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(54) Title: ACTIVE VARIABLE STIFFNESS ABSORBER

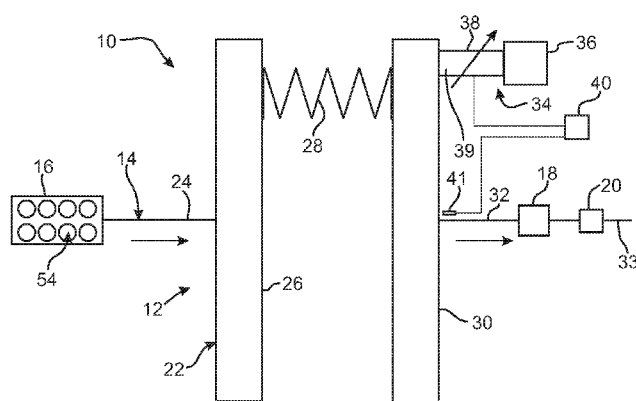


Fig. 1

(57) Abstract: A product and method that may involve a first mass, a second mass, and a variable element engaged between the first and second masses. The variable element may be responsive to a variable input to provide different states to the variable element each of which may be selected to target the attenuation of a specific frequency.

ACTIVE VARIABLE STIFFNESS ABSORBER

TECHNICAL FIELD

[0001] The field to which the disclosure generally relates includes absorbers and in particular, includes absorbers for rotating systems that may operate in varying modes.

BACKGROUND

[0002] The operation of machinery may involve moving masses that may accelerate and decelerate. Changes in velocity may create vibrations. The vibrations may be sensed by human occupants, and/or may have other effects that may be undesirable. Vibrations may be generated in a number of forms, including axial, transverse, and/or torsional. An axial mode of vibration may occur in a direction corresponding to the axis of rotation of mass components. A transverse mode of vibration may occur in a direction perpendicular to the axis of rotation of mass components. Torsional vibration may arise, in particular, as a result of rotary motion of the mass components, and may also be referred to as angular vibration. Torsional vibration may occur for example, in power transmission systems that have rotating elements. As an example, the power plant of a motor vehicle may generate multiple modes of vibration, including torsional vibration. In some applications, an engine may be connected to the vehicle's driveline through a transmission, and the resulting system may have a number of rotating elements. The individual components of the system may be connected to operate in a number of different ways to propel the associated vehicle under a number of conditions, which may constantly vary, compounding the nature of generated vibrations. Addressing the resulting vibrations is therefore, challenging.

SUMMARY OF ILLUSTRATIVE VARIATIONS

[0003] A number of variations may involve a product that may include a first mass, a second mass, and a variable element engaged between the first and second masses. The variable element may be responsive to a variable input to provide different states of the variable element, each of which may be selected to target the attenuation of a specific frequency.

[0004] A number of additional variations may involve a method and may include connecting a driving component to the first mass, directly or indirectly. The driving component may be operated in variable modes. A current mode in which the driving component is operating, may be determined. The variable element may be set to a state corresponding to the current mode.

[0005] Other illustrative variations within the scope of the invention will be apparent from the detailed description provided herein. It should be understood that the detailed description and specific examples, while disclosing variations within the scope of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Select examples of variations within the scope of the invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0007] Figure 1 is a schematic illustration of a rotating system according to a number of variations.

[0008] Figure 2 is a schematic illustration in cross section of a rotating system according to a number of variations.

[0009] Figure 3 is a schematic cross sectional illustration of the rotating system of Figure 2 taken along the line indicated at 3-3 in Figure 2.

[0010] Figure 4 is a schematic cross sectional illustration of the rotating system of Figure 2 taken along the line indicated at 4-4 in Figure 2.

[0011] Figure 5 is a schematic illustration of a rotating system according to a number of variations.

[0012] Figure 6 is a graph of vibration amplitude versus frequency for a number of variations.

[0013] Figure 7 is a diagram of a method according to a number of variations.

DETAILED DESCRIPTION OF ILLUSTRATIVE VARIATIONS

[0014] The following description of the variations is merely illustrative in nature and is in no way intended to limit the scope of the invention, its application, or uses.

[0015] In a number of variations as illustrated in Figure 1, a product 10 may be used in a system, which may be a rotating system 12. For purposes of illustration the rotating system 12 may be a propulsion system 14. The illustration of Figure 2 presents a linearized representation of the rotational system. The propulsion system 14 may include a power plant, such as an engine 16, which may be connected such as through a transmission 18, to a vehicle's driveline 20. The engine 16 may be an internal combustion engine or may be an alternative propulsion system such as a hybrid or electric system. The transmission 18 may be of a multiple gear type, continuously variable type, or another type that may provide various torque and speed ratio options between the engine 16 and the driveline 20. A rotating mass 22 may be included in the rotating system 12 and may include any of a torque transfer element 24, a mass 26, a damper 28, a mass 30, and /or a torque transfer element 32. The torque transfer elements 24, 32 may be shafts or other structures that transfer rotation from one element to another, and that may rotate about an axis 33. The torque transfer element 24 may be a crankshaft of the engine 16, or may be connected therewith. In a number of variations, the mass 26, damper 28 and mass 30, may be assembled as a dual mass flywheel, or may be otherwise configured. In a number of variations, the mass 26 may be a flywheel and the mass 30 may be an inertia ring. One or more dampers 28 may be disposed between the mass 26 and the mass 30 to dampen vibrations. The damper(s) 28 may be springs which may store and release energy as fluctuations in the engine 16, and/or in other components may occur, which may offset generated vibrations.

