline, suspension and body resonances to produce noise. Since this noise can be tonal in nature, it is usually readily detected by the occupants of a vehicle regardless of other noise levels. Common driveline excitation sources can include driveline imbalance and/or run-out, fluctuations in engine torque, engine idle shake, and motion variation in the meshing gear teeth of the hypoid gear set (i.e., the pinion gear and the ring gear of a differential assembly).

Motion variation is the slight variation in angular displacement between the input and output gears of a gear set. This variation is typically very small and can be on the order of tens of millionths of an inch (measured tangentially at the pitch line of the gear) for a modern automotive differential assembly. Motion variation is typically not constant (e.g., it will typically vary as a function of load, temperature, gearset build position, and break-in wear) and moreover, it cannot be reduced beyond certain levels without severe economic penalties.

Propeller (prop) shafts are typically employed to transmit rotary power in a driveline. Modern automotive propshafts are commonly formed of relatively thin-walled steel or aluminum tubing and as such, can be receptive to various driveline excitation sources. The various excitation sources can typically cause the propshaft to vibrate in a bending (lateral) mode, a torsion mode and a shell mode. Bending mode vibration is a phenomenon wherein energy is transmitted longitudinally along the shaft and causes the shaft to bend at one or more locations. Torsion mode vibration is a phenomenon wherein energy is transmitted tangentially through the shaft and causes the shaft to twist. Shell mode vibration is a phenomenon wherein a standing wave is transmitted circumferentially about the shaft and causes the cross-section of the shaft to deflect or bend along one or more axes.

Several techniques have been employed to attenuate vibrations in propshafts including the use of weights and liners. U.S. Pat. No. 2,001,166 to Swennes, for example, discloses the use of a pair of discrete plugs or weights to attenuate vibrations. The weights of the '166 patent are frictionally engaged to the propshaft at experimentally-derived locations and as such, it appears that the weights are employed as a resistive means to attenuate bending mode vibration. As used herein, resistive attenuation of vibration refers to a vibration attenuation means that deforms as vibration energy is transmitted through it (i.e., the vibration attenuation means) so that the vibration attenuation means absorbs (and thereby attenuates) the vibration energy. While this technique can be effective, the additional mass of the weights can require changes in the propshaft mounting hardware and/or propshaft geometry

(e.g., wall thickness) and/or can change the critical speed of the propshaft. Moreover, as the plugs tend to be relatively short, they typically would not effectively attenuate shell mode vibration or torsion mode vibration.

U.S. Pat. No. 3,075,406 to Butler Jr., et al. appears to disclose a single damper that is inserted to a hollow shaft. The damper includes a pair of resilient members, which frictionally engage the interior surface of the hollow shaft, and a metal bar that is suspended within the interior of the hollow shaft by the resilient members. The '406 patent explains that at the resonant vibration frequency of the propeller shaft, "the motion of the mass is out of phase with the radial motion of the tubular propeller shaft". Accordingly, the damper of the '406 patent appears to be a reactive damper for attenuating bending mode vibration. As used herein, reactive attenuation of vibration refers to a mechanism that can oscillate in opposition to the vibration energy to thereby "cancel out" a portion of the vibration energy. The damper of the '406 patent appears to be ineffective at attenuating torsion mode vibration and shell mode vibration due to its relatively short length and its contact with a relatively small portion of the interior surface of the propshaft.

U.S. Pat. No. 2,751,765 to Rowland et al., U.S. Pat. No. 4,014,184 to Stark and U.S. Pat. Nos. 4,909,361 and 5,976,021 to Stark et al. disclose hollow liners for a propshaft. The '765 and '184 patents appear to disclose hollow multi-ply cardboard liners that are press-fit to the propshaft; the cardboard liners are relatively long and appear to extend substantially coextensively with the hollow shaft. The '361 and '021 patents appear to disclose liners having a hollow cardboard core and a helical retaining strip that extends a relatively short distance (e.g., 0.03 inch) from the outside diameter of the core. The retaining strip has high frictional properties to frictionally engage the propshaft. Accordingly, the liners of the '765, '184, '361 and '021 patents appear to disclose a resistive means for attenuating shell mode vibration. These liners, however, do not appear to be suitable for attenuating bending mode vibration or torsion mode vibration.

