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(54) **Static and dynamic load dissipating and limiting device for civil and industrial works,**

(57) The present invention relates to a load dissipating and limiting device for protecting, recovering and making civil and industrial works, having a high strength against undesired static, seismic, aeolian and dynamic effects, comprising a plurality of shape memory alloy wires operating under a super-elastic effect and having their end portions interconnected to connecting element for coupling to a construction to be protected.

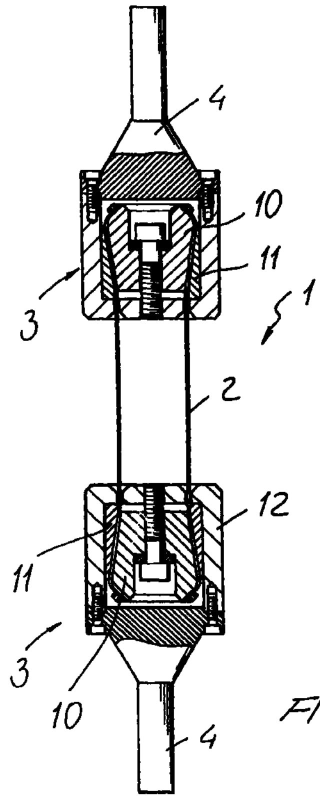

FIG. 1

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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a load dissipating and limiting device for protecting, recovering and making civil and industrial works, having a high strength against undesired static, seismic, aeolian and dynamic effects.

[0002] As is known, in the civil and industrial construction field, as well as in the historical monument field, it is necessary to provide structural protection against non frequent but predictable events such as earthquakes, wind storms and any other dynamic effects susceptible to cause vibrations.

[0003] The mentioned constructions must safely resist against the above mentioned loading conditions, possibly without any structural damages.

[0004] Moreover, it is also necessary to consider all those phenomena, having a not dynamic origin, subjecting the constructions to undesired deformations.

[0005] Also known is the fact that at present, near all the existing constructions, both of historical and civil and economic interest, have not been designed and built for resisting against the mentioned events and, actually, they have been found as unsatisfactory from the strength and resistance standpoint.

SUMMARY OF THE INVENTION

[0006] Thus, the aim of the present invention is to overcome the above mentioned drawbacks, by providing a load dissipating and limiting device, providing an improved stability and increased damping of the vibrations, as well as the possibility of connecting two or more constructional or structural elements which could be subjected to mutual displacements, in order to dampen and limit said possible displacements.

[0007] Within the scope of the above mentioned aim, a main object of the present invention is to provide a damping technique which can be easily applied owing to the use of very compact and/or easily concealable devices, thereby overcoming any architectural limitation imposed by the designer.

[0008] A further object is to provide a damping material having a very good resistance against to the atmospheric agents.

[0009] Yet another object of the present invention is to provide such a device allowing to limit the loading applied to the end portions thereof, as a strain or deformation is imposed and which, moreover, is specifically designed for limiting a displacing exceeding a maximum designed value, with the additional possibility of self-orienting according to a direction required by the structure or construction, by means of anchoring articulated connections and/or by exploiting its flexibility or elastic properties.

[0010] Another object of the present invention is to provide such a dissipating device which is very stable in operation also under temperature variations and as the load application frequency is changed.

[0011] Th above mentioned aim and objects, as well as yet other objects, which will become more apparent hereinafter, are achieved by a load dissipating and limiting device for protecting, recovering or making civil and industrial works, having a high strength against undesired static effects, seismic effects, aeolian and dynamic effects in general, characterized in that said device comprises a plurality of shape memory alloy wires operating based on a super-elastic effect and being provided with end portions interconnected to connecting elements for coupling to a construction to be protected.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] Further characteristics and advantages will become more apparent hereinafter from the following detailed disclosure of a preferred, though not exclusive, embodiment of a load dissipating and limiting device, which is illustrated, by way of an indicative but not limitative example, with reference to the accompanying drawings, where:

