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F2S SCL

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US 5346192 A **US 4624435 A**

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(54) Abstract Title

A vibration isolation mount

(57) The vibration isolation mount mounting a first member to a second member comprises an electromagnetic coil member 7 and a magnetically susceptible or magnetisable member 1. The magnetically susceptible or magnetisable member and the electromagnetic coil member are held apart by resilient material 15 which lies in the flux path generated between the electromagnetic coil member and the magnetically susceptible or magnetisable member.

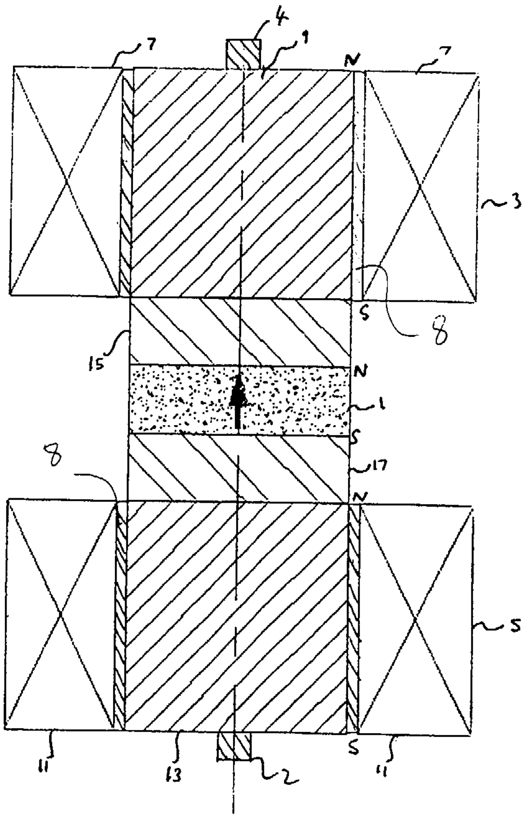

FIGURE 1

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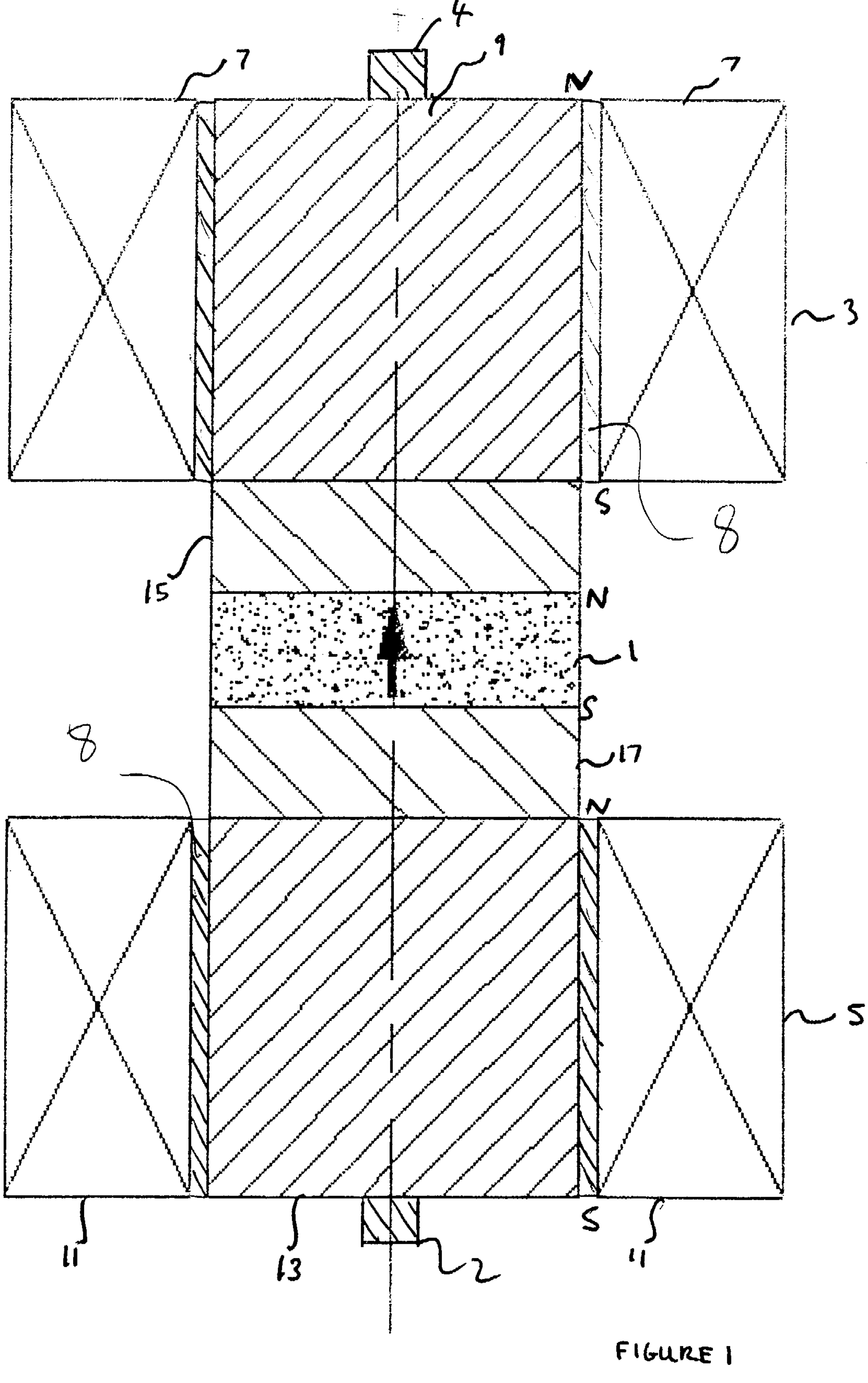