In view of the foregoing, there remains a need in the art for an improved method for damping various types of vibrations in a hollow shaft. This method facilitates the damping of shell mode vibration as well as the damping of bending mode vibration and/or torsion mode vibration.

SUMMARY

In one form, the present teachings provide a method for manufacturing a shaft assembly of a driveline system. The driveline system can include a first driveline component and a second driveline component and the shaft assembly can be configured to transmit torque between the first driveline component and the second driveline component. The method can include: providing a hollow shaft member; and inserting at least one liner into the shaft member, the at least one liner being configured for damping shell mode vibrations in the shaft member by an amount that is greater than or equal to about 2%, the at least one liner also being configured for damping bending mode vibrations in the shaft member, the at least one liner being tuned to within about ±20% of a bending mode natural frequency of the shaft assembly as installed in the driveline system.

In another form, the present teachings provide a method for manufacturing a shaft assembly of a driveline system. The driveline system can include a first driveline component and a second driveline component and the shaft assembly can be configured to transmit torque between the first driveline component and the second driveline component. The method can

include: providing a hollow shaft member; and inserting at least one liner into the shaft member, the at least one liner being configured for damping shell mode vibrations in the shaft member by an amount that is greater than or equal to about 2%, the at least one liner also being tuned to within about ±20% of a natural frequency of the driveline system in a torsion mode.

In another form, the present teachings provide a method for manufacturing a shaft assembly of a driveline system. The driveline system can include a first driveline component and a second driveline component and the shaft assembly can be configured to transmit torque between the first driveline component and the second driveline component. The method can include: providing a hollow shaft member; tuning a mass and a stiffness of at least one liner; and inserting the at least one liner into the shaft member. The at least one liner is a tuned resistive absorber for attenuating shell mode vibrations and is a tuned reactive absorber for attenuating bending mode vibrations.

In still another form, the present teachings provide a method for manufacturing a shaft assembly of a driveline system. The driveline system can include a first driveline component and a second driveline component and the shaft assembly can be configured to transmit torque between the first driveline component and the second driveline component. The method can include: providing a hollow shaft member; tuning a mass and a stiffness of at least one liner; and inserting the at least one liner into the shaft member. The at least one liner is a tuned resistive absorber for attenuating shell mode vibrations and is a tuned reactive absorber for attenuating torsion mode vibrations.

Further areas of applicability will become apparent from the description provided herein. It should be understood that the description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings described herein are for illustration purposes only and are not intended to limit the scope of the present disclosure in any way.

FIG. **1** is a schematic illustration of an exemplary vehicle constructed in accordance with the teachings of the present disclosure;

FIG. **2** is a top partially cut-away view of a portion of the vehicle of FIG. **1** illustrating the rear axle and the propshaft assembly in greater detail;

FIG. **3** is a sectional view of a portion of the rear axle and the propshaft assembly;

FIG. **4** is a top, partially cut away view of the propshaft assembly;

FIG. **5** is a schematic illustration of a portion of a driveline illustrating an undamped propshaft vibrating in a second bending mode;

FIG. **6** is a sectional view of a portion of the undamped propshaft taken perpendicular to the longitudinal (rotational) axis of the propshaft illustrating the propshaft vibrating in a first shell mode;

FIG. **7** is a schematic illustration of a portion of a driveline illustrating an undamped propshaft vibrating in a torsion mode;

FIG. **8** is a side view of a liner for damping a propshaft in accordance with the teachings of the present disclosure;

FIG. **9** is a section view of a portion of the liner illustrating the coupling of the resilient member to the structural portion in more detail;

FIG. **10** is a perspective view of a second liner for damping a propshaft in accordance with the teachings of the present disclosure;

FIG. **11** is a perspective view of a third liner for damping a propshaft in accordance with the teachings of the present disclosure;

FIG. **12** is a section view of a fourth liner for damping a propshaft in accordance with the teachings of the present disclosure;

FIG. **13** is a perspective view of a fifth liner for damping a propshaft in accordance with the teachings of the present disclosure; and

FIG. **14** is a perspective view of a sixth liner for damping a propshaft in accordance with the teachings of the present disclosure.