Figure 1 is a schematic cross-sectional view illustrating the load dissipating device according to the present invention;

Figure 2 is a graphic diagram illustrating the axial stress depending on the percentage strain;

Figure 3 is further graphic diagram illustrating the force versus the displacement;

Figure 4 illustrates a load dissipating and limiting device provided with a fluid holding bellow assembly;

Figures 5a, 5b and 5c illustrate characteristic curves as obtained by the inventive device and by a further arrangement of the super-elastic effect S.M.A. wires; and

Figure 6 illustrates a pattern in which the wires, being pre-stretched, under any mutual displacement applied to the anchoring end portions, are deformed under pulling and react according to a characteristic curve as that shown in Figure 2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0013] With reference to the above mentioned figures, the load dissipating and limiting device, for protecting, recovering and making civil and industrial works, having a high strength or resistance against undesired effects such as static effects, seismic effects, aeolian effects and dynamic effects in general, according to the present invention, which has been generally indicated in Figure 1 by the reference number 1, comprises a plurality of wires 2 made of a shape memory alloy (S.M.A.), exploiting the super-elastic effect, which are arranged in an adjoining mutual relationship, thereby the individual wires will operate in parallel to provide the designed reaction, the length of said wires being set depending on the designed displacement

[0014] At their end portions, said wires 2 are coupled to locking elements, generally indicated by the reference number 3, which are coupled to articulated coupling elements or connecting elements 4, in order to apply them to the structures to be protected, possibly under a stretched condition.

[0015] The locking elements comprise a conic locking wedge 10, which is engaged in a sleeve 11 having an inner conic surface, and therebetween the end portions of said wires 2 are arranged; the wedge and sleeve or jacket are made of a material having a surface hardness less than that of said wires, thereby the inner conic wedge, having a less hardness, is forcibly engaged in its seat thereby locking said wires.

[0016] A glass element 12 is moreover provided for holding therein said sleeve or jacket and wedge, said element 12 being coupled to the connecting or coupling elements which, for example, can comprise a latching stem.

[0017] If it is required to provide resistance against very high frequencies, then the wires 2 are introduced into a liquid, a fat material or gel material, having high thermally conductive characteristics and, in particular, having a thermal transmission equal to or better than that of ethylenglycol.

[0018] To that end, a liquid or fluid holding bellows 20 for holding therein a liquid or fluid 21 is provided.

[0019] The operation or performance of the device will depend on the thermomechanical characteristics of the shape memory alloy as used and installed under a wire form.

[0020] Figure 2 illustrates a graphic diagram related to the mechanical characteristics of the used wires and clearly illustrating the obtained super-elastic effect by subjecting to an axial deformation or strain a wire sample.

[0021] The material, which at the start was in an austenitic phase, presents now an elastic phase, to which a proportional relationship between the applied stress and obtained strain would correspond.

[0022] Upon achieving a critical strain ε_A, the austenite starts to transform to martensite, to which would correspond a nearly constant stress up to the end of the transformation occurring at a critical strain or deformation ε_M.

[0023] This deformation or strain range ε_A - ε_M, in which the phase transformation occurs, can be used for the intended purposes.

[0024] In fact, in the mentioned characteristic range, as the applied load is removed, the material will tend to return to its unstrained or unstrained condition, thereby providing an elastic recovering due to the martensite-austenite transformation as shown by the bottom curve of the pseudo-hysteretical cycle shown in Figure 2.

[0025] More specifically, the cycle of Figure 2 shows the energy dissipated for unit of volume by the used material, and can be easily transformed into the characteristic curve of the full limiting device, if the number, diameter and length of the used wires are known, as clearly shown in Figure 3.

[0026] The subject device will be conventionally designed to operate in a displacement range $S_A \div S_M$, at a force level within the range of $F_1 \div F_2$.

[0027] Moreover, the device can be pre-stretched to a designing force level by applying a displacement S* corresponding to a preset strain or deformation ε* in the range $\varepsilon_A \div \varepsilon_M$.

