The invention is a heat-resistant drive shaft damper adapted to be inserted into a hollow automotive drive shaft. The damper with improved heat-resistant and NVH-reduction properties includes a retaining member that extends above the damper's outside surface and possesses a maximum operating temperature of 175° C. or higher. The invention further relates to a method of forming such a damper.
HEAT-RESISTANT DRIVE SHAFT DAMPER HAVING IMPROVED DAMPENING PERFORMANCE

CROSS-REFERENCE TO PRIORITY APPLICATION


FIELD OF THE INVENTION

[0002] The invention relates to a heat-resistant drive shaft damper adapted for use in a hollow automotive drive shaft to dampen vibrations and attenuate sound in vehicles, such as cars, trucks, tractors, and heavy machinery. The invention further relates to methods of forming and using such drive shaft dampers.

BACKGROUND OF THE INVENTION

[0003] An automobile conventionally employs a hollow, tubular drive shaft to transmit torque from the transmission to the differential gears. Such drive shafts, however, often produce annoying NVH (i.e., noise, vibration, and harshness). Accordingly, it is desirable to dampen NVH to provide for a quieter and smoother ride. Furthermore, it is desirable to prevent vibration to avoid mechanical failure from the loosening of assembled vehicle parts.

[0004] Several commonly assigned patents address NVH reduction. For example, U.S. Pat. No. 4,909,361 to Stark et al. discloses a drive shaft damper having a base tube or core formed of helically wound paper. A helical retaining strip, such as ethylene propylene diene monomer rubber (i.e., EPDM) is fixed to the core to engage the bore of the drive shaft.

[0005] Another example is U.S. Pat. No. 5,976,021 to Stark et al. U.S. Pat. No. 5,976,021 improves the drive shaft damper disclosed in U.S. Pat. No. 4,909,361 by including sealed ends and an innermost layer of waterproof material, such as aluminum foil.

[0006] Yet another example is U.S. Pat. No. 5,924,531 to Stark et al. U.S. Pat. No. 5,924,531 discloses a vibration damping shaft liner having a cylindrical core and a corrugated layer wound around the core in alternating helical grooves and flutes.

[0007] Each of the above-referenced patents is herein incorporated by reference in its entirety.

[0008] The drive shaft dampers disclosed in the foregoing, commonly assigned patents are well suited for their intended purposes. That notwithstanding, even more manufacturers are producing drive shafts having standardized end diameters. Such drive shafts accommodate universal joint flanges, which attach the drive shaft to the gearboxes and differentials in motor vehicles. This standardization is achieved by reducing the diameter at the respective drive shaft ends, a process referred to as “swaging.”

[0009] The reduction of the drive shaft ends necessitates the insertion of the damper into the drive shaft prior to the swaging process. Thereafter, the drive shaft is heat treated under extreme conditions (e.g., 350°F) for a period sufficient to strengthen the drive shaft (e.g., about 6-8 hours).

[0010] Accordingly, there is a need for drive shaft dampers that can withstand the extreme heat-treatment conditions required for modern drive shaft manufacturing. In particular, there is a need for drive shaft dampers that can be inserted into drive shafts before swaging.

SUMMARY OF THE INVENTION

[0011] It is an object of the present invention to provide a drive shaft damper that can withstand extreme conditions (e.g., high temperatures) during the heat-aging and strengthening processes.

[0012] It is yet a further object of the present invention to provide a drive shaft damper that minimizes NVH.

[0013] It is yet a further object of the present invention to provide a drive shaft damper that possesses greater resistance to corrosive chemicals that may be encountered during the manufacturing of swaged drive shafts.

[0014] It is yet a further object of the present invention to provide a drive shaft damper that has improved resistance to in-use deterioration (i.e., while installed and used in a vehicle).

[0015] It is yet a further object of the present invention to provide a drive shaft damper that, once positioned, stays fixed within the drive shaft.

[0016] It is yet a further object of the present invention to provide a dampered hollow drive shaft that includes a hollow drive shaft and a convolute or spirally wound damper secured within the drive shaft.

[0017] The foregoing, as well as other objectives and advantages of the invention and the manner in which the same are accomplished, is further specified within the following detailed description and its accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] FIG. 1 depicts an exemplary drive shaft damper having a spirally wound retaining member.

[0019] FIG. 2 depicts a section of an exemplary drive shaft damper.

[0020] FIG. 3 depicts an exemplary drive shaft damper having a circumferentially positioned retaining member.