[0016] In a number of variations the rotating system 12 may include a variable absorber system 34. The variable absorber system 34 may include a mass 36, which may be engaged with the mass 30 through a variable isolator 38. The mass 30 may be movable to oscillate in response to vibrations, and the variable isolator 38 may be adjustable in real time to target the reduction

of vibrations at various and changing frequencies. The variable absorber system 34, which may include the variable isolator 38 and the mass 36, may be connected with electronic controller components 40.

[0017] In operation of the electronic controller components 40, methods, algorithms, or parts thereof may be implemented in a computer program(s) product including instructions or calculations carried on a computer readable medium for use by one or more processors to implement one or more of the method steps or instructions. The computer program product may include one or more software programs comprised of program instructions in source code, object code, executable code or other formats; one or more firmware programs; or hardware description language (HDL) files; and any program related data. The data may include data structures, look-up tables, or data in any other suitable format. The program instructions may include program modules, routines, programs, objects, components, and/or the like. The computer program may be executed on one processor or on multiple processors in communication with one another.

[0018] In a number of variations, the program(s) may be embodied on computer readable media, which can include one or more storage devices, articles of manufacture, or the like. Illustrative computer readable media may include computer system memory, e.g. RAM (random access memory), ROM (read only memory); semiconductor memory, e.g. EPROM (erasable, programmable ROM), EEPROM (electrically erasable, programmable ROM), flash memory; magnetic or optical disks or tapes; and/or the like. The computer readable medium also may include computer to computer connections, for example, when data may be transferred or provided over a network or another communications connection (either wired, wireless, or a combination thereof). Any combination(s) of the above examples is also included within the scope of the computer-readable media. It is therefore to be understood that methods may be at least partially performed by any electronic articles and/or devices capable of executing instructions corresponding to one or more steps of the disclosed methods. The electronic controller components 40 may implement programs to continuously adjust the variable isolator 38 to specific states and/or through a range of spring rates and firmness states to maximize the reduction of targeted vibrations.

[0019] In a number of variations, the mass 36 may be engaged with the mass 30 through an element 39 that may be a smart material responsive to a stimulus such as electric or magnetic sources, to result in variable properties being exhibited by the material. For example, the element 39 may be formed of a known material that may be electrorheological, with properties such as deformation behavior in response to stress, which are a function of an applied electric field strength. The element 39 may be formed of a known material that may be magnetorheological, with properties such as deformation behavior in response to stress, which are a function of an applied magnetic field strength. The element 39 may be formed of a known material that may be electrostrictive, with properties such as physical size, which may vary in response to an applied electric field. The element 39 may be formed of a known material that may be magnetostrictive, with properties such as physical size, which may vary in response to an applied magnetic field. In a number of variations the material may be a composite that may be a metal, ceramic or polymeric composite, or a combination thereof. In a number of variations the element 39 may be an elastomer whose properties vary with an applied field and may be any of the foregoing type. The material selected may vary according to the requirements of the application to provide the necessary spring rate(s), and may be a material that may exhibit variable stiffness under a variable input such as various electrical current or magnetic field conditions. This change in stiffness may be selected on a real-time basis to modify the target frequency to be absorbed. The resulting response allows absorption characteristics that may be matched to operating conditions of the rotating system 12. The electric or magnetic field may be varied through operation of the electronic controller components 40.

[0020] With reference to Figure 2, a number of variations are illustrated in schematic cross section. The rotating system 12 may include the masses 26, 30 and the damper(s) 28. The masses 26, 30 may include features 42, 43 respectively, between which the damper(s) 28 may be compressible to dampen vibrations. The variable isolator 38 may include a rotor 44 that may be fixed to, or may be formed with, the mass 30, and may be a component thereof. Additional reference is directed to Figure 3. The rotor 44 may present a structure 46 that may be a channel and/or that may be annular, and/or that