[0028] The above mentioned pre-stretching will allow to immediately actuate the operating dissipating effect of the device, according to the characteristic curve of Figure 3, for any displacement applied to the structure.

[0029] If the strain or deformation of the wires would exceed the value ε_M, than the wire, in a full martensitic phase, would display an immediate stiffening up to a deformation corresponding to the martensite yielding point ε_Y, with a subsequent plasticizing and work hardening of the material to a breaking point ε_R.

[0030] The stress corresponding to the deformation or strain ε_Y, much greater than the austenite-martensite transformation stress, will provide a safety factor, of a comparatively very high value, both on the yielding and on the breaking point.

[0031] The progressive stiffening effect, corresponding to strains greater than ε_M, can be used for limiting the displacement of the structure the dissipating device is applied to, thereby preventing any undesired deformations of the structures from occurring.

[0032] As mentioned, in the case of a vibration having a frequency greater than or equal to 1 Hertz, it would be suitable to immerge the shape memory material wires into a fluid (fat or gel) such as ethylenglycol, operating to dispose of the generated heat to the outside.

[0033] The invention, as disclosed, is susceptible to several modifications and variations, all of which will come within the scope of the inventive idea.

[0034] Moreover, all of the details can be replaced by other technically equivalent elements.

[0035] Thus, for example, even if a conic wedge has been used in the locking elements, it would be possible, based on the same principle, to use a prismatic wedge configuration.

[0036] A further SMA super-elastic wire arrangement can provide a characteristic curve of the subject device among them shown in Figure 5 (Figures 5a, 5b and 5c).

[0037] In fact, according to this arrangement (see Figure 6), the wire, which are pre-stretched to a strain or deformation level of ε*, with $0 \leq \varepsilon^* < \varepsilon_M$, for any mutual displacement imposed to the anchoring ends thereof, will be always strained under a pulling force and will react according to the characteristic curve already shown in Figure 2.

[0038] In the latter case, the wires (Figure 6 - elements of type 1) are wound in the assembling step on spools (Figure 6 - elements of type 2) which will be threaded on respective pin elements (Figure 6 - elements of type 3).

[0039] The assembling of the spools, the axial distance of which will be advantageously equal or less than that of the respective pin elements, on said pin elements, can be carried out exclusively by stretching the wires and, accordingly, by deforming them to increase their axial distance to the distance existing between the pin elements.

[0040] To this size difference of the inter-axes will correspond a deformation or strain ε* of the wires.

[0041] If desired, the pin-spool system can also comprise a single monolithic element, in order to allow a simple assembling to be easily performed.

[0042] The anchoring hardware (Figure 6 - elements of the type 4 and 5) must be suitably perforated, by elongated holes, to provide both an abutment of a pin element and an entraining displacement as imposed by the other pin.

[0043] This would allow the wires to be stressed always under a pulling stress, for any mutual displacement applied to the end portions of the device.

[0044] This system, as the first, can provide, for operating at a frequency greater than 1 Hz, to immerge the wires in a suitable medium (Figure 6 - element of type 6).

[0045] Moreover, the anchoring of the wires shown in Figure 6 can be replaced by the other above disclosed type using the wedge locking system.

[0046] The details of the system for anchoring the device to the structure can be designed depending on the contingent requirements, to better fit the considered type of construction.

[0047] The main feature of the latter system is that, differently from the first, it would not require to be prestretched on the field or as it is applied to the structure, since the wires are actually prestretched during the assembling thereof.

[0048] It should be apparent that the device does not apply to the structure any stresses, since it is self balanced in its inside.

[0049] In particular, the device will provide a reaction exclusively as a mutual displacement occurs.

Claims

1. A load dissipating and limiting device for protecting, recovering or making civil and industrial works, having a high strength against undesired static effects, seismic effects, aeolian and dynamic effects in general, characterized in that said device comprises a plurality of shape memory alloy wires operating based on a super-elastic effect and being provided with end portions interconnected to connecting elements for coupling to a construction to be protected.