DETAILED DESCRIPTION OF THE VARIOUS EMBODIMENTS

With reference to FIG. **1** of the drawings, an exemplary vehicle constructed in accordance with the teachings of the present disclosure is generally indicated by reference numeral **10**. The vehicle **10** can include an engine **14** and a driveline **16**. The driveline **16** can include a transmission **18**, a propshaft assembly **20**, a rear axle **22** and a plurality of wheels **24**. The engine **14** can produce rotary power that can be transmitted to the transmission **18** in a conventional and well known manner. The transmission **18** can be conventionally configured and can include a transmission output shaft **18***a* and a gear reduction unit (not specifically shown). As is well known in the art, the gear reduction unit can change the speed and torque of the rotary power provided by the engine such that a rotary output of the transmission **18** (which can be transmitted through the transmission output shaft **18***a*) can have a relatively lower speed and higher torque than that which was input to the transmission **18**. The propshaft assembly **20** can be coupled for rotation with the transmission output member **18***a* to permit drive torque to be transmitted from the transmission **18** to the rear axle **22** where it can be selectively apportioned in a predetermined manner to the left and right rear wheels **24***a* and **24***b*, respectively.

It will be appreciated that while the vehicle in the particular example provided employs a driveline with a rear-wheel drive arrangement, the teachings of the present disclosure have broader applicability. In this regard, a shaft assembly constructed in accordance with the teachings of the present disclosure may interconnect a first driveline component with a second driveline component to transmit torque therebetween. In the context of an automotive vehicle, the driveline components could be a transmission, a transfer case, a viscous coupling, an axle assembly, or a differential, for example.

With reference to FIG. **2**, the rear axle **22** can include a differential assembly **30**, a left axle shaft assembly **32** and a right axle shaft assembly **34**. The differential assembly **30** can include a housing **40**, a differential unit **42** and an input shaft assembly **44**. The housing **40** can support the differential unit **42** for rotation about a first axis **46** and can further support the input shaft assembly **44** for rotation about a second axis **48** that is perpendicular to the first axis **46**.

With additional reference to FIG. **3**, the housing **40** can be formed in a suitable casting process and thereafter machined as required. The housing **40** can includes a wall member **50** that can define a central cavity **52** that can have a left axle aperture **54**, a right axle aperture **56**, and an input shaft aperture **58**. The differential unit **42** can be disposed within the central cavity **52** of the housing **40** and can include a case **70**, a ring gear **72**, which can be fixed for rotation with the case **70**, and a gearset **74** that can be disposed within the case **70**. The gearset **74** can include first and second side gears **82** and **86** and a plurality of differential pinions **88**, which can be rotatably supported on pinion shafts **90** that can be mounted to the case **70**. The case **70** can include a pair of trunnions **92** and **96** and a gear cavity **98**. A pair of bearing assemblies **102** and **106** can support the trunnions **92** and **96**, respectively, for rotation about the first axis **46**. The left and right axle assemblies **32** and **34** can extend through the left and right axle apertures **54** and **56**, respectively, where they can be coupled for rotation about the first axis **46** with the first and second side gears **82** and **86**, respectively. The case **70** can be operable for supporting the plurality of differential pinions **88** for rotation within the gear cavity **98** about one or more axes that can be perpendicular to the first axis **46**. The first and second side gears **82** and **86** each include a plurality of teeth **108** which meshingly engage teeth **110** that are formed on the differential pinions **88**.

The input shaft assembly **44** can extend through the input shaft aperture **58** where it can be supported in the housing **40** for rotation about the second axis **48**. The input shaft assembly **44** can include an input shaft **120**, a pinion gear **122** having a plurality of pinion teeth **124** that meshingly engage the teeth **126** that are formed on the ring gear **72**, and a pair of bearing assemblies **128** and **130** that can cooperate with the housing **40** to rotatably support the input shaft **120**. The input shaft assembly **44** can be coupled for rotation with the propshaft assembly **20** and can be operable for transmitting drive torque to the differential unit **42**. More specifically, drive torque received by the input shaft **120** can be transmitted by the pinion teeth **124** to the teeth **126** of the ring gear **72** such that drive torque is distributed through the differential pinions **88** to the first and second side gears **82** and **86**.

The left and right axle shaft assemblies **32** and **34** can include an axle tube **150** that can be received into the associated axle aperture **54** and **56**, respectively, and an axle half-shaft **152** that can be supported for rotation in the axle tube **150** about the first axis **46**. Each of the axle half-shafts **152** can include an externally splined portion **154** that can meshingly engage a mating internally splined portion (not specifically shown) that can be formed into the first and second side gears **82** and **86**, respectively.