may be U-shaped. In a number of variations the shape of the structure 46 may vary. The structure 46 may be used to shape the magnetic field in a way that appropriately energizes the element 48 of the variable isolator 38 such as when activated by a magnetic field. Accordingly, the rotor 44 may be comprised of a magnetic material. The structure 46, when in the shape of an annular channel, may face in the axial direction to open away from the mass 30. The torque transfer element 32 may extend out through the axial center of the rotor 44. The mass 36 may be ring shaped and may be suspended to within the structure 46. The mass 36 may be engaged with the structure 46 through the element 48, which may serve the functions of element 39 of Figure 1, and which may, for example, be a magnetorheological composite with ferromagnetic particles in an elastomeric carrier. The element 48 may be bonded or otherwise fixed to the mass 36 and/or to the rotor 44, and may be located inside the structure 46. In a number of variations, the mass 36 and the element 48 may be disposed entirely within the structure 46. A variable magnetic element 50 may be disposed adjacent the element 48. The variable magnetic element 50 may be, or may include, an electric coil 51 that may be supplied with a variable current as may be controlled by the electronic controller components 40. The coil may be annular in shape and may extend into the structure 46, and may in-particular extend into an open end of the U-shaped channel, which may place it near the element 48. The magnetic field generated by the variable magnetic element 50 may be varied by varying its supplied current to change the magnetic field to which the element 48 is subjected. The magnetic field may be increased or decreased to increase and decrease the stiffness of the element 48. The magnetic field may be tailored to establish its desired effect on the element 48 by selecting the shape of the structure 46. In a number of variations the variable magnet element 50 may be fixed or grounded, such as to a case 52, so that it may not rotate with the rotor 44. The torque transfer element 32 may extend out through the axial center of the variable magnetic element 50 and may freely spin relative thereto. In a number of variations, the damper(s) 28 may be compressible between the masses 26, 30 as additionally shown in Figure 4, with the spring type dampers 28 disposed between the features 42 on the mass 26 and the features 43 on the mass 30. The features 42, 43 may take the form of tabs or

stops on the masses 26, 30. By varying the stiffness of the element 48, the mass 36 may operate to absorb vibrations at different frequencies, which may be targeted to dampen vibrations at particular frequencies, in addition to any damping provided by the dampers 28.

[0021] In a number of variations, the electronic controller components 40 may be programmed to vary the magnetic field to target the suppression of vibrations generated at identified frequencies. For example, the engine 16 may have a number of cylinders 54 as shown in Figure 1. In a number of variations, the engine 16 may have eight cylinders. In other variations the engine 16 may have a different number of cylinders. The engine 16 may be operated to fire all eight cylinders, or may be operated with a number of cylinders (e.g. two or four, or another number), deactivated. When the engine 16 may operate in a mode using eight cylinders, measurable vibrations may be generated at an identifiable frequency or frequency range. In this mode the variable magnetic element 50 may be supplied with a current to set the element 48 at a stiffness where suppression of vibrations at the target frequency, or frequency range, is maximized. When the engine 16 may operate in a mode using six cylinders, measurable vibrations may be generated at another identifiable frequency or frequency range. In this mode the variable magnetic element 50 may be supplied with a different current to set the element 48 at a stiffness where suppression of those vibrations at this target frequency, or frequency range, is maximized. When the engine 16 may operate in a mode using four cylinders, measurable vibrations may be generated at yet another identifiable frequency or frequency range. In this mode the variable magnetic element 50 may be supplied with a different current to set the element 48 at a stiffness where suppression of these vibrations at the target frequency, or frequency range, is maximized. It should be understood that suppressing varying vibrations generated by cylinder use or deactivation is but one example of the use of the product 10 to absorb vibrations for variable systems, or for those that operate in different modes. In a number of variations, the electronic controller components 40 may factor in sensed operating conditions such as speed, torque, etc. from sensors 41. The operating conditions may be used to add a variation to the states

corresponding to the operating mode to set the actual state of the variable isolator 38.

[0022] In a number of variations as shown in Figure 5, a variable isolator 56, may be similar to the variable isolator 38 and may be applied to a rotating system 58. The illustration of Figure 5 presents a linearized representation on the rotational system. The rotating system 58 may have a driving component 60 and a driven component 62. The driving component 60 and driven component 62 may be connected through a mass 64. The mass 64 may be a torque transfer element such as a shaft or other structure to transfer rotation from the driving component 60 to the driven component 62. The mass 64 may include a flywheel 70 or other structure mounted to rotate with a shaft 72 that may extend between the driving component 60 and the driven component 62. The variable isolator 56 may include a mass 74 and an element 76 that may be responsive to stimulus such as electric or magnetic, to result in variable properties – such as stiffness -- being exhibited by the material of the element 76. As demonstrated by the graph of excitation 78 in Figure 6, vibration cancellation by the variable stiffness absorber may be used to target different frequencies. The amplitude (on axis 81), of vibration cancellation may be a maximum at point 79, which may be moved along the frequency range of axis 80 as indicated by the variable location 82, by changing the stimulus. In a number of variations, the stimulus is varied by varying the electrical current to the variable isolator 56.