2. A load dissipating and limiting device, according to the preceding Claim, characterized in that said device comprises, at the end portions of said wires, locking elements for coupling to said connecting or coupling elements.

3. A load dissipating and limiting device, according to the preceding claims, characterized in that said locking elements comprise a locking conical wedge arranged in a sleeve having a conical inner surface, said wedge and sleeve being made of a material having a surface hardness less than that of said wires.

4. A load dissipating and limiting device, according to one or more of the preceding claims, characterized in that said device comprises a glass element for holding therein said sleeve and wedge, said glass element being coupled to said connecting or coupling elements.

5. A load dissipating and limiting device, according to one or more of the preceding claims, characterized in that said device comprises a space defined about said wires for holding herein a fluid, a fat or a gel having thermal transmission characteristics equal to or greater than those of ethylenglycol, for operating at a frequency greater than or equal to 1 Hertz.

6. A load dissipating and limiting device, according to one or more of the preceding claims, characterized in that said device comprises a bellows coupled, to the end portions thereof, to said locking elements and holding said fluid therein.

7. A load dissipating and limiting device, according to one or more of the preceding claims, characterized in that said wires are wound, during an assembling operation thereof, on spools threaded on respective pin elements.

8. A load dissipating and limiting device, according to one or more of the preceding claims, characterized in that said device is provided with a plurality of spools having an inter-axis equal to or less than that of said respective pin elements, said spools being assembled on said pin elements by stretching said wires and thereby straining said wires to

increase said inter-axis to the spacing of said pin elements.

9. A load dissipating and limiting device, according to Claim 8, characterized in that said size difference of said inter-axes corresponds to a straining of said wires.

10. A load dissipating and limiting device, according to one or more of the preceding claims, characterized in that the pin element-spool system can also comprise a single monolithic element.

11. A load dissipating and limiting device, according to one or more of the preceding claims, characterized in that said device comprises anchoring means provided with elongated holes to allow both a mechanical abutment on a pin element and an entraining displacement as applied to the other pin element.

12. A load dissipating and limiting device, according to one or more of the preceding claims, characterized in that said wires are stressed by a pulling force for any mutual displacement applied to the end portions of said device.

13. A load dissipating and limiting device, according to one or more of the preceding claims, characterized in that, for operating at a frequency greater than 1 Hz, said device provides to immerge said wires into a suitable medium.

14. A load dissipating and limiting device, according to one or more of the preceding claims, characterized in that said wires are anchored by a wedge anchoring system.

15. A load dissipating and limiting device, according to one or more of the preceding claims, characterized in that said device is so designed that said wires are pre-stretched during the assembling thereof and wherein said device does not apply any stress to said structure, since it is innerly self-balanced, to react exclusively as a mutual displacement is applied.

16. A load dissipating and limiting device for protecting, recovering and making civil and industrial works, having a high strength against undesired static, seismic, aeolian and dynamic effects, according to the preceding claims, and as substantially disclosed and illustrated and for the intended aim and objects.