[0021] FIG. 4 depicts an exemplary drive shaft damper having an axially positioned retaining member.

[0022] FIGS. 5a-5g depict exemplary retaining member structures.

[0023] FIG. 6 illustrates the superior performance of dampers that include silicone-containing retaining members.

DETAILED DESCRIPTION

[0024] The invention embraces tubular drive shaft dampers having improved heat resistance and NVH-reduction properties.

[0025] In one aspect, the invention is an improved drive shaft damper formed of a substantially cylindrical structure, such as a convolute tube or, more typically, a spirally wound tube. The substantially cylindrical structure itself is typically formed of fibrous material, such as paper or other polymeric material.
In another aspect, the invention is a method of making dampers with improved heat-resistance and NVH-reduction properties. Typically, this includes inserting the improved damper into a tubular drive shaft, then swaging the ends of the drive shaft by rolling the ends under high radial pressure using shaped rollers (i.e., roll swaging).

Thereafter, the drive shaft is heated to a temperature of 350° F. for a period sufficient to increase its strength and wear (e.g., between about 4 to 12 hours).

In another aspect, the invention is a dampered tubular drive shaft with swaged ends. The dampered tubular drive shaft includes the improved drive shaft damper according to the foregoing description. A portion of the tubular drive shaft may possess a substantially fixed inner diameter between its swaged ends, thereby providing space for the present damper to be positioned (i.e., within the drive shaft’s substantially fixed inner diameter). This dampered drive shaft is typically formed of metal (e.g., aluminum).

In yet another aspect, the invention embraces a vehicle that includes this kind of dampered drive shaft.

The substantially cylindrical structure of the drive shaft damper is typically made up of one or more spirally wound plies. These plies may be configured to form butt joints, overlap joints, and/or seam gap joints. The spirally wound plies may also include one or more moisture-resistant layers. In addition, the spirally wound plies may include one or more adhesive layers positioned between adjacent plies so that adjacent plies are affixed to one another.

FIG. 1 depicts an exemplary drive shaft damper positioned within a tubular drive shaft having an inside surface and an outside surface. The drive shaft damper is partly characterized by its substantially cylindrical structure. Thus, the outside surface of the substantially cylindrical structure is positioned adjacent to the inside surface of the drive shaft. As depicted in FIG. 1, the radius defined by this internal annular space refers, for example, to that part of the tubular drive shaft that possesses a substantially fixed inner diameter (i.e., between the swaged ends). In this way, the drive shaft damper, once positioned within the drive shaft, stays frictionally secured.

In one embodiment of the drive shaft damper, the substantially cylindrical structure includes an outermost layer of corrugated paper or cardboard. In another embodiment, the substantially cylindrical structure includes an outermost layer of (non-corrugated) cardboard (i.e., having a smooth surface). Surprisingly, a drive shaft damper configuration in which the outermost layer is formed of smooth-surface paperboard seems to have better noise attenuation as compared with a configuration in which the outermost layer is formed of corrugated paperboard.

Table 1 (below) compares power spectrum data for dampers having various constructions (e.g., dampers having three-rib rubber retaining members and/or single faced corrugated surface layers).

<table>
<thead>
<tr>
<th>Plot</th>
<th>Level</th>
<th>Reduction</th>
<th>Frequency</th>
<th>Drive Shaft Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>−13 dB</td>
<td>−</td>
<td>815 Hz</td>
<td>no damper (progressive example)</td>
</tr>
<tr>
<td>2</td>
<td>−44 dB</td>
<td>−31 dB</td>
<td>942 Hz</td>
<td>corrugated damper w/ 3-rib rubber</td>
</tr>
</tbody>
</table>

In one such embodiment, the retaining member is spirally wound around the substantially cylindrical structure, typically along the entire length of the substantially cylindrical structure. See FIG. 1.
TABLE 1-continued

<table>
<thead>
<tr>
<th>Plot</th>
<th>Level</th>
<th>Reduction</th>
<th>Frequency</th>
<th>Drive Shaft Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>−64 dB</td>
<td>−51 dB</td>
<td>1475 Hz</td>
<td>smooth-surface damper w/3-rb rubber</td>
</tr>
<tr>
<td>4</td>
<td>−58 dB</td>
<td>−45 dB</td>
<td>905 Hz</td>
<td>damper w/two 3-rb rubber</td>
</tr>
<tr>
<td>5</td>
<td>−42 dB</td>
<td>−29 dB</td>
<td>942 Hz</td>
<td>welded on yokes w/ single 3-rb rubber</td>
</tr>
<tr>
<td>6</td>
<td>−27 dB</td>
<td>−14 dB</td>
<td>960 Hz</td>
<td>damper w/corrugated w/o rubber</td>
</tr>
</tbody>
</table>

[0045] Table 1 suggests that the smooth-surface damper with a three-rb retainer member performs best at NVH reduction (i.e., this damper achieved the greatest decibel reduction).