FIGURE 1

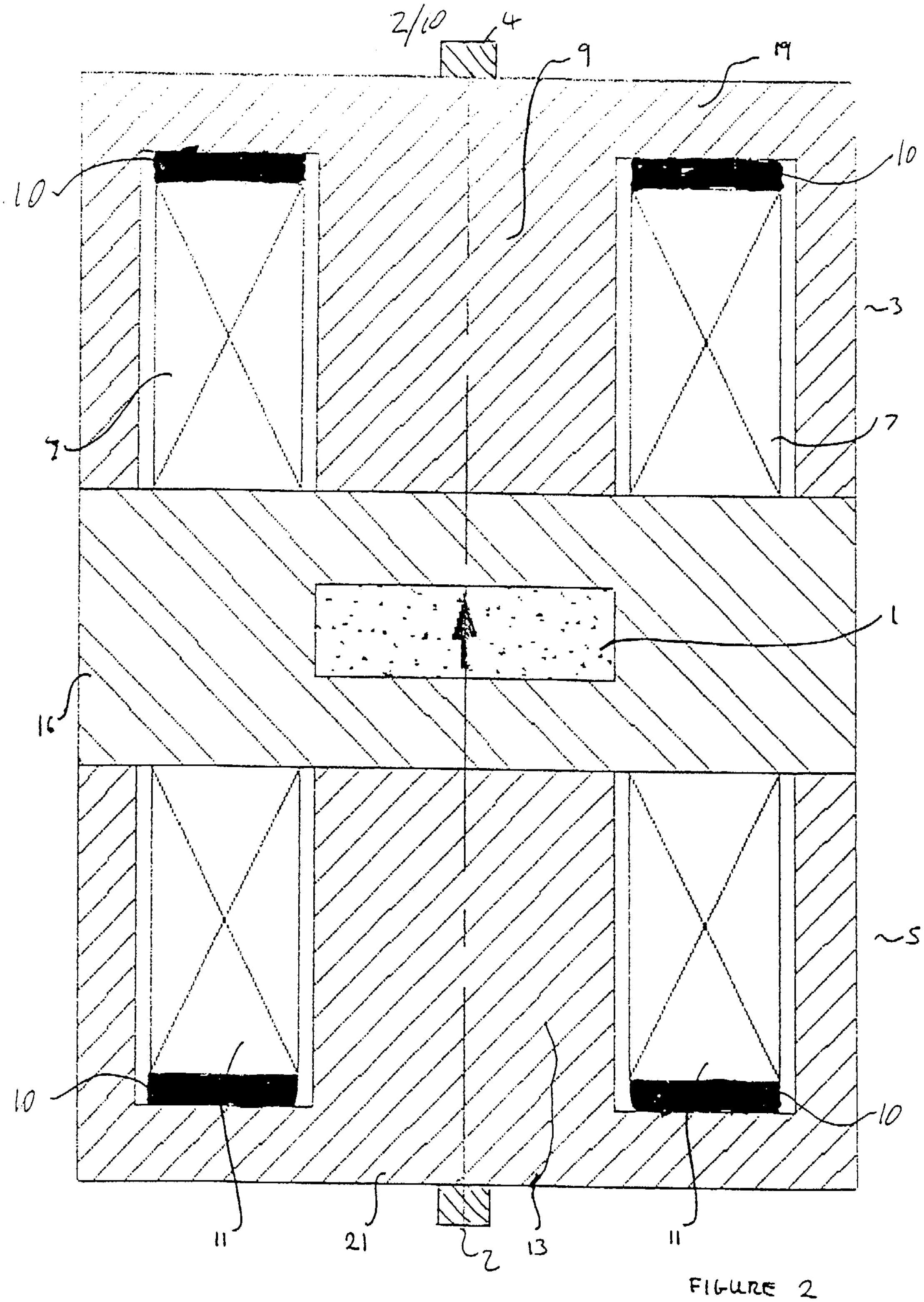

FIGURE 2

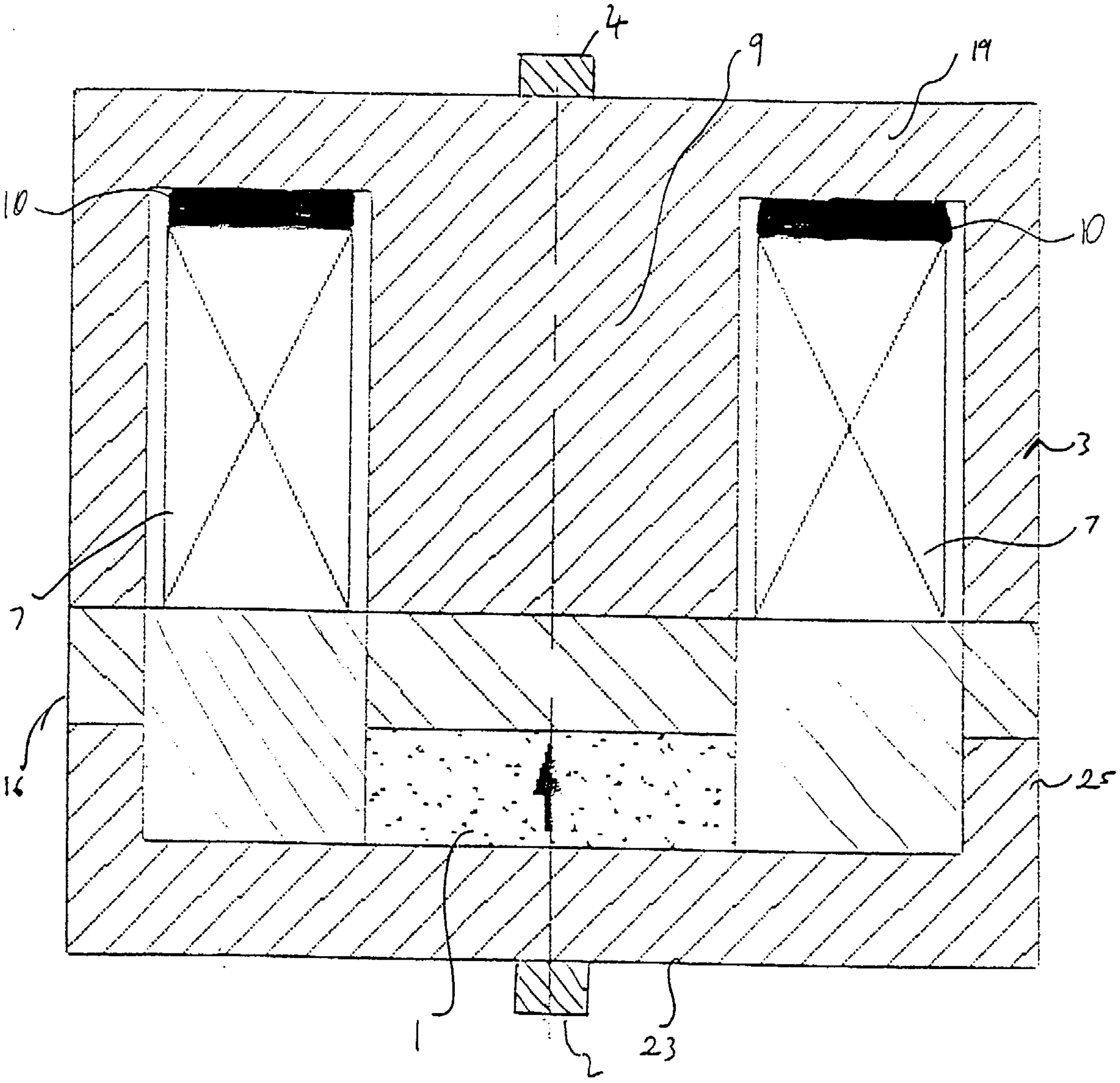

FIGURE 3

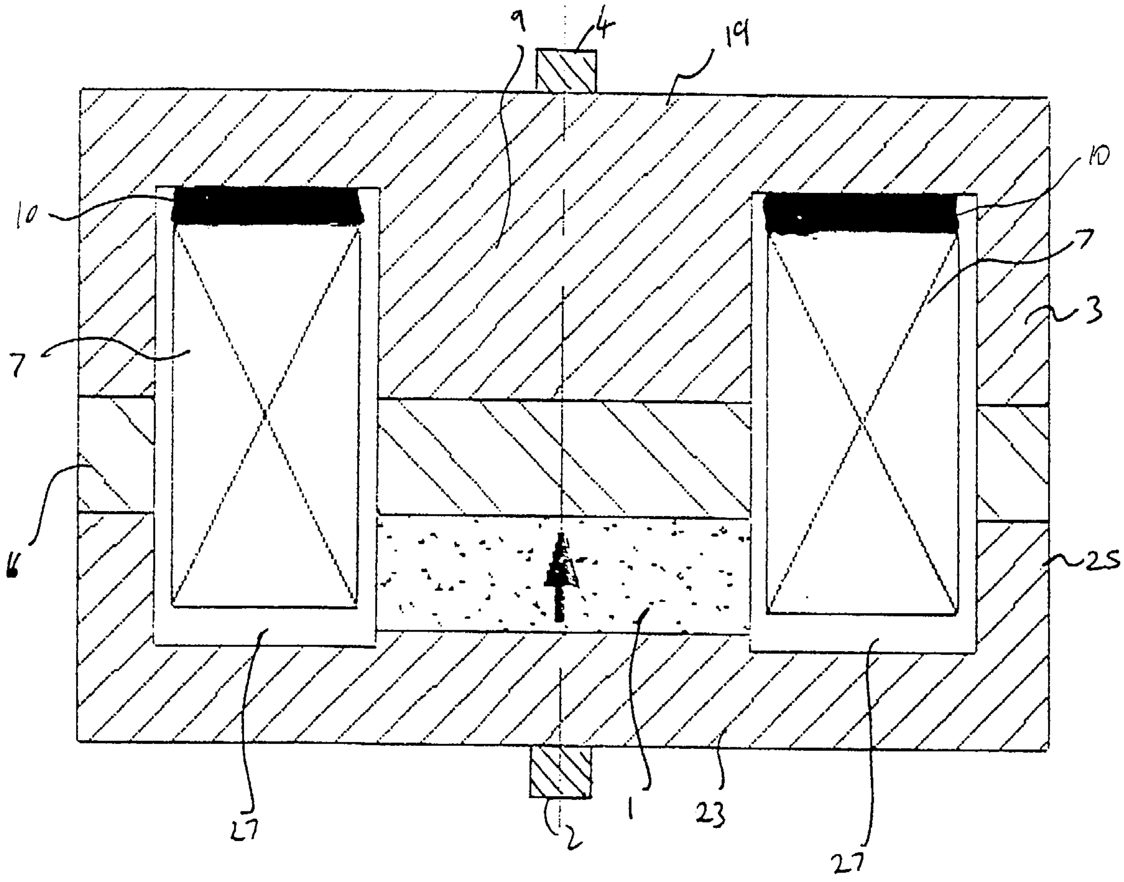

FIGURE 4

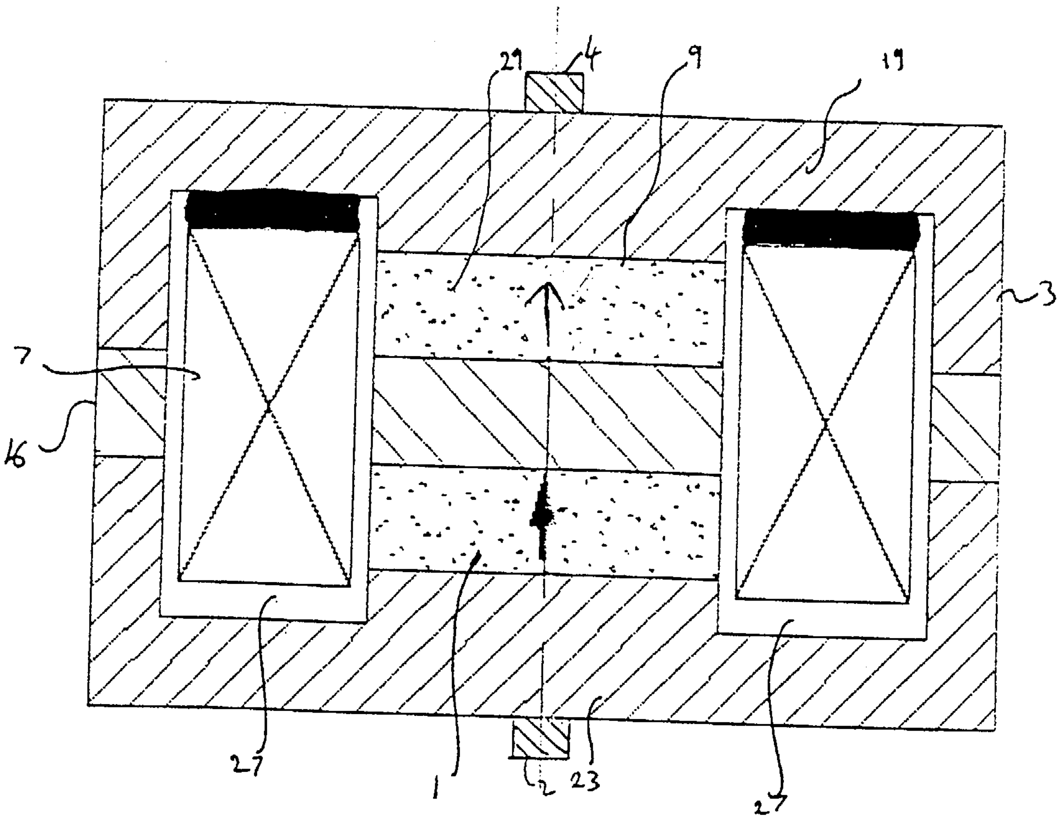

FIGURE 5

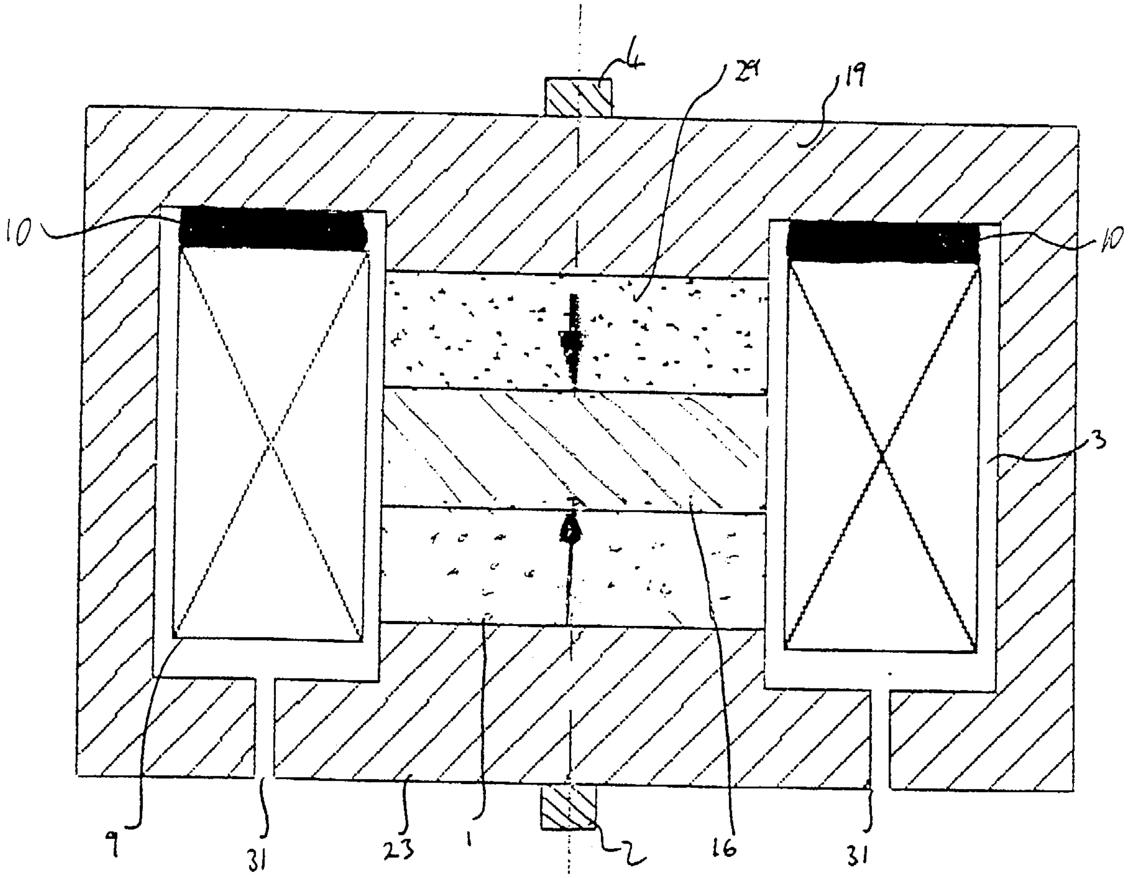

FIGURE 6

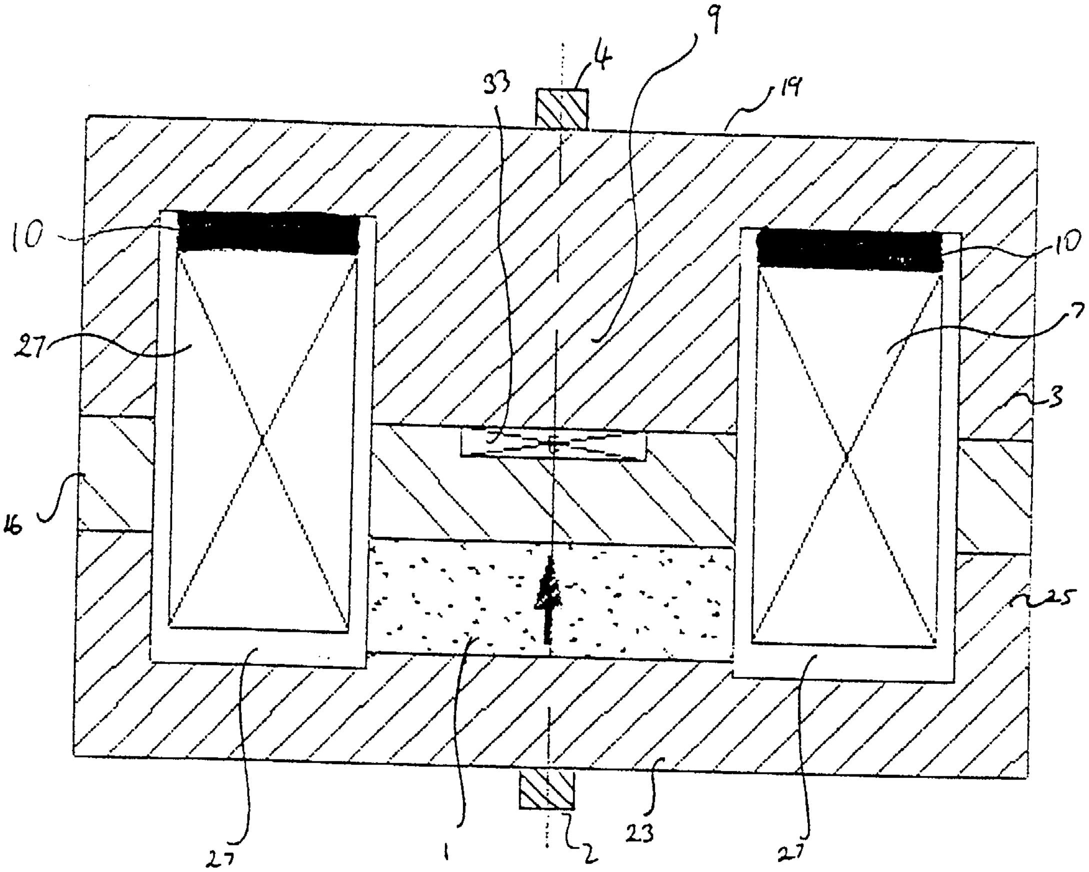

FIGURE 7

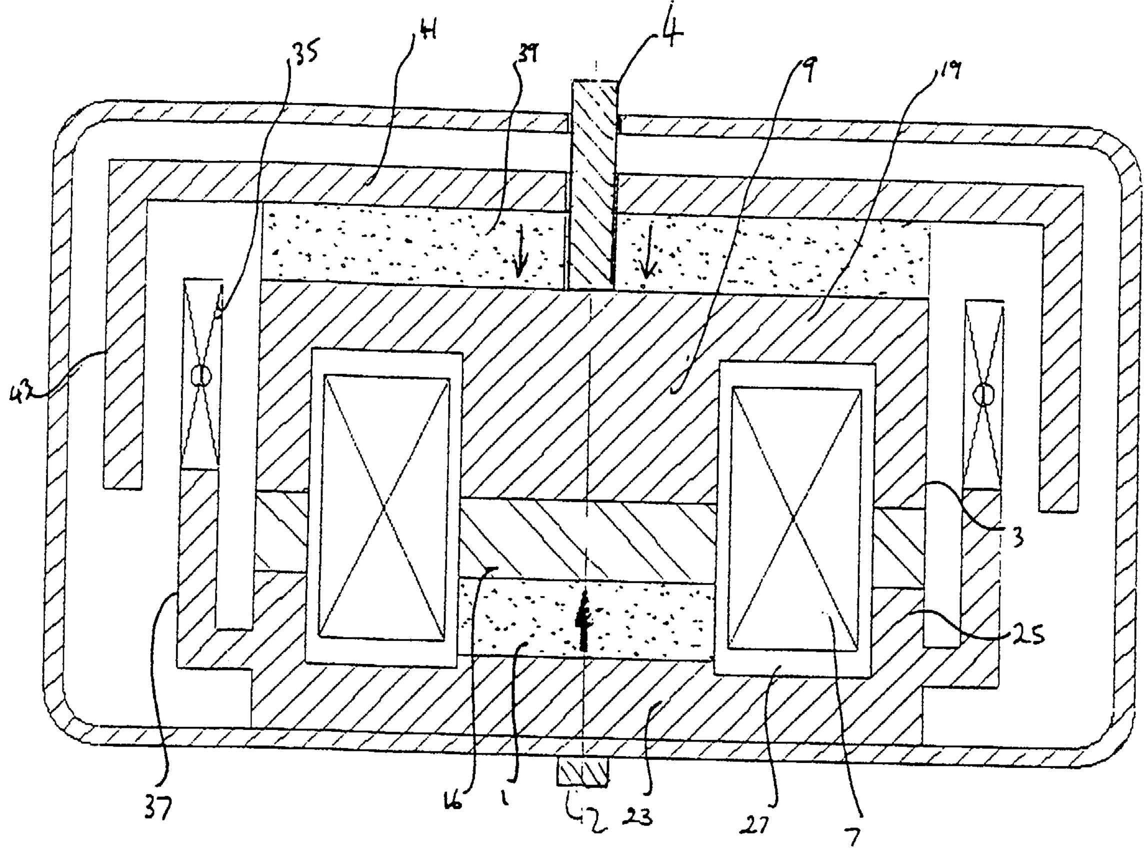

FIGURE 8

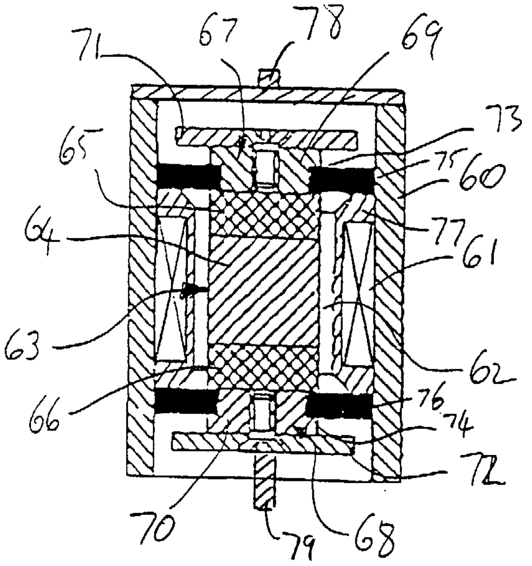

Figure 9

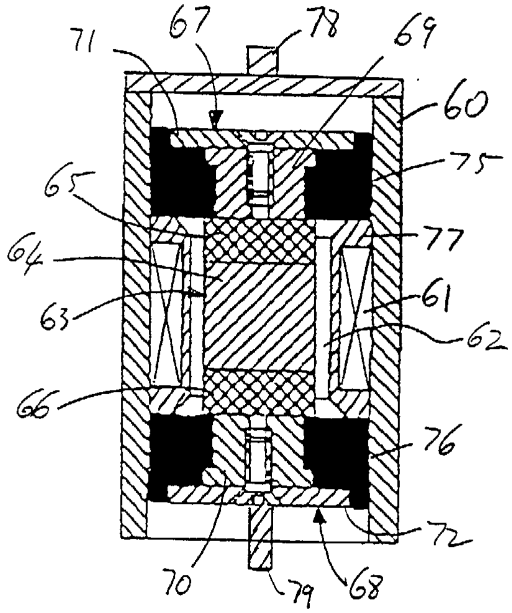

Figure 10

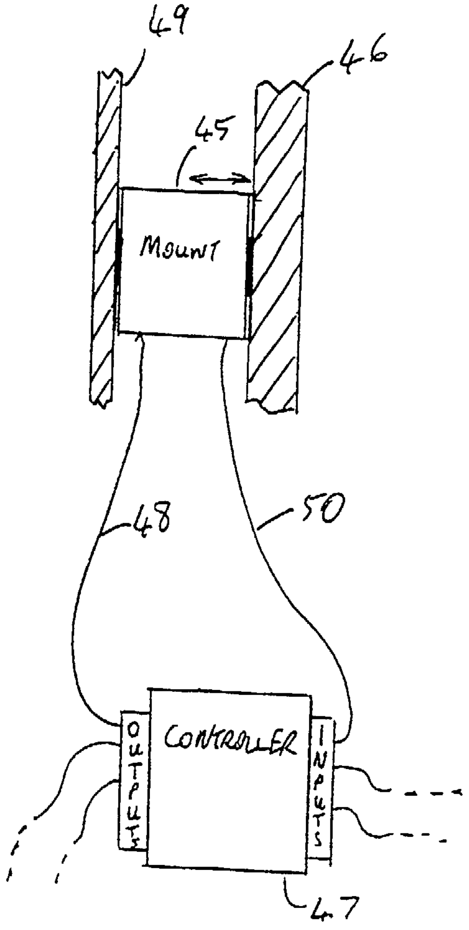

Figure 11

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A VIBRATION ISOLATION MOUNT

The present invention relates to an isolation mount for mounting a first member to a second member such that substantial vibrations from the first member are not transferred to the second member and vice versa.