With reference to FIG. **4**, the propshaft assembly **20** can include a shaft structure **200**, first and second trunnion caps **202*a*** and **202*b***, at least one liner **204**, first and second spiders **206*a*** and **206*b***, a yoke assembly **208** and a yoke flange **210**. The first and second trunnion caps **202*a*** and **202*b***, the first and second spider **206*a*** and **206*b***, the yoke assembly **208** and the yoke flange **210** can be conventional in their construction and operation and as such, need not be discussed in detail. Briefly, the first and second trunnion caps **202*a*** and **202*b*** can be fixedly coupled to the opposite ends of the shaft structure **200**, typically via a weld. Each of the first and second spiders **206*a*** and **206*b*** can be coupled to an associated one of the first and second trunnion caps **202*a*** and **202*b*** and to an associated one of the yoke assembly **208** and the yoke flange **210**. The yoke assembly **208**, first spider **206*a***, and first trunnion cap **202*a*** can collectively form a first universal joint **212**, while the yoke flange **210**, second spider **206*b*** and second trunnion cap **202*b*** can collectively form a second universal joint **214**.

A splined portion of the yoke assembly **208** can be rotatably coupled with the transmission output shaft **18*a*** and the yoke flange **210** can be rotatably coupled with the input shaft **120**. The first and second universal joints **212** and **214** can facilitate a predetermined degree of vertical and horizontal offset between the transmission output shaft **18*a*** and the input shaft **120**.

The shaft structure **200** can be generally cylindrical, having a hollow central cavity **220** and a longitudinal axis **222**. The shaft structure **200** can be formed of any suitable material. In the particular example provided, the shaft structure **200** is formed of welded seamless 6061-T6 aluminum tubing conforming to ASTM B-210. Also in the particular embodiment illustrated, the shaft structure **200** is uniform in diameter and cross-section between the ends **224**, but it will be appreciated that the shaft structure could be otherwise formed. For example, the ends **224** of the shaft structure **200** could be necked-down (e.g., via rotary swaging) relative to the central portion **226** of the shaft structure **200**.

With reference to FIGS. **5** through **7**, it will be appreciated that an undamped propshaft assembly **20'** (e.g., the propshaft assembly **20** without the at least one liner **204**) could be susceptible to several types of vibration. In FIG. **5**, for example, the undamped propshaft assembly **20'** is illustrated as vibrating at a bending mode natural frequency (i.e., a second bending mode (n=2) natural frequency) of the propshaft assembly **20'** as installed in the driveline **16'**. In this regard, those of ordinary skill in the art will appreciate that the bending mode natural frequency is a function of not only the propshaft assembly **20'**, but also of the “boundary conditions” (i.e., the manner in which the propshaft assembly **20'** is coupled to the driveline **16'**). Consequently, the term “propshaft assembly as installed in the driveline” will be understood to include not only the shaft assembly but also the boundary conditions under which the shaft assembly is installed to the two driveline components.

In FIG. **6**, the propshaft assembly **20'** is illustrated as vibrating at a shell mode natural frequency (i.e., a first (n=1) shell mode natural frequency) of the shaft structure **200**.

In FIG. **7**, the propshaft assembly **20'** is illustrated as vibrating at a natural torsion frequency of the driveline **16'** in a torsion mode (i.e., a first (n=1) torsion mode). In this regard, those of ordinary skill in the art will appreciate that the natural torsion frequency is a function of not only the propshaft assembly **20'**, but also of the first and second driveline components (e.g., the transmission **18** and the rear axle **22**) to which the propshaft assembly is coupled.

Returning to FIG. **4**, the propshaft assembly **20** of the particular example provided includes two liners **204** that are identically configured. It will be appreciated in view of this disclosure, however, that other quantities of liners **204** may be utilized and that the liners **204** need not be identically configured (i.e., each insert **204** can have different damping characteristics and a first one of the liners **204** can be different from a second one of the liners **204**).

With additional reference to FIGS. **8** and **9**, the liner **204** can be constructed in a manner that is similar to that which is described in U.S. Pat. No. 4,909,361, the disclosure of which is hereby incorporated by reference as if fully set forth in its entirety herein. Briefly, the liner **204** can include a structural portion **300** and one or more resilient members **302** that are coupled to the structural portion **300**. The liners **204** are sized such that the structural portion **300** is smaller than the inner diameter of the shaft member **200** but the resilient member(s) **302** is/are sized to frictionally engage the inner diameter of the shaft member **200**.