[0023] With reference to Figure 7 a method 84 may be used for operating the product 10 to target the suppression of certain vibrations. The method 84 may begin at step 85 and may proceed to step 86 where a determination of the current mode in which the product 10 is operating may be determined. In a number of variations, a determination of whether the system is operating in a first mode may be made. In a number of variations, the method 84 may determine whether the engine 16 is operating in an eight cylinder mode. If the determination is positive, the method 84 may proceed to step 87 where the variable isolator 38, 56 may be set to a first state where the element 48, 76 may exhibit properties that maximize the reduction of vibrations generated when the system operates in the first mode. From step 87 the method 84 may return to step 85 and may proceed therefrom, such as

in continuous iterations. If the determination at step 86 is negative, the method 84 may proceed to step 88 where a determination of whether the system is operating in a second mode may be made. For example, the method 84 may determine whether an engine is operating in a six cylinder mode. If the determination is positive, the method 84 may proceed to step 90 where the variable isolator 38, 56 may be set to a second state where the element 48, 76 may exhibit properties that maximize the reduction of vibrations generated when the system operates in the second mode. From step 90 the method 84 may return to step 85 and may proceed therefrom. If the determination at step 88 is negative, the method 84 may proceed to step 92 where a determination of whether the system is operating in a third mode may be made. In a number of variations, the method 84 may determine whether the engine 16 is operating a four cylinder mode. If the determination is positive, the method 84 may proceed to step 94 where the variable isolator 38, 56 may be set to a third state where the element 48, 76 may exhibit properties that maximize the reduction of vibrations generated when the system operates in the third mode. From step 94 the method 84 may return to step 85 and may proceed therefrom. If the determination at step 92 is negative, the method 84 may return to step 85 and may proceed therefrom. In other variations where the associated system operates in a different number of modes or in a range of variable modes, a different number of states may be correspondingly effected. In a number of variations the first, second and third states may be a number of variable states and/or ranges. For variable states, the method 84 may factor in sensed operating conditions such as speed and torque. Accordingly, in a number of variations, the electronic controller components 40 may communicate with speed and torque sensors 41. The operating conditions may be used to add a variation to the states corresponding to the determined operating mode to set the actual state of the variable isolator 38, 56. In a number of variations the method 84 may include selecting the shape of the structure 46 to shape the magnetic field in a way that appropriately energizes the element 48 of the variable isolator 38 when activated by a magnetic field.

[0024] Through the foregoing variations a product, and a method of selectively absorbing torsional vibration over a number of, or a range of,

frequencies is provided. This can enable, for example, comfortable use of a motor vehicle engine over a wider range of operating conditions and cylinder activation states. The description of variants is only illustrative of components, elements, acts, product and methods considered to be within the scope of the invention and are not in any way intended to limit such scope by what is specifically disclosed or not expressly set forth. The components, elements, acts, product and methods as described herein may be combined and rearranged other than as expressly described herein and still are considered to be within the scope of the invention.

[0025] Variation 1 may involve a product that may include a first mass, a second mass, and a variable element engaged between the first and second masses. The variable element may be responsive to a variable input to provide different states to the variable element each of which may be selected to target the attenuation of a specific frequency.

[0026] Variation 2 may include the product according to variation 1 wherein the variable element may be an elastomer that may be fixed to the first and second masses.

[0027] Variation 3 may include the product according to variation 1 wherein the elastomer may comprise a magnetorheological material with ferromagnetic particles.

[0028] Variation 4 may include the product according to variation 3 and may include a variable magnetic element disposed adjacent the elastomer.

[0029] Variation 5 may include the product according to variation 1 and may include an axis about which the first and second masses rotate.

[0030] Variation 6 may include the product according to variation 1 and may include a third mass. A damper may be compressed between the first and third masses.

[0031] Variation 7 may include the product according to variation 1 and may include a rotor that may be connected with the first mass so that the first mass and rotor rotate together. The rotor may present a structure within which the second mass may be disposed.

[0032] Variation 8 may include the product according to variation 7 wherein the variable element may be connected with the rotor and the second mass and may be disposed within the structure channel.

[0033] Variation 9 may include the product according to variation 1 and may include a third mass. A damper may be disposed between the first and third masses. An engine may be connected to the third mass and a transmission may be connected to the first mass.

[0034] Variation 10 may include the product according to variation 1 wherein the variable input may include a variable electric current or a variable magnetic field.

[0035] Variation 11 may involve a method and may include connecting a driving component to the first mass. The driving component may be operated in variable modes. A current mode in which the driving component is operating, may be determined. The variable element may be set to a state corresponding to the current mode.

[0036] Variation 12 may include the method according to variation 11 wherein the driving element may be an engine. The variable modes may involve operating the engine with a first number of cylinders activated, and may involve operating the engine with some of the first number of cylinders deactivated.

[0037] Variation 13 may include the method according to variation 11 and may include providing a magnetorheological material in the variable element.

[0038] Variation 14 may include the method according to variation 11 and may include providing a third mass that may be connected between the driving component and the first mass. A damper may be provided and may be compressible between the first and third masses.

[0039] Variation 15 may include the product according to variation 11 and may include providing a magnetic coil adjacent the variable element.

[0040] The above description of select variations within the scope of the invention is merely illustrative in nature and, thus, variations or variants thereof are not to be regarded as a departure from the spirit and scope of the invention.