There is often a need to isolatively mount a first member onto a second member. For example, in an aircraft, the trim panels are mounted onto the fuselage of the aircraft. It is necessary to prevent or at least substantially minimise vibrations from the fuselage from being carried to the trim panels. Similarly vibrations from the cabin to the fuselage must also be minimised. Trim panel vibrations are often caused by unpredictable events such as turbulent airflow or vibrating machinery. Such a mount may be subjected to vibrations perpendicular to the two members and, to shear forces. Such shear forces can potentially affect the functioning of the mount and are often unpredictable e.g. people or objects leaning against the panels.

US 4 624 435 and US 5 346 192 describe a mount for mounting an engine in a vehicle. The mount has an electromagnet and a permanent magnet which attract one another, an elastomeric member is provided to force the two magnets apart. By varying the current through the electromagnetic the natural resonant frequency of the mount can be varied to isolate vibrations of the required frequency. However, in both of these mounts, any shear forces applied to the mount could result in the electromagnet being shorted to the permanent magnet or part of the casing of the mount.

The concept of damping vibrations by balancing a magnetic force against a restoring force provided by an elastomeric member has been described in US 5 236 186 which relates to dampers. A damper is placed against a panel or the like in order to dampen the vibrations of the panel. The vibration damper is provided to damp vibrations in a member such as a panel and is thus different to vibration isolation mounts which reduce vibrations being transferred from one member to another whilst mounting one member on the other. The considerations for reducing vibrations are different.

The present invention addresses the problems of prior isolation mounts which occur if the mount shears.