In the example provided, the structural portion **300** includes a hollow core **310**, one or more intermediate members **312** and a cover member **314**. The core **310** can be formed of a fibrous material, such as cardboard. In the particular example provided, the core **310** is formed of a suitable number of plies of helically wound paperboard. The intermediate members **312** can also be formed of a paperboard and can be helically wound onto and adhered (via a suitable adhesive) to the core **310** in a manner that forms one or more helical gaps **316**. In the particular example provided, one helical gap **316** is formed. It will be appreciated that the structural portion **300** could be formed of any appropriate material, including cardboard, plastic resins, carbon fiber, fiberglass, metal and combinations thereof. It will also be appreciated that the structural portion **300** need not include an intermediate member **312** or a cover member **314** and need not define one or more gaps **316**. It will further be appreciated that the gaps **316**, if used, need not be helical in shape but rather could be formed in other manners, such as circumferentially or longitudinally.

The resilient members **302** can be formed of an appropriate elastomer and can include a base **320** and one or more lip members **322** that can be coupled to the base **320**. The base **320** can be fixedly coupled to the structural portion **300** via a suitable adhesive such that the lip members **322** extend radially outwardly therefrom. The cover member **314** can be wrapped over the intermediate member(s) **312** and the base **320** and can be employed to further secure the resilient members **302** to the structural portion **300**.

It will be appreciated from this disclosure that where two or more resilient members **302** are employed, the resilient members **302** can be formed of the same material and are coupled to the structural portion **300** such that their bases **320** are received in an associated gap **316**. It will also be appreciated from this disclosure that in the alternative, the resilient members **302** may be formed differently (e.g., with different materials, different sizes and/or different cross-sections).

With reference to FIGS. **1**, **4** and **8**, it will be further appreciated from this disclosure that the mass and the stiffness of the liner(s) **204** are tuned to the driveline **16** such that the liner(s) **204** acts or act as (a) a tuned resistive absorber for attenuating shell mode vibrations; and (b) as one or more of (i) a tuned reactive absorber for attenuating bending mode vibrations, and (ii) a tuned reactive absorber for attenuating torsion mode vibrations. The liner(s) **204** may be tuned such that a ratio of the mass of the liner(s) **204** to a mass of the shaft member **200** is about 5% to about 30%. In the particular example provided, the ratio of the mass of the liners **204** to the mass of the shaft member **200** is about 16.9%.

Preferably, the liner(s) **204** is/are tuned to a natural frequency corresponding to at least one of a first shell mode, a second shell mode and a third shell mode. Where the liner(s) **204** is/are employed to attenuate bending mode vibrations, they are preferably tuned to a natural frequency corresponding to at least one of a first bending mode, a second bending mode and a third bending mode of the propshaft assembly **20** as installed to the driveline **16**. Where the liner(s) **204** is/are employed to attenuate torsion mode vibrations, they are preferably tuned to a natural frequency of the driveline **16** in a torsion mode, such as to a frequency that is less than or equal to about 600 Hz.

It will also be appreciated from this disclosure that various characteristics of the liner **204** can be controlled to tune its damping properties in the shell mode and in one or both of the bending mode and the torsion mode. In the particular example provided, the following variables were controlled: mass, length and outer diameter of the liner **204**, diameter and wall thickness of the structural portion **300**, material of which the structural portion **300** was fabricated, the quantity of the resilient members **302**, the material of which the resilient members **302** was fabricated, the helix angle **330** and pitch **332** with which the resilient members **302** are fixed to the structural portion **300**, the configuration of the lip member(s) **322** of the resilient member **302**, and the location of the liners **204** within the shaft member **200**. In the particular example provided:

- the shaft member **200** can have an outside diameter of about 4.0 inches, a wall thickness of about 0.08 inch, a length of about 64 inches, and can have a mass of about 3.2 kg;
- the liners **204** can have an outer diameter (over the resilient member(s) **302**) of about 4.0 inches, a length of about 14 inches, a mass of about 270 grams, the structural portion **300** of the liner **204** can be formed of paperboard and can have a wall thickness of about 0.07 inch and an inner diameter of about 3.56 inch, one resilient member **302** can be coupled to the structural portion **300** at a helix angle **330** of about 22.5° and a pitch **332** of about 4.5 inches, the resilient member **302** can have a single lip member **322** and can be formed of a silicon material that conforms to ASTM D2000 M2GE505 having a durometer of about 45 Shore A to about 55 Shore A; and
- each of the liners **204** can be inserted into an associated end of the shaft member **200** such that they are disposed generally symmetrically about an associated one of the second (n=2) bending nodes **230** (FIG. **4**).