[0046] As noted, the drive shaft damper according to the present invention is typically inserted into a tubular drive shaft before the drive shaft is swaged and thereafter subjected to heat treatment and aging. To endure the extreme heat-treatment conditions required for modern drive shaft manufacturing, the retaining member must be heat resistant. In particular, the heat-resistant retaining member must be able to endure an operating temperature of about 175°F or more (i.e., greater than about 347°F). Those having ordinary skill in the art will appreciate that 175°F is above the serviceable temperature of EPDM and natural rubber. See R.A. Higgins, Properties of Engineering Materials, 2nd ed., Industrial Press Inc., 1994, p. 314.

[0047] For some applications, the heat-resistant retaining member will possess a maximum serviceable temperature (i.e., maximum operating temperature) greater than about 190°F (i.e., greater than about 375°F), typically greater than 200°F (i.e., greater than about 390°F), such as 205°C (i.e., greater than about 400°F). In other words, as used herein, the term "operating temperature" refers to those temperatures in which the heat-resistant retaining member continues to maintain its structural integrity and effectively reduces NVH as part of the drive shaft damper.

[0048] For some extreme heat applications, the heat-resistant retaining member will possess a maximum serviceable temperature greater than about 250°F (i.e., greater than about 480°F), typically greater than 275°F (i.e., greater than about 525°F), such as 285°C (i.e., greater than about 545°F).

[0049] Silicone-containing polymeric material is particularly suitable for a heat-resistant retaining member. In this regard, silicone-containing polymeric material is serviceable up to at least 285°C.

[0050] In addition, heat-resistant retaining members formed from silicone-containing polymeric material have been observed to possess enhanced dampening characteristics. This is unexpected.

[0051] In this regard, FIG. 6 depicts the performance of three drive shaft dampers possessing smooth paper surfaces. In particular, FIG. 6 compares various frequency response functions (energy versus frequency) for a 78-inch aluminum drive shaft (i.e., prop shaft). The undamped aluminum drive shaft (i.e., the control) showed undesirable frequency response as indicated by the frequent spikes. The same kind of aluminum drive shaft showed lower frequency response (i.e., dampening ratio) when damped using either (i) one 59 inch rolled paper liner (i.e., a convolute tube) or (ii) two 29-inch EPDM-modified dampers (i.e., modified with an EPDM rubber retaining member).

[0052] That said, the same kind of aluminum drive shaft showed far better frequency response when dampered using two 29-inch silicone-modified dampers according to the present invention (i.e., modified with a silicone rubber retaining member). Upon examination of FIG. 6, those having ordinary skill in the art will recognize that the frequency response of the drive shaft damper with a silicone rubber retaining member is remarkably smooth (i.e., dampened). This demonstrates the superior dampening performance (i.e., dampening ratio) of drive shaft dampers according to the present invention.

[0053] A heat-resistant retaining member formed from silicone rubber is capable of withstanding not only extremely high temperatures (e.g., 350°F or more) but also extremely cold temperatures (e.g., −60°F or less). Accordingly, a silicone-containing retaining member possesses a broad operating temperature range.

[0054] In forming the heat-resistant retaining member, silicone-containing polymeric material, such as silicone rubber, may be employed alone or with other materials. A silicone rubber that is suitable for forming heat-resistant retaining members is available from Timco Rubber Products, Inc. as 50 DUOMETER SILICONE.