The present invention provides a vibration isolation mount mounting a first member to a second member. The mount comprises an electromagnetic coil member which can be mounted to the first member and a magnetically susceptible or magnetisable member which can be connected to the second member and is moveable relative to the electromagnetic coil member. The resilient material is arranged to resiliently hold the electromagnetic coil member and the magnetically susceptible or magnetisable member apart. The resilient material is arranged in a flux path generated between the electromagnetic coil member and the magnetically susceptible or magnetisable member. When the electromagnetic coil member is energised, the electromagnetically susceptible or magnetisable member is arranged to experience a force.

Thus by varyingly energising the electromagnetic coil member, the magnetic force experienced by the magnetically susceptible or magnetisable member can be varied. The resilient member which holds the electromagnetic coil member and the magnetically susceptible or magnetisable member apart is thus stretched or compressed. In this way the vibration isolation properties of the mount can be varied.

The flux path between the electromagnetic coil member and the magnetically susceptible or magnetisable member generally comprises an air path between the two bodies. In order to improve the efficiency of the device generally, it is desirable to reduce this air gap. However, the reduction of the air gap brings with it the disadvantage that a shear force on the mount can result in the closing of the air gap. The provision of the resilient material in the flux path thus directly prevents contact and improves the resistance of the mount to shear forces.

In one embodiment which provides the maximum protection against sheer forces, the resilient material is placed in a minimal gap region between the electromagnetic coil member and the magnetically susceptible or magnetisable member. This however a trade off between placing the resilient material in the minimal gap region or placing it between a larger gap region where the larger amount of resilient material will allow for a larger relative displacement between the electromagnetic coil member and the magnetically susceptible or magnetisable member. In one embodiment the electromagnetic coil member comprises and electromagnet having a coil surrounding and fixed to a magnetisable core to exert an attractive or repulsive force on said magnetically susceptible or magnetisable member. In such an arrangement the resilient material is provided between the magnetisable core and the magnetically susceptible or magnetisable member.

In another embodiment at least one permanent magnet is arranged with the resilient material between the magnetisable core and the magnetically susceptible or magnetisable member to provide a biasing magnetic force between the electromagnetic coil member and the magnetically susceptible or magnetisable member.

In one embodiment which provides a symmetric arrangement, the magnetically susceptible or magnetisable member comprises a second electromagnet having a coil surrounding and fixed to a magnetisable core. In a specific embodiment to improve the efficiency of the arrangement, each electromagnetic includes a magnetically susceptible or magnetisable shoe magnetically connected to the core and extending around the coil to provide a flux path around the coil.

The resilient material can lie between the core of the second electromagnet and the permanent magnet and between the permanent magnet and the core of the first electromagnet. Alternatively the resilient material can lie at least between the magnetically susceptible or magnetisable shoes of the electromagnets.

In alternative embodiment, the electromagnet includes a magnetically susceptible or magnetisable shoe magnetically connected to the core and extending around the core to provide a return flux path. The magnetically susceptible or magnetisable member extends to face the core and the shoe and the resilient material lies between at least the shoe and the magnetically susceptible or magnetisable member.

The permanent magnet can lie adjacent to the magnetically susceptible or magnetisable member or between the permanent magnet and the core of the electromagnet.

The permanent magnet can comprise any magnetic material such as NdFeB, $SmCo_5$ or ferrite material. The electromagnetic core can comprise any suitable magnetically susceptible or magnetisable material such as steel.

In another embodiment of the present invention, the electromagnetic coil member comprises a coil surrounding a core region and a magnetically susceptible or magnetisable shoe extending from the core region around the coil to provide a flux path around the outside of the coil. The magnetically susceptible or magnetisable member is arranged to face the core region and the magnetically susceptible or magnetisable shoe. The first permanent magnet is arranged in the core region attached to the magnetically susceptible or magnetisable member and a second permanent magnet is arranged in the core region attached to the shoe. The resilient material is arranged between the shoe and the magnetically susceptible or magnetisable member where they face one another around the coil and/or between the first and second permanent magnets. Where the two permanent magnets are arranged with their polarisations in line, the lines of flux pass around the coil. Alternatively the permanent magnets can be of opposite polarisation whereby the flux lines extend out of the resilient material through the coil into the shoe surrounding the coil.

In a further embodiment of the present invention the electromagnetic coil member comprises a magnetically susceptible or magnetisable sleeve extending along an axis and a coil mounted coaxially within and fixed to a sleeve and defining an axial core region. The magnetically susceptible or magnetisable member is arranged coaxially with the electromagnetic core member and lies in and extending out of the core region. It experiences an axial force when the coil is energised. The resilient material lies radially between the magnetically susceptible or magnetisable member and the electromagnetic coil member. In this embodiment the energising of the electromagnetic coil member causes the relative lateral movement of the magnetically susceptible or magnetisable member. Thus the resilient material experiences shear forces rather than compression forces under normal operation. When a shear force is applied to the mount, the resilient material experiences a compression force.

In one embodiment the magnetically susceptible or magnetisable member has radially enlarged end portions which extend radially towards the sleeve. This provides the return flux path outside the coil of the electromagnetic coil member.

In one preferred embodiment the resilient material lies between end regions of the magnetically susceptible or magnetisable member and the sleeve.

In another further embodiment the resilient material lies between the sleeve and the radially enlarged end portions and/or between said sleeve and regions of the magnetically susceptible or magnetisable member intermediate to said radially enlarged end portions said portion lying within the core region.

In an embodiment the magnetically susceptible or magnetisable member comprises a middle portion between two opposed polarity permanent magnets and end regions of magnetisable material connected to the magnets. The middle portion and the magnets are arranged to lie in the core region and the end regions extend out of the core region. The middle portion is preferably but not necessarily made of magnetisable material.

In one embodiment detecting means is provided for detecting the force applied to the resilient material. The detecting means can comprise a piezo electric member provided in or next to the resilient material. Alternatively the detecting means comprises an inductive coil rigidly connected to either the electromagnetic coil member or the magnetically susceptible or magnetisable member, and flux generating means rigidly connected to the other of the electromagnetic coil member or the magnetically susceptible or magnetisable member. The inductive coil and the flux generating means are arranged so that when there is movement therebetween, voltage or current is induced in the inductive coil because the coil passes through flux generated by the flux generating means. In a preferred embodiment the flux generating means comprises a permanent magnet.

In addition to a mount the present invention also provides a vibration reduction system comprises one or more vibration isolation mounts and control means to control the energisation of the electromagnetic coil member of the or each vibration isolation mount. The control means can be configured to pass a current through a coil within a electromagnetic coil member which is calculated on the basis of a change of a parameter of the mount. Such a parameter may be the time varying component of the force through the resilient member, the relative velocity of the electromagnetic coil member and the magnetically susceptible or magnetisable member, the relative displacement of the electromagnetic coil member with respect to the magnetically susceptible or magnetisable member, the acceleration of the electromagnetic coil member is relative to an inertial frame of a reference or the product of the relative velocity of the electromagnetic coil member with respect to the magnetically susceptible or magnetisable member and the force through the resilient member (in other words the power dissipated through the device).

In a specific embodiment the control means are configured to minimise the measured parameter. In order to achieve this, the control means will perform an adaptive algorithm which can control the current through the coil in the electromagnetic coil member in order to compensate for the measured parameter. Such adaptive algorithms and means for performing such adaptive algorithms are well known in the art and are discussed in “Adaptive Signal Processing” by Bernard Widrow and Samuel Stearns (Prentice Hall inc. 1995) and subsequent works.

One feature of the vibration isolation mount of the present invention is that should for any reason the power to the magnet in the electromagnetic member fail, or if the control system should fail, the mount will still act as a passive mount because of the presence of the resilient material holding the two parts apart.

In one embodiment of the present invention where two electromagnets are used (i.e. the magnetically susceptible or magnetic member comprises a second electromagnet) with a permanent magnet arranged therebetween, the same driving current can be passed through the coils of both electromagnets so that they are polarised in the same direction. In one polarisation the two electromagnets will be attracted to the permanent magnet, thus compressing the resilient material therebetween. When the current flows in the opposite direction, the electromagnets will repel the permanent magnet thus expanding the resilient material therebetween. The use of two electromagnets provides a more sensitive mount. In other words the response of the magnet to a given control signal will be greater than when there is only one electromagnetic. Also, the device has the advantage of symmetry which will reduce distortions within the mount.