It will be appreciated that in certain situations it may not be possible to exactly tune the liner **204** to the two or more relevant frequencies associated with a given propshaft assembly **20**, as when a particular liner **204** is used across a family of propshaft assemblies. As such, it will be understood that a liner **204** will be considered to be tuned to a relevant frequency if it is effective in attenuating vibration at the relevant frequency. For example, the liner **204** can be considered to be tuned to a relevant frequency if a frequency at which it achieves maximum attenuation is within ±20% of that relevant frequency. Preferably, the liner **204** is considered to be tuned to the relevant frequency if the frequency at which it achieves maximum attenuation is within ±15% of the relevant frequency. More preferably, the liner **204** is considered to be tuned to the relevant frequency if the frequency at which it achieves maximum attenuation is within ±10% of the relevant frequency. Still more preferably, the liner **204** is considered to be tuned to the relevant frequency if the frequency at which it achieves maximum attenuation is within ±5% of the relevant frequency.

As another example, the liner **204** can be considered to be tuned to a relevant shell mode frequency if it damps shell mode vibrations by an amount that is greater than or equal to about 2%.

While the propshaft assembly **20** has been described thus far as including a liner **204** having a resilient member **302** that is disposed helically about and along a structural portion **300**, it will be appreciated that the methodology of the present disclosure, in its broader aspects, may be performed somewhat differently. In this regard, the liner can be constructed as shown in FIGS. **10** through **14**.

In FIG. **10**, for example, the liner **204*a*** includes a plurality of circumferentially-extending resilient members **302*a*** that are coupled to the structural portion **300*a***. The resilient members **302*a*** are spaced apart from one another along the longitudinal axis of the structural portion **300*a***. It will be appreciated that while the resilient members **302*a*** are illustrated as having a generally flat outer surface, they could be formed to include one or more lip members (similar to the lip member **322** of FIG. **9**). In such case, the lip member(s) may be extend in a desired manner, such as circumferentially.

In FIG. **11**, the liner **204*b*** includes a plurality of longitudinally-extending resilient members **302*b*** that are coupled to the structural portion **300*b***. The resilient members **302*b*** are spaced circumferentially apart from one another about the circumference of the structural portion **300***b*. It will be appreciated that while the resilient members **302***b* are illustrated as having an arcuate outer surface, they could be formed to include one or more lip members (similar to the lip member **322** of FIG. **9**). In such case, the lip member(s) may be extend in a desired manner, such as longitudinally.

In FIG. **12**, the liner **204***c* includes a resilient member **302***c* that covers substantially the entire outer surface of the structural portion **300***c*. The resilient member **302***c* can be a discrete component that is separately formed and thereafter assembled to the structural portion **300***c*. In this regard, the resilient member **302***c* can be formed as a sheet and then bonded to outer surface of the structural portion **300***c* via a suitable adhesive. Alternatively, the resilient member **302***c* could be overmolded onto the structural portion **300***c*.

The liner **204***d* of FIG. **13** is similar to the liner **204***c* of FIG. **12** except that a plurality of void spaces **400** may be formed into the resilient member **302***d* to control the stiffness of the liner **204***d* in a desired direction. While the void spaces **400** are illustrated to be diamond-shaped holes that extend completely through the resilient member **302***d*, it will be appreciated that the void spaces **400** need not extend completely through the resilient member **302***d* and thus could form blind holes, channels and/or grooves. Moreover, it will be appreciated that the void spaces **400** may be shaped and arranged in any desired manner.

The liner **204***e* of FIG. **14** can be similar to the liner **204***d* of FIG. **13**, except that the resilient member **302***e* includes a plurality of fingers **450**. Each finger **450** can be shaped in a desired manner, such as a prism, a pyramid, a cylinder, a cone, a plinth, or as a portion of a doubled-curved surface, such as a sphere, torus or ellipsoid. It may be beneficial to shape the fingers **450** in the shape of a prism, especially a rectangular parallelepiped, so as to more easily tailor the stiffness of the fingers **450** in two or more directions. In this regard, the width and depth of the cross section of the fingers **450** and the height of the fingers **450** may be controlled independently of one another.