TABLE 2

(50 DUOMETER SILICONE)

<table>
<thead>
<tr>
<th>General Purpose Properties</th>
<th>Typical Value</th>
<th>ASTM Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness (Shore A)</td>
<td>50</td>
<td>D 2240</td>
</tr>
<tr>
<td>Compression set (22 h @ 100°C, max %)</td>
<td>20</td>
<td>D 395</td>
</tr>
<tr>
<td>Ozone resistance (100 MPa, 100 h @ 40°C, 20% elongation)</td>
<td>No cracks</td>
<td>D 1149</td>
</tr>
<tr>
<td>Tensile strength (psi)</td>
<td>725</td>
<td>D 412 Die C</td>
</tr>
<tr>
<td>Elongation @ rupture (min, %)</td>
<td>300</td>
<td>D412 Die c</td>
</tr>
<tr>
<td>Heat aging (70 h @ 100°C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hardness increase, (max, duro, points)</td>
<td>+5</td>
<td>D 573</td>
</tr>
<tr>
<td>Change in tensile strength, (max %)</td>
<td>−15</td>
<td>D 573</td>
</tr>
<tr>
<td>Change in elongation, max %</td>
<td>−21</td>
<td>D 573</td>
</tr>
<tr>
<td>Tear strength (min. kn/m (by/in))</td>
<td>(136)</td>
<td>D624 Die B</td>
</tr>
</tbody>
</table>

[0055] In the specification and drawings, typical embodiments of the invention have been disclosed and, although specific terms have been employed, they have been used in a generic and descriptive sense only and not for purposes of limitation.

1. A drive shaft damper possessing improved heat-resistance and NVH-reduction properties, comprising:
   a) a substantially cylindrical structure defining an inside surface and an outside surface; and
   a heat-resistant retaining member secured to said outside surface of said substantially cylindrical structure, said heat-resistant retaining member possessing maximum operating temperature of at least about 350°F; whereon said heat-resistant retaining member extends above said outside surface of said substantially cylindrical structure.
2. A drive shaft damper according to claim 1, wherein said retaining member possesses a maximum operating temperature of at least about 375°F.

3. A drive shaft damper according to claim 1, wherein said retaining member possesses a maximum operating temperature of at least about 400°F.

4. A drive shaft damper according to claim 1, wherein said retaining member possesses a maximum operating temperature of at least about 425°F.

5. A drive shaft damper according to claim 1, wherein said retaining member possesses a maximum operating temperature of at least about 450°F.

6. A drive shaft damper according to claim 1, wherein said retaining member possesses a maximum operating temperature of at least about 500°F.

7. A drive shaft damper according to claim 1, wherein substantially cylindrical structure comprises a spirally wound tube.

8. A drive shaft damper according to claim 1, wherein substantially cylindrical structure comprises one or more spirally wound plies.

9. A drive shaft damper according to claim 8, wherein said spirally wound plies form butt joints.

10. A drive shaft damper according to claim 8, wherein said spirally wound plies form overlap joints.

11. A drive shaft damper according to claim 8, wherein said spirally wound plies form seam gap joints.

12. A drive shaft damper according to claim 11, wherein part of said retaining member is positioned between said seam gap joints and another part of retaining member is positioned underneath said seam gap joints.

13. A drive shaft damper according to claim 1, wherein said substantially cylindrical structure comprises a convolute tube.

14. A drive shaft damper according to claim 1, wherein said retaining member comprises:
   a base that is secured to said substantially cylindrical structure; and
   at least one protuberance that extends above said outside surface of said substantially cylindrical structure.

15. A drive shaft damper according to claim 14, wherein said protuberance extends above said outside surface of said substantially cylindrical structure by at least about 0.2 inch.

16. A drive shaft damper according to claim 1, wherein the retaining member is spirally wound around said substantially cylindrical structure.

17. A drive shaft damper according to claim 1, wherein the retaining member is spirally wound along the length of said substantially cylindrical structure.

18. A drive shaft damper according to claim 1, wherein at least one retaining member is positioned substantially parallel to the axis of said substantially cylindrical structure.

19. A drive shaft damper according to claim 1, wherein at least one retaining member is circumferentially positioned about said substantially cylindrical structure.

20. A drive shaft damper according to claim 1, wherein said drive shaft damper provides improved dampening ratio as compared with an otherwise identical damper having an EPDM-rubber retaining member.

21. A drive shaft damper according to claim 1, wherein said substantially cylindrical structure comprises a substantially cylindrical fibrous structure.

22. A drive shaft damper according to claim 1, wherein said substantially cylindrical structure comprises a substantially cylindrical paperboard structure.

23. A drive shaft damper according to claim 1, wherein said substantially cylindrical structure comprises substantially smooth paperboard that defines said outside surface of said substantially cylindrical structure.

24. A drive shaft damper according to claim 23, wherein said drive shaft damper provides improved dampening ratio as compared with an otherwise identical damper having an EPDM-rubber retaining member.