CLAIMS

What is claimed is:

1. A product comprising a first mass, a second mass, a variable element engaged between the first and second masses, a variable input, the variable element responsive to the variable input to provide different states to the variable element each of which is selected to target the attenuation of a specific frequency.
2. The product according to claim 1 wherein the variable element is an elastomer that is fixed to the first and second masses.
3. The product according to claim 1 wherein the elastomer comprises a magnetorheological material with ferromagnetic particles.
4. The product according to claim 3 comprising a variable magnetic element disposed adjacent the elastomer.
5. The product according to claim 1 comprising an axis about which the first and second masses rotate.
6. The product according to claim 1 comprising a third mass, and a damper compressed between the first and third masses.
7. The product according to claim 1 comprising a rotor connected with the first mass so that the first mass and rotor rotate together, the rotor presenting a structure within which the second mass is disposed.
8. The product according to claim 7 wherein the variable element is connected with the rotor and the second mass and is disposed within the structure.
9. The product according to claim 1 comprising a third mass, a damper disposed between the first and third masses, an engine connected to the third mass and a transmission connected to the first mass.
10. The product according to claim 1 wherein the variable input comprises a variable electric current or a variable magnetic field.
11. A method of operating the product of claim 1 comprising connecting a driving component to the first mass, operating the driving component in variable modes, determining a current mode of the variable modes in which the driving component is operating, and setting the variable element to a state corresponding to the current mode.

12. The method of claim 11 wherein the driving element is an engine, the variable modes involve operating the engine with a first number of cylinders activated, and involve operating the engine with some of the first number of cylinders deactivated.
13. The method according to claim 11 comprising providing a magnetorheological material in the variable element.
14. The method according to claim 11 comprising providing a third mass connected between the driving component and the first mass and providing a damper compressible between the first and third masses.
15. The method according to claim 11 comprising providing a magnetic coil adjacent the variable element.