Embodiments of the present invention will now be described with reference to the following drawings in which:

Figure 1 shows a mount having two electromagnets in accordance with an embodiment of the present invention;

Figure 2 shows a variation on the structure of Figure 1 where a steel shoe is placed around the structure;

Figure 3 shows a further embodiment of the present invention comprising a single electromagnet;

Figure 4 shows a more compact version of the structure of Figure 3;

Figure 5 shows a further embodiment of the present invention having two permanent magnets and a single electromagnet;

Figure 6 shows a variation on the structure of Figure 5;

Figure 7 shows a variation on the structure of Figure 4 having a piezo electric member to measure the force in the elastomeric member;

Figure 8 shows a further variation on the structure of Figure 4 where a coil is used to relative movement in the structure; and

Figure 9 shows a further embodiment of the present invention,

Figure 10 shows a modified version of Figure 9;

Figure 11 shows a block diagram of a vibration control system.

The mount of Figure 1 has a permanent magnet 1 located between an upper electromagnet 3 and a lower electromagnet 5. The upper electromagnet 3 comprises an induction coil 7 formed around a steel core 9. Similarly, the lower electromagnet 5 comprises an induction coil 11 formed around a steel core 13. The cores 9 and 13 are fixed to the respective electromagnets 3 and 5 by adhesive 8 or the like.

An upper resilient member 15 is provided between the steel core 9 of upper magnet 3 and permanent magnet 1. The resilient member 15 is connected to both the upper core 9 and the permanent magnet 1.

A lower resilient member 17 is provided between the core 13 of lower electromagnet 5 and permanent magnet 1. The lower resilient member is in contact with both permanent magnet 1 and lower core 13. The upper and lower cores 9, 13, upper and lower resilient members 15, 17 and permanent magnet 1 are aligned so that they form a central axis and their outer surfaces are flush with one another.

Permanent magnet 1 is polarised such that its north pole lies at its interface with the upper resilient material 15 and its south pole lies at the opposite face where the permanent magnet 1 contacts the lower resilient material 17. The current passed through upper 3 and lower 5 electromagnet originates from the same source (not shown). Also, the current through both the upper 3 and lower 5 electromagnets is passed in the same direction through the coils. In the mount of Figure 1, the current is passed through the coils such that the upper surface of upper electromagnet 3 is north and the upper surface of lower electromagnet 5 (the surface which abuts against lower resilient member 17) is also north, the opposite lower faces of both electromagnets form south poles. In this arrangement, the upper surface of the lower electromagnet 5 is attracted towards the lower surface (south pole) of the permanent magnet 1 compressing resilient member 17. In a similar fashion, the lower surface of the upper electromagnet 3 is attracted towards the upper surface (north pole) to permanent magnet 1 thus compressing the upper resilient member 15. The compression of both resilient members 15, 17 causes a reduction in the overall length of the mount.

When the current is passed through the upper 3 and lower 5 electromagnets in the reverse direction, the polarity is reversed. In this situation, the upper 3 and lower 5 electromagnets are repelled from permanent magnet 1 thus extending the upper 15 and lower 17 resilient members. This causes an overall increase in the length of the mount.

Thus, the length of the device can be varied by switching the direction of current through the electromagnets 3, 5. Vibrations from a first member mounted on the upper surface of upper electromagnet 3 can be prevented from causing the lower surface of the lower electromagnet 5 to vibrate by varying the current through the upper 3 and lower 5 electromagnet as required.

The mount shown in Figure 1 is intended for use in structures such as an aircraft in order to mount the trim panels onto the fuselage. Mounting connection 2 and 4 are provided for mounting the mount to the fuselage and trim panels respectively. The mount needs to be able to withstand the vibrations of these members and also compensate for their vibrations so that vibrations in the trim panel are not passed through the fuselage and vice versa. However, the mount will also be subjected to shear forces. In the mount of Figure 1, the position of the upper 15 and lower 17 resilient members make it virtually impossible for the upper 7 and lower 11 coils to contact with the permanent magnet and to short out the current flowing in the coils.

The upper 15 and lower 17 resilient members are also physically connected to the upper and lower cores 9, 13 respectively and the permanent magnet 1. Therefore, the mount does not fall apart in the event of a power cut or when the current direction is chosen such that the upper 3 and lower 5 electromagnets repel from the permanent magnet 1. Also, because the resilient members separate the electromagnets, the mount can still act as a passive mount in the event of a power cut or failure of the control system.

Figure 2 shows a variation on the structure of Figure 1. To avoid unnecessary repetition, like reference numerals will be used to denote like features. A permanent magnet 1 is provided between an upper electromagnet 3 and a lower electromagnet 5. The permanent magnet is surrounded by resilient member 16 which extends above, below and to the side of permanent magnet 1.

Upper electromagnet 3 abuts against the upper surface of resilient member 16 and lower electromagnet 5 abuts against the lower surface of resilient member 16. As described with reference to Figure 1, the resilient member 16 is connected to both the upper 3 and lower 5 electromagnets.

As described with reference to Figure 1, the upper electromagnet 3 has a coil 7 which is wound around core 9. In this example, core 9 is integral with a steel shoe 19 which extends over the top of coils 7 and around the outer side surface of coils 7. The coil 7 is fixed to the steel shoe 19 by adhesive 10 or the like. Steel shoe 19 provides a lower impedance pathway to the magnetic flux generated by the coils and hence increases the sensitivity of the magnet to current. Lower electromagnet 5 is formed in the same way as upper electromagnet 3, here coil 11 is formed around steel core 13 which is integral with steel shoe 21. The steel shoe 21 extends around the outside of coils 11. The coils are effectively mounted to the steel shoe.

The operation of the device is identical to that described with reference to Figure 1. As appropriate current flow through the upper 3 and lower 5 electromagnets, the mount constricts due to the electromagnet attracting the permanent magnet 1, compressing the resilient member 16.

However, the sensitivity of the mount is greatly improved over that of Figure 1 since the steel shoes 19 and 21 provide a lower impedance to the magnetic flux.

The positioning of resilient members 16 in the flux path between the electromagnets again prevents coils 7 and 11 from shorting if the mount shears.

The mount of Figure 3 has a single upper electromagnet 3. The upper electromagnet 3 has an identical construction to that of Figure 2 where the steel core 9 is integral with steel casing 19 and the coil 7 is mounted to the core 9 of steel structure 19.

Permanent magnet 1 is provided overlying and in contact with a steel base structure 23 which comprises a magnetically susceptible member. Steel base structure 23 has a lip 25 formed about its circumference on its upper surface. Resilient member 16 is interposed between the upper electromagnet 3, the permanent magnet 1 and the lower steel frame 23. The resilient member 16 also extends in the gap between the lip 25 of steel base 23 and the steel shoe 19 of upper magnet 3.

As described for Figures 1 and 2, by changing the direction of the current flowing through the coils 7 of electromagnet 3, the electromagnet 3 will either repel or attract permanent magnet 1. When permanent magnet 1 is attracted to electromagnet 3, the resilient member 16 compresses and hence the total length of the mount is shortened. Similarly, when electromagnet 5 repels permanent magnet 1, the resilient member 16 is stretched and the total length of the mount increases.

The mount of Figure 3 will not be as sensitive to current changes as that of Figures 1 and 2 as only one electromagnet 3 is provided in the mount of Figure 3. However, the mount of Figure 3 has a large advantage over those of Figures 1 and 2 in that it is only necessary to contact to just one side of the device in order to compress or expand resilient member 16. When the mount is in place in, for example, an aircraft, it is desirable to minimise the number of connections which need to be made to the mount as such connections will often involve drilling holes through various parts of the aircraft. The mount of Figure 3 also has the advantage in that it is far more compact than those described with reference to Figures 1 and 2. This compactness is also advantageous as often, it is desirable for there to be as little space as possible between the fuselage and the trim panels.

Figure 4 shows a variation on the mount of Figure 3. In order to avoid unnecessary repetition, like reference numerals will be used to denote like features. Upper electromagnet 3 has a partial steel core 9 and coils 7. The coils are formed around the steel core 9 and fixed in the shoe 19 by adhesive 10 or the like. However, the coil extends downward into the structure beyond the end of the steel core 9. Steel shoe 19 again is formed integral with steel core 9. Steel shoe 19 overlies the upper surface of the coils and also extends a part of the way down the outside side surface of the coils.

Essentially, coils 7 of the upper magnet 3 extend as a large circular projection from the casing 19 and steel core 19. As described with reference to Figure 3, permanent magnet 1 is provided on a lower steel base 23 which has a circumferential lip 25. Resilient material 16 is provided between the upper surface of permanent magnet 1 and the lower surface of core 9. It is also provided between the lip 25 of steel base 23 and the upper casing 19.

The coils 7 extend between the gaps in the resilient material 16, the gap being formed between the portion of the resilient material formed overlying the magnet 1 and the circumferential part of the resilient material formed overlying circumferential lip 25. The coils also extend into the gap formed between permanent magnet 1 and lip 25. Coils 7 are mounted to the core 9 and casing 19. An air gap 27 is formed between the lower surface of the coils 7 and the steel base 23 in order to allow compression of resilient member 16.