In some situations it may be beneficial to chill the liners prior to their installation to a shaft member to reduce the overall diameter of the liner and/or to provide sufficient rigidity to the resilient member(s).

It may also be beneficial in some situations to provide a secondary means for retaining the liner to the shaft member. The secondary means can be employed to resist or inhibit axial movement of the liner within the shaft member and can comprise a structure that is axially offset from the liner and coupled to the shaft member. The structure can be configured to effectively reduce the inside diameter of the shaft member at a desired location to an extent that resists or inhibits axial movement of the liner. The structure can be formed via an adhesive, a weld, a dimple, or a necked-down (e.g., rotary swaged) section, for example.

While specific examples have been described in the specification and illustrated in the drawings, it will be understood by those of ordinary skill in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the present disclosure as defined in the claims. Furthermore, the mixing and matching of features, elements and/or functions between various examples is expressly contemplated herein so that one of ordinary skill in the art would appreciate from this disclosure that features, elements and/or functions of one example may be incorporated into another example as appropriate, unless described otherwise, above. Moreover, many modifications may be made to adapt a particular situation or material to the teachings of the present disclosure without departing from the essential scope thereof. Therefore, it is intended that the present disclosure not be limited to the particular examples illustrated by the drawings and described in the specification as the best mode presently contemplated for carrying out this invention, but that the scope of the present disclosure will include any embodiments falling within the foregoing description and the appended claims.

What is claimed is:

1. A method for manufacturing a shaft assembly of a driveline system, the driveline system further including a first driveline component and a second driveline component, the shaft assembly being adapted to transmit torque between the first driveline component and the second driveline component, the method comprising:

providing a hollow shaft member;

tuning at least one liner to attenuate at least two types of vibration transmitted through the shaft member; and

positioning the at least one liner within the shaft member such that the at least one liner is configured to damp shell mode vibrations in the shaft member by an amount that is greater than or equal to about 2%, and the at least one liner is also configured to damp bending mode vibrations in the shaft member, the at least one liner being tuned to within about ±20% of a bending mode natural frequency of the shaft assembly as installed in the driveline system.

2. The method of claim **1**, wherein the at least one liner is tuned within ±15% of the bending mode natural frequency of the shaft assembly as installed in the driveline system.

3. The method of claim **2**, wherein the at least one liner is tuned to within ±10% of the bending mode natural frequency of the shaft assembly as installed in the driveline system.

4. The method of claim **3**, wherein the at least one liner is tuned to within ±5% of the bending mode natural frequency of the shaft assembly as installed in the driveline system.

5. The method of claim **3**, wherein the shell mode is at least one of a first shell mode, a second shell mode and a third shell mode.

6. The method of claim **5**, wherein the bending mode is at least one of a first bending mode, a second bending mode and a third bending mode.

7. The method of claim **3**, wherein the liner is further tuned within ±20% to a natural frequency of the driveline system in a torsion mode.

8. The method of claim **7**, wherein the liner is tuned to within ±15% to the natural frequency of the driveline system in the torsion mode.

9. The method of claim **8**, wherein the liner is tuned to within ±10% to the natural frequency of the driveline system in the torsion mode.

10. The method of claim **9**, wherein the liner is tuned within ±5% to the natural frequency of the driveline system in the torsion mode.

11. The method of claim **9**, wherein the natural frequency of the driveline system is below about 600 Hz.

12. The method of claim **3**, wherein the at least one liner includes a structural portion and at least one resilient member that is coupled to the structural portion, the liner being inserted to the shaft member such that a wall of the shaft member contacts the at least one resilient member.

13. The method of claim **12**, wherein the at least one resilient member extends helically about and along the structural portion.

14. The method of claim **12**, wherein the at least one resilient member extends longitudinally along the structural portion.

15. The method of claim **12**, wherein the at least one resilient member extends circumferentially about the structural portion.

16. The method of claim **12**, wherein a first one of the resilient members is formed of a first material and a second one of the resilient members is formed of a second material that is different from the first material.

17. The method of claim **12**, wherein the at least one resilient member is overmolded to the structural portion.

18. The method of claim **12**, wherein the at least one resilient member includes a plurality of fingers, each of the fingers being disposed between the shaft member and the structural portion.