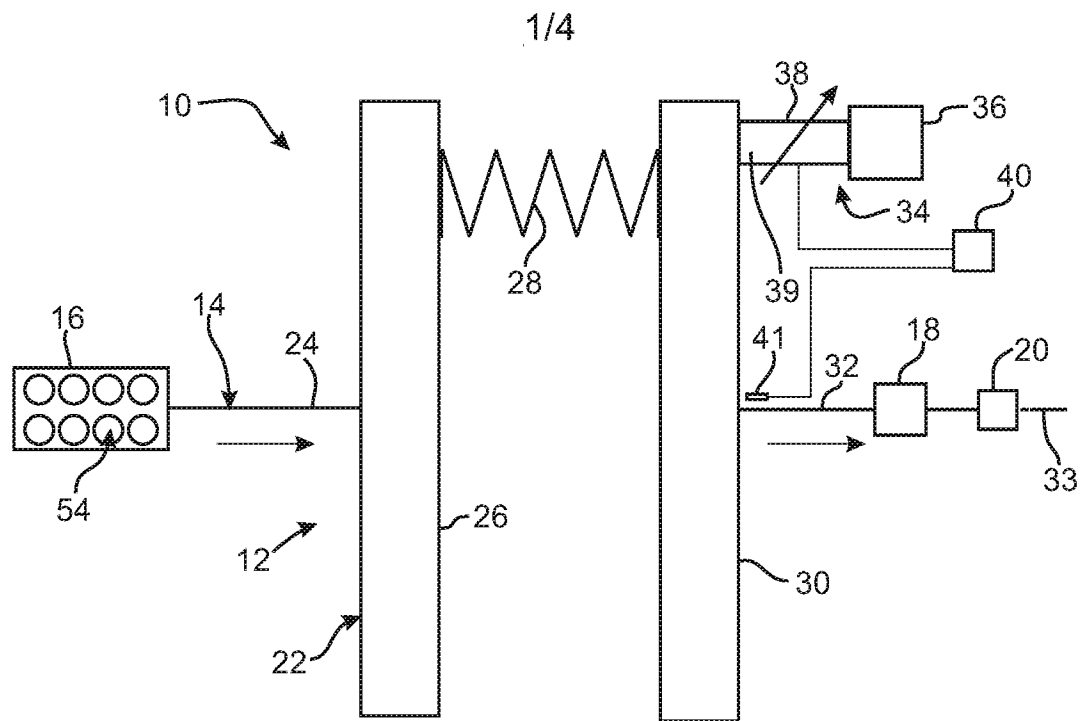


Fig. 1

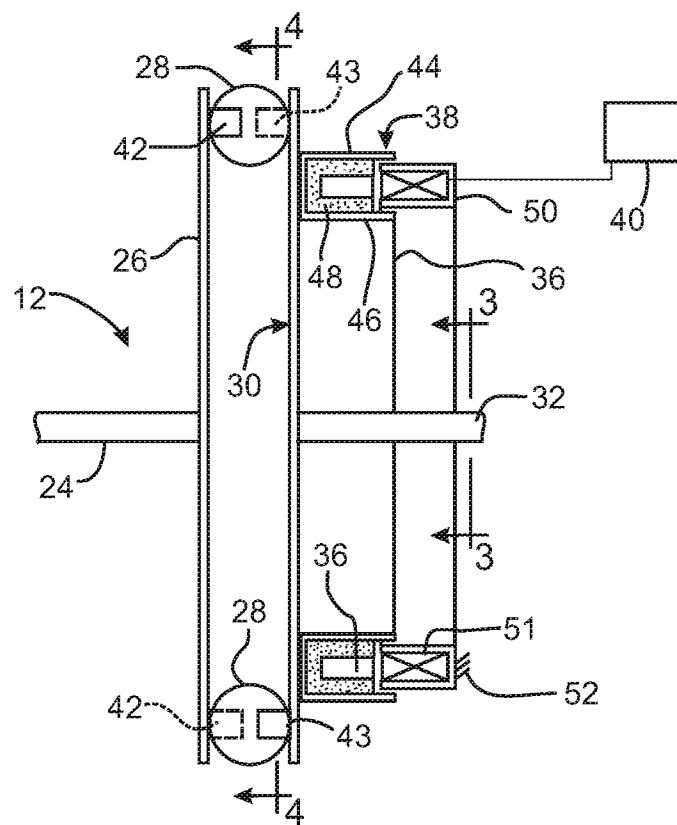


Fig. 2

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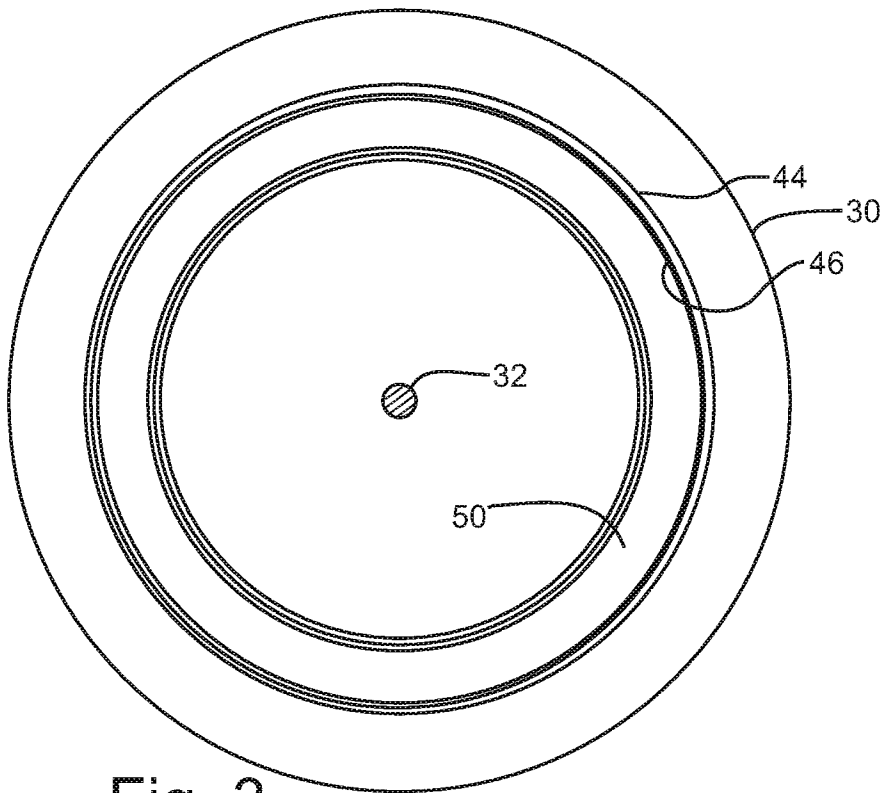