The device essentially works identical to that described with reference to Figure 3. Dependent on the direction of the current passed through coils 7, the core 9 and casing 19 will either be attracted towards permanent magnet 1 (thereby compressing the resilient material 16) or repelled from permanent magnet 1 (thereby expanding resilient material 16).

Figure 5 shows a further variation on the structure of Figure 4. To avoid unnecessary repetition, like reference numerals will be used to denote like features. In this mount, the core 9 of upper electromagnet 3 comprises a second permanent magnet 29. This permanent magnet 29 is polarised with the same polarity as that of the first permanent magnet 1. Coils 7 are connected to the core 9 and casing 19 by adhesive or the like 10 such that they are rigidly connected to permanent magnet 29.

When no current flows through coils 7, the first 1 and second 29 permanent magnets attract one another. When a current is passed through the coils 7, this attraction is either increased therefore further compressing resilient member 16 or decreased, thus expanding resilient member 16.

As there is a magnetic force compressing resilient member 16 even when the power is cut, this arrangement is particularly advantageous as there is no danger of the mount falling apart in the event of a power cut. Also the use of the permanent magnet in this and the previous embodiments provides a biasing magnetic force. This puts the resilient material under a biasing force and enables the device to be driven by alternating current to actuate in a bidirectional manner.

Figure 6 shows a variation on the mount of Figure 5. To avoid unnecessary repetition, like reference numerals will be used to denote like features. The arrangement of the first 1 and second 29 permanent magnets separated by resilient member 16 formed inside circular coil 7 remains the same as that of Figure 5. However, the upper steel casing 19 extends over the top surface of coil 7, surrounds the outside of cylindrical coil 7 and extends around the whole of the outside of coil 7 and partially underneath coil 7. Steel base 23 supports permanent magnet 1, but only partially extends underneath cylindrical coils 7. A circular gap 31 is formed between the steel base 23 and upper steel casing 19.

In this arrangement, upper electromagnet 3 which comprises coils 7, core 9 (which comprises permanent magnet 29) is connected to upper steel casing 19. Permanent magnet 1 is only connected to lower steel casing 23. These two structures are then separated by resilient member 16.

In use, the upper steel casing 19 is connected to the first member and the lower steel casing 23 is connected to a second member. Often, one of the two members will have considerably lower mass than the other member, for example, in the case of an aircraft, the fuselage is much heavier than the trim panels. In this type of arrangement, it is not desirable to attach a particularly heavy mass to the trim panels as the heavy mass itself will affect the movement of the trim panels. The mount of Figure 6 avoids this problem as the mass attached to the trim panels is not considerably reduced from that shown in Figure 5.

It is necessary to control the current through cores 7 so that the mount is shortened and extended as required. The mount of Figure 7 is substantially similar to that of Figure 4. To avoid unnecessary repetition, like reference numerals will be used to denote like features. A piezo sensor 33 is provided within resilient member 16. In the specific mount shown in Figure 7, the piezo sensor 33 is mounted on core 9 of upper electromagnet 3. The piezo sensor 33 could be provided anywhere within resilient member 16. As the force on the resilient member 16 changes due to the electromagnet 3 being repelled and attracted to permanent magnet 1, the force on the piezo changes. Piezo sensor 33 generates an electric current dependent on the force applied to piezo sensor 33.

In the mount of Figure 7, the current passed through coils 7 is controlled in order to minimise the force on piezo sensor 33.

There are other parameters which can be measured in order to control the mount. Figure 8 shows an arrangement which can be used to measure the displacement of the resilient member or the velocity at which the upper electrode magnet 3 and the permanent magnet 1 move together or apart. This mount is again based on the mount shown in Figure 4 and to avoid unnecessary repetition, like reference numerals will be used to denote like features.

Instead of piezo member 33, sensor coil which is just simply an inductive coil 35 is provided attached to steel base 23 via circular wall 37. Thus, coil 35 is rigidly attached to permanent magnet 1 such that relative movement between coil 35 and magnet 1 is not possible in operation. In this device, it is important to be able to measure the movement of electromagnet 3. A sensor permanent magnet 39 is provided overlying and in contact with the upper surface of casing 19. Circular steel cap 41 is provided overlying and in contact with the upper surface of sensor magnet 39. A circular wall 43 is provided about the circumference of circular cap 41. Wall 43 extends downwards from the circular cap. The wall extends to the level of at least the junction between steel core 9 and resilient member 16. Circular sensing coil 35 is provided in the gap between circular wall 43 and steel casing 19.

Sensing magnet 39 is polarised such that its north pole lies at the interface between magnet 39 and steel casing 19. Flux from the sensing magnet 39 extends into the steel casing and out towards circularly wall 43, such that sensing coil 35 passes through the lines of magnetic flux generated by sensing magnet 39. As the electromagnet 3 attracts or repels the permanent magnet 1, sensor coil 35 moves through flux lines generated by sensing magnet 39. The EMF generated in sensing coil 35 is equal to the product of the magnetic flux density (which can be easily calculated by knowing the parameters of the system), the length of the coil and the velocity of movement of the coil. Therefore, the velocity of the coil can be easily derived. The current through the coils 7 can thus be altered to minimise the measured velocity.

Figure 9 shows a cross section through another embodiment of the present invention in which the resilient material experiences a shear force rather than a compression force during normal operation of the mount. The mount comprises a magnetically susceptible or magnetisable sleeve 60 of cylindrical shape. Within the sleeve 60 there is provided a cylindrical coil 61 arranged coaxially on the inner face of the sleeve 60. The coil 61 defines a cylindrical core region 62 in which is arranged a magnetically susceptible or magnetisable member 63 which extends coaxially with the coil 61 and the sleeve 60. The magnetically susceptible or magnetisable member 63 has a cylindrical body comprised of a middle portion 64, a first permanent magnet 65 and a second permanent magnet 66 between which lies the middle portion 64. At each end of the magnetically susceptible or magnetisable member 63 there is provided a magnetically susceptible or magnetisable end region 67 and 68 which extends along the axis out of the core region 62. The end regions 67 and 68 comprise an intermediate region 69 and 70 respectively which are of the same radial dimensions as the permanent magnets 65 and 66 and the middle portion 64. Also end plates 71 and 72 are provided at the ends of the magnetically susceptible or magnetisable member 63 which are of larger radial dimensions and extend towards the sleeve 60. Intermediate regions 69 and 70 are each provided with annular recesses 73 and 74 into which resilient washers 75 and 76 are fitted. The resilient washers 75 and 76 abatt radial faces of a housing 77 of the coil 61. In this way the resilient washers 75 and 76 are held in place within the sleeve 60 and hold the magnetically susceptible or magnetisable member 63 resiliently in place within the sleeve 60.

A first mounting 78 is provided for mounting the sleeve 60 to a first member. A second mounting 79 is provided for mounting one end of the magnetically susceptible or magnetisable member 63 to a second member.

In this embodiment the two permanent magnets 65 and 66 are oppositely polarised. The middle region 64 may or may not be of magnetically susceptible or magnetisable material. Thus in this arrangement the magnetic flux path flows through the coil 61 around the sleeve 60 and back through the end regions 67 and 68 of the magnetically susceptible or magnetisable member 63. Thus the resilient washers 75 and 76 lie within the flux path. The magnetic flux is however particularly concentrated at the end plates 71 and 72 which are arranged to extend such that there is a small air gap between the end plates 71 and 72 and the sleeve 60. Alternatively the permanent magnets 65 and 66 could be polarised in the same direction so that the flux path flows around the coil 61. This is however a less efficient arrangement.

Thus this embodiment of the present invention acts like a piston which is resiliently mounted in the sleeve. Under normal actuation the resilient washers 75 and 76 experience shear forces when the mount experiences shear forces the resilient washers 75 and 76 experience compressional forces. Thus the resilient washers 75 and 76 can be formed of any suitable resilient compressable or elastomeric material which can for example be stiffer in compression than in shear to provide a high degree of resistance to prevent contact of the magnetically susceptible member 63 with the sleeve 60.

In this embodiment of the present invention the flux path through the magnetically susceptible or magnetisable member and the sleeve remains constant even at high degrees of positive or negative displacement because the magnetically susceptible or magnetisable member 63 remains within the sleeve 60 such that the flux path between the sleeve 60 and the end plates 71 and 72 remains constant. The greatly enhances the linearity of the behaviour of the mount.