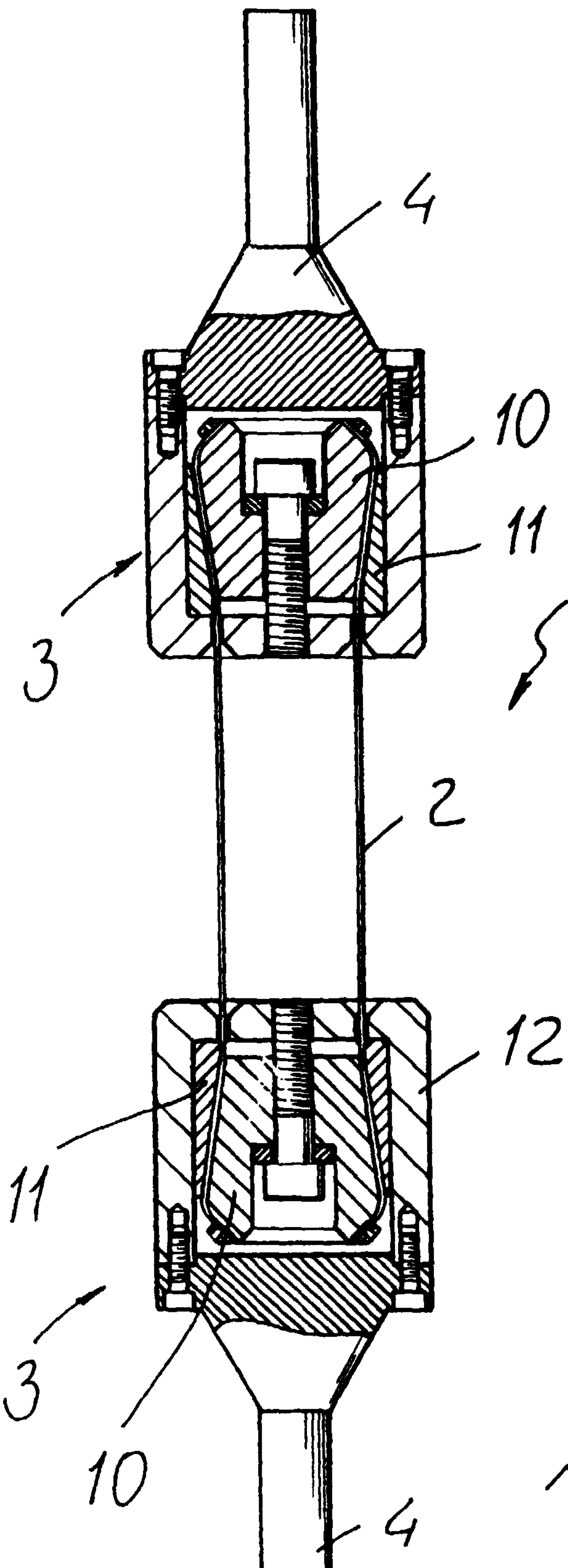
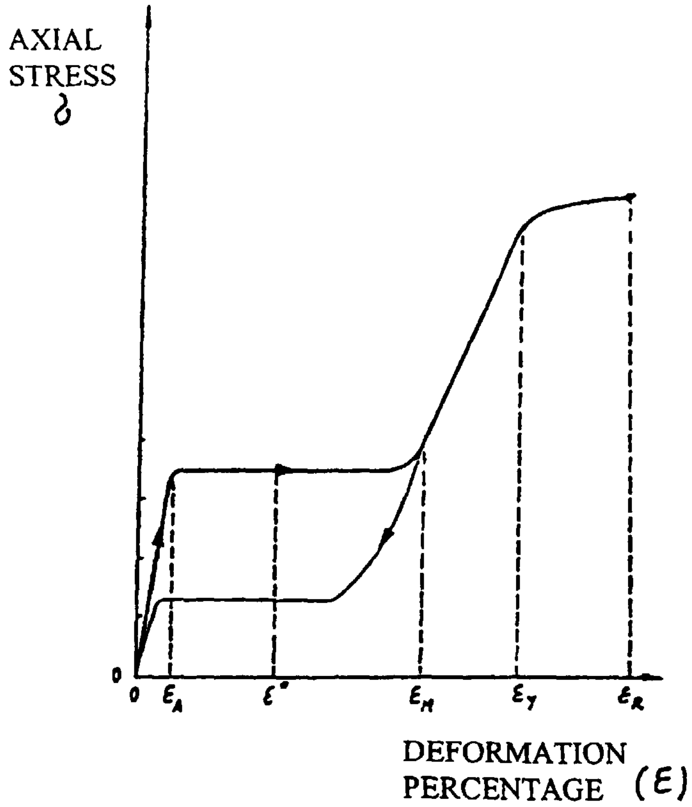