Fig. 3

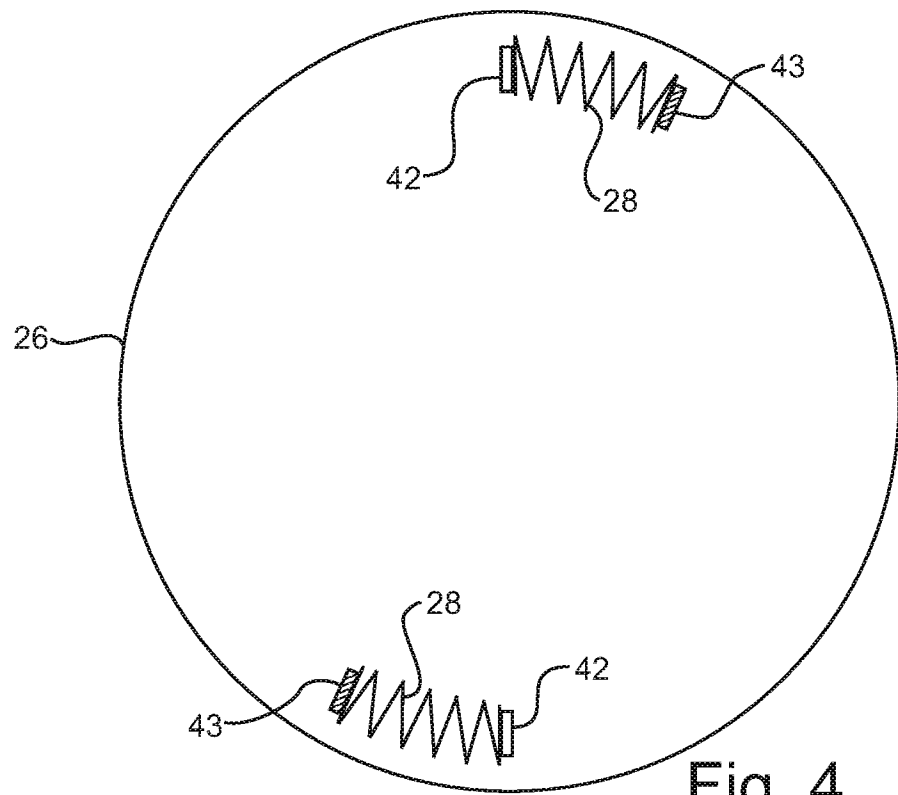


Fig. 4

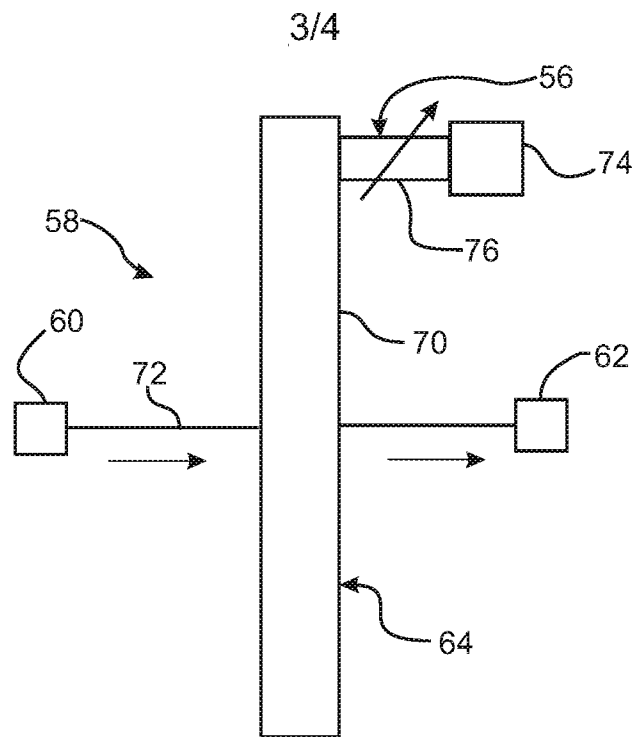


Fig. 5

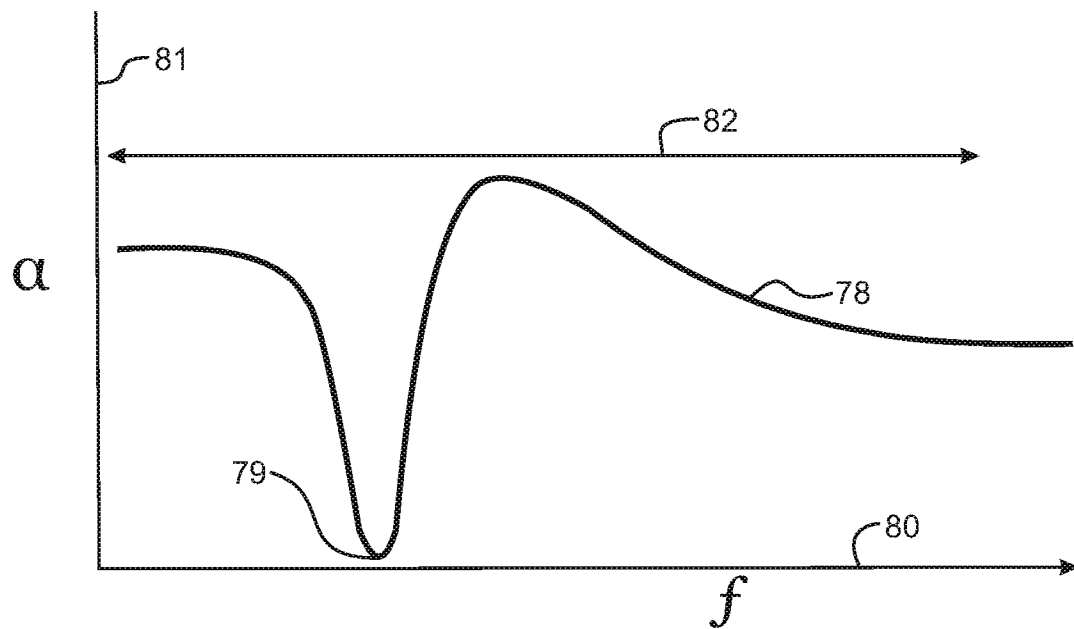


Fig. 6

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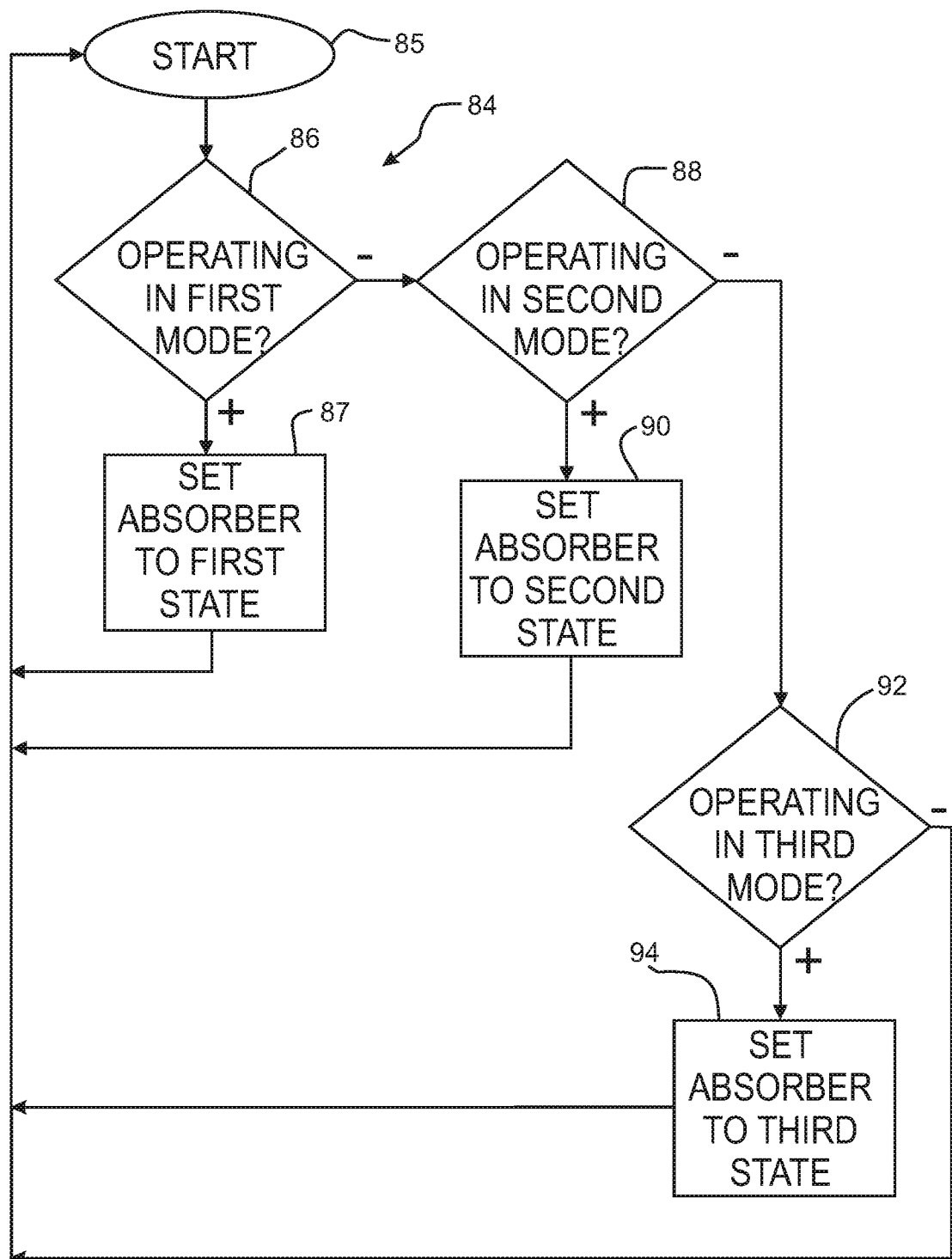


Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/047364**A. CLASSIFICATION OF SUBJECT MATTER****F16F 13/30(2006.01)i, F16F 7/10(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F16F 13/30; F16F 9/00; F16F 15/131; F16D 3/80; F16F 15/129; F16F 15/30; F16F 15/16; F02B 77/00; F16F 15/14; F16F 7/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & keywords: engine, transmission, torsional vibration, mass, variable element, variable input, elastomer, and magnetorheological

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5829319 A (MOKEDDEM, MOHAMED) 03 November 1998 See column 2, line 52 - column 3, line 46 and figure 1.	1,5,7-8,10
Y		2-4,6,9,11-15
Y	JP 08-021487 A (NOK MEGURASUTIKKU K.K.) 23 January 1996 See abstract, paragraphs [0008]-[0011], and figures 1-2.	2-4
Y	US 2014-0298952 A1 (MENDE et al.) 09 October 2014 See abstract, paragraphs [0026]-[0027], claim 1, and figure 1.	6,9,11-15
A	US 2005-0181880 A1 (FRIEDMANN, OSWALD) 18 August 2005 See paragraphs [0026]-[0030] and figure 1.	1-15
A	JP 05-071588 A (ATSUGI UNISIA CORP.) 23 March 1993 See abstract, paragraphs [0011]-[0020], and figures 1-2.	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search

16 May 2017 (16.05.2017)

Date of mailing of the international search report

17 May 2017 (17.05.2017)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/047364

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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