19. The method of claim **12**, wherein the structural portion is formed of a material selected from a group consisting of cardboard, plastic resin, carbon fiber, fiberglass, metal and combinations thereof.

20. The method of claim **3**, wherein a first one of the liners is positioned along the shaft member symmetrically about a bending anti-node.

21. The method of claim **20**, wherein a second one of the liners is positioned along the shaft member symmetrically about another bending anti-node.

22. A method for manufacturing a shaft assembly of a driveline system, the driveline system further including a first driveline component and a second driveline component, the shaft assembly being adapted to transmit torque between the first driveline component and the second driveline component, the method comprising:

providing a hollow shaft member;

tuning a mass and a stiffness of at least one liner; and

inserting the at least one liner into the shaft member;

wherein the at least one liner is a tuned resistive absorber for attenuating shell mode vibrations and wherein the at least one liner is a tuned reactive absorber for attenuating bending mode vibrations.

23. The method of claim **22**, wherein the at least one liner is tuned to at least one of a first shell mode, a second shell mode and a third shell mode.

24. The method of claim **23**, wherein the at least one liner is tuned to at least one of a first bending mode, a second bending mode and a third bending mode.

25. The method of claim **24**, wherein the at least one liner further acts as a tuned reactive absorber for attenuating torsion mode vibrations.

26. The method of claim **24**, wherein the at least one liner includes a structural portion and at least one resilient member that is coupled to the structural portion, the at least one liner being inserted to the shaft member such that a wall of the shaft member contacts the at least one resilient member.

27. The method of claim **26**, wherein the at least one resilient member extends helically about and along the structural portion.

28. The method of claim **26**, wherein the at least one resilient member extends longitudinally along the structural portion.

29. The method of claim **26**, wherein the at least one resilient member extends circumferentially about the structural portion.

30. The method of claim **26**, wherein a first one of the resilient members is formed of a first material and a second one of the resilient members is formed of a second material that is different from the first material.

31. The method of claim **26**, wherein the structural portion is formed of a material selected from a group consisting of cardboard, plastic resin, carbon fiber, fiberglass, metal and combinations thereof.

32. The method of claim **26**, wherein the at least one resilient member is overmolded to the structural portion.

33. The method of claim **26**, wherein the at least one resilient member includes a plurality of fingers, the fingers being disposed between the structural portion and the shaft member.

34. The method of claim **22**, wherein a first one of the liners is positioned along the shaft member symmetrically about a bending anti-node.

35. The method of claim **34**, wherein a second one of the liners is positioned along the shaft member symmetrically about another bending anti-node.

36. A method for manufacturing a shaft assembly of a driveline system, the driveline system further including a first driveline component and a second driveline component, the shaft assembly being adapted to transmit torque between the first driveline component and the second driveline component, the method comprising:

providing a hollow shaft member;

tuning a mass and a stiffness of at least one liner; and

inserting the at least one liner into the shaft member;

wherein a ratio of a mass of the at least one liner to a mass of the shaft member is about 5% to about 30%;

wherein the at least one liner is a tuned resistive absorber for attenuating shell mode vibrations; and

wherein the at least one liner is a tuned reactive absorber for attenuating at least one of bending mode vibrations and torsion mode vibrations.

* * * * *

CERTIFICATE OF SERVICE

I hereby certify that, on the 29th day of June, 2018, I electronically filed the foregoing with the Clerk of Court using the CM/ECF system which thereby served a copy upon all counsel of record.

Upon acceptance by the Court of the e-filed document, six paper copies of the brief will be filed with the Court via Federal Express, priority overnight, within the time provided in the Court's rules.

Dated: June 29, 2018

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CERTIFICATE OF COMPLIANCE

I hereby certify that this brief complies with the type-volume limitations of Fed. Cir. R. 32(a). This brief contains 13,558 words (including diagrams and images), excluding the parts of the brief exempted by Fed. R. App. P. 32(f) and Fed. Cir. R. 32(b), as counted by Microsoft® Word 2010, the word processing software used to prepare this brief.

This brief complies with the typeface requirements of Fed. R. App. P. 32(a)(5) and the type style requirements of Fed. R. App. P. 32(a)(6). This brief has been prepared in a proportionally spaced typeface using Microsoft® Word 2010, Times New Roman, 14 point.

Dated: June 29, 2018

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