25. A drive shaft damper according to claim 23, wherein said drive shaft damper provides improved dampening ratio as compared with an otherwise identical comparative damper having a corrugated paperboard ply that defines the comparative damper's outside surface.

26. A drive shaft damper according to claim 23, wherein said drive shaft damper provides improved dampening ratio as compared with an otherwise identical comparative damper having (i) a corrugated paperboard ply that defines the comparative damper's outside surface and (ii) an EPDM-rubber retaining member.

27. A drive shaft damper according to claim 23, wherein said substantially cylindrical structure comprises at least one single-faced corrugated paperboard ply.

28. A drive shaft damper according to claim 27, wherein said substantially cylindrical structure comprises a paperboard tube whose outside surface is formed by said single-faced corrugated paperboard ply.

29. A drive shaft damper according to claim 1, wherein said substantially cylindrical structure comprises polymeric material.

30. A drive shaft damper according to claim 1, wherein said substantially cylindrical structure comprises moisture-resistant material.

31. A drive shaft damper according to claim 1, wherein the retaining member comprises silicone-containing polymeric material.

32. A drive shaft damper according to claim 1, wherein the retaining member consists essentially of silicone rubber.

33. A dampened tubular drive shaft formed from the drive shaft damper according to claim 1, wherein the drive shaft damper is frictionally secured within the tubular drive shaft.

34. A vehicle comprising the dampened tubular drive shaft of claim 33.

35. A method of forming a dampened drive shaft using the drive shaft damper according to claim 1, the method comprising the following steps:
   a. inserting the drive shaft damper into a tubular drive shaft;
   b. thereafter, swaging the ends of the drive shaft; and
   c. heating the swaged drive shaft to a temperature of at least about 350°F. for a period sufficient to increase the strength and wear properties of the drive shaft.

36. A method according to claim 35, wherein the step of heating the swaged drive shaft to increase the strength and wear properties of the drive shaft comprises heating the swaged drive shaft to a temperature of at least about 400°F. for at least six hours.

37. A method of making a dampened drive shaft having improved NVH-reduction, comprising:
   providing a drive shaft damper comprising:
   a substantially cylindrical structure defining an inside surface and an outside surface; and
a heat-resistant retaining member secured to said outside surface of said substantially cylindrical structure, said heat-resistant retaining member possessing maximum operating temperature of at least about 350°F; and

wherein said heat-resistant retaining member extends above said outside surface of said substantially cylindrical structure;

providing a tubular drive shaft having substantially constant inner diameter;

inserting the drive shaft damper into the portion of the tubular drive shaft having substantially constant inner diameter;

thereafter swaging at least one end of the tubular drive shaft such that the swaged end has an inner diameter that is less than the drive shaft’s maximum inner diameter; and

thereafter heating the drive shaft damper and swaged tubular drive shaft to a temperature of at least about 350°F for a period sufficient to increase the strength properties of the drive shaft.

38. A method according to claim 37, wherein the step of heating the swaged drive shaft to increase the strength properties of the drive shaft comprises heating the swaged drive shaft to a temperature of at least about 350°F for between about six and eight hours.

39. A dampened drive shaft possessing improved NVH-reduction, comprising:

a tubular drive shaft defining an internal annular space;

a damper positioned within the tubular drive shaft, the damper comprising:

a substantially cylindrical structure defining an inside surface, an outside surface, and a central axis; and

a heat-resistant retaining member secured to said outside surface of said substantially cylindrical structure, said heat-resistant retaining member possessing an operating temperature greater than 175°C; and

wherein said heat-resistant retaining member extends above said outside surface of said substantially cylindrical structure, thereby defining the damper’s maximum radius as measured from the central axis of the substantially cylindrical structure and the outermost point of the retaining member; and

wherein the damper’s maximum radius is greater than the radius of the internal annular space of said tubular drive shaft.

40. A dampened drive shaft according to claim 39, wherein said damper’s heat-resistant retaining member comprises silicone-containing polymeric material.

41. A dampened drive shaft according to claim 39, wherein said damper’s heat-resistant retaining member contacts the inside surface of the tubular drive shaft.

42. A dampened drive shaft a according to claim 39, wherein said damper’s heat-resistant retaining member is frictionally fixed within the tubular drive shaft.

43. A dampened drive shaft according to claim 39, wherein said tubular drive shaft possesses a substantially fixed inner diameter between its swaged ends.

44. A dampened drive shaft according to claim 43, wherein said damper is positioned within the portion of the tubular drive shaft having a substantially fixed inner diameter.

* * * * *