Figure 10 illustrates a variation of the embodiment of figure 9 in which the end regions 69 and 70 are extended and the resilient washers 75 and 76 are replaced with resilient material filling the entire region between the sleeve 60 and the end portion 67 and 68. Otherwise in figure 10 like reference denote like features. In this embodiment there is a greater resistance to shear forces on the mount since the resilient material 75 and 76 provides higher compressional resistance. However, the greater mass of the resilient material also provides a greater resistance to shear forces which are required for the normal operation of the mount. Thus the mount of this embodiment will have a reduced displacement capability but a greater shear resistance capability.

The vibration isolation control system will now be described with reference to figure 11. A mount 45 is mounted between a first member 46 and a second member 49. A first member 46 can for example be the air frame of an aircraft and the second member 49 can be a trim panel. A controller 47 is provided having inputs and outputs. A lead 48 carries the current for the coil within the mount 45 in order to control it in accordance with the carried current. The lead 50 carries the output of a force, velocity, displacement or acceleration measurement within the mount 45. The controller 47 can operate any one of a number of one known algorithms for adaptively controlling the mount in order to achieve vibration isolation. For example, algorithms described in "Adaptive Signal Processing" by Bernard Widrow and Samuel Stearns (Prentice Hall 1985) can be used. The disclosure in the Widrow and Stearn's book is hereby incorporated by reference.

Lead 50 can carry the output from a piezo (for example, the type discussed with reference to the mount shown in Figure 7) or the EMF generated by an induction sensing coil of the type described with reference to the mount shown in Figure 8. The mount can be controlled in accordance with a number of different rules:

the time dependent part of the force measured through the resilient member can be minimised;

the velocity of one end of the element with respect to the other end of the mount can be minimised;

the acceleration (or displacement) of one end of the mount relative to the other end can be minimised;

the power dissipated in the mount (product of the time dependent force and the velocity of the displacement of one end of the mount) can also be minimised.

When measuring the force, the time varying part of the force and the external force will be added at a summing junction. The output from the summing junction will then be used as an error signal, which is then subjected to a transfer function in order to calculate the current to be passed through the coils. Typically, an adaptive algorithm is used to provide the transfer function, this adaptive algorithm will take into account the changes in the mount due to loading. This is because the algorithm used to vary the current flow through the coils will differ dependent on the background external force applied to the mount.

CLAIMS:

1. A vibration isolation mount for mounting a first member on a second member, the mount comprising first mount means for mounting on said first member, an electromagnetic coil member connected to said first mount means, second mount means for mounting on said second member, a magnetically susceptible or magnetisable member connected to said second mount means and moveable relative to said electromagnetic coil member, and resilient material arranged to resiliently hold said electromagnetic coil member and said magnetically susceptible or magnetisable member apart, wherein said resilient material lies in a flux path generated between said electromagnetic coil member and said magnetically susceptible or magnetisable member and said magnetically susceptible or magnetisable member is arranged to experience a force when said electromagnetic coil member is energised.

2. A vibration isolation mount according to claim 1 including wherein said resilient material is arranged at least in a minimal gap region between said electromagnetic coil member and said magnetically susceptible or magnetisable member.

3. A vibration isolation mount according to claim 1 or claim 2 wherein said electromagnetic coil member comprises an electromagnet having a coil surrounding and fixed to a magnetisable core to exert an attractive or repulsive force on said magnetically susceptible or magnetisable member.

4. A vibration isolation mount according to claim 3 further comprising at least one permanent magnet arranged with said resilient material between said magnetisable core and said magnetically susceptible or magnetisable member to provide a biasing magnetic force between said electromagnetic coil member and said magnetically susceptible or magnetisable member.

5. A vibration isolation mount according to claim 3 or claim 4 wherein said magnetically susceptible or magnetisable member comprises a further electromagnet having a coil surrounding and fixed to a magnetisable core.

6. A vibration isolation mount according to claim 5 wherein each said electromagnet includes a magnetically susceptible or magnetisable shoe magnetically connected to the core and extending around the coil to provide a flux path around the coil.

7. A vibration isolation mount according to claim 5 or claim 6 wherein said resilient material lies between the core of the further electromagnet and said permanent magnet and between said permanent magnet and the core of said electromagnet.

8. A vibration isolation mount according to claim 6 wherein said resilient material lies at least between the magnetically susceptible or magnetisable shoes of said electromagnets.

9. A vibration isolation mount according to claim 3 or claim 4 wherein said electromagnet includes a magnetically susceptible or magnetisable shoe magnetically connected to the core and extending around the coil to provide a flux path around the coil, said magnetically susceptible or magnetisable member extends to face said core and said shoe, and said resilient material lies between at least said shoe and said magnetically susceptible or magnetisable member.

10. A vibration isolation mount according to claim 4 wherein said permanent magnet lies adjacent said magnetically susceptible or magnetisable member.

11. A vibration isolation mount according claim 10 wherein said resilient material lies between said permanent magnet and said core of said electromagnet.

12. A vibration isolation mount according to claim 1 or claim 2 wherein said electromagnetic coil member comprises a coil surrounding a core region and a magnetically susceptible or magnetisable shoe extending from the core region around the coil to provide a flux path around the outside of the coil, said magnetically susceptible or magnetisable member is arranged to face said core region and said magnetically susceptible or magnetisable shoe, a first permanent magnet is arranged in said core region attached to said magnetically susceptible or magnetisable member, a second permanent magnet is arranged in said core region attached to said shoe, and said resilient material is arranged between said shoe and said magnetically susceptible or magnetisable member where they face one another around said coil and/or between said first and second permanent magnets.

13. A vibration isolation mount according to claim 12 wherein said first and second permanent magnets attract.

14. A vibration isolation mount according to claim 12 wherein said first and second permanent magnets repel.

15. A vibration isolation mount according to claim 1 or claim 2 wherein said electromagnetic coil member comprises a magnetically susceptible or magnetisable sleeve extending along an axis and a coil mounted coaxially within and fixed to said sleeve, said coil defining a coaxial core region, said magnetically susceptible or magnetisable member being arranged coaxially with said electromagnetic coil member to lie in and extend out of said core region and to experience an axial force when said coil is energised, and said resilient material lies radially between said magnetically susceptible or magnetisable member and said electromagnetic coil member.

16. A vibration isolation mount according to claim 15 wherein said magnetically susceptible or magnetisable member has radially enlarged end portions which extend radially towards said sleeve.

17. A vibration isolation mount according to claim 15 wherein said resilient material lies between end regions of said magnetically susceptible or magnetisable member and said sleeve.

18. A vibration isolation mount according to claim 16 wherein said resilient material lies between said sleeve and said radially enlarged end portions and/or between said sleeve and regions of said magnetically susceptible or magnetisable member intermediate said radially enlarged end portions and a portion lying within said core region.

19. A vibration isolation mount according to any one of claims 15 to 18 wherein said magnetically susceptible or magnetisable member comprises a middle portion between two opposed polarity permanent magnets, and end regions of magnetically susceptible or magnetisable material connected to said magnets, said middle portion and said magnets being arranged to lie in said core region and said end regions extending out of said core region.

20. A vibration isolation mount according to any one of claims 15 to 19 wherein said resilient material has a higher stiffness in a radial direction than in an axial direction.

21. A vibration isolation mount according to any one of claims 15 to 20 wherein said first mount means is arranged on said sleeve and said second mount means is arranged on an end of said magnetically susceptible or magnetisable member.

22. A vibration isolation mount according to any preceding claim including detecting means for detecting force applied to the resilient material.

23. A vibration isolation mount according to claim 22 wherein said detecting means comprises a piezoelectric member provided in or next to said resilient material.

24. A vibration isolation mount according to claim 22 wherein said detecting means comprises an inductive coil rigidly connected to one of said electromagnetic coil member or said magnetically susceptible or magnetisable member, and flux generating means rigidly connected to the other of said electromagnetic coil member or said magnetically susceptible or magnetisable member, said inductive coil and said flux generating means being arranged so that when there is relative movement therebetween a current or a voltage is induced in said inductive coil as the coil passes through flux generated by said flux generating means.

25. A vibration isolation mount according to claim 24 wherein said flux generating means comprises a permanent magnet.

26. A vibration reduction system comprising one or more vibration isolation mounts according to any preceding claim, and a control means for controlling the energisation of said electromagnetic coil member of the or each said vibration isolation mount.

INVESTOR IN PEOPLE

Application No:	GB 0022733.0	**Examiner:**	Colin Thompson
Claims searched:	1 to 26	**Date of search:**	6 December 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): F2S (SCL)

Int Cl (Ed.7): F16F 15/03

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	US 5346192 A (Weltin)	
A	US 4624435 A (Freudenberg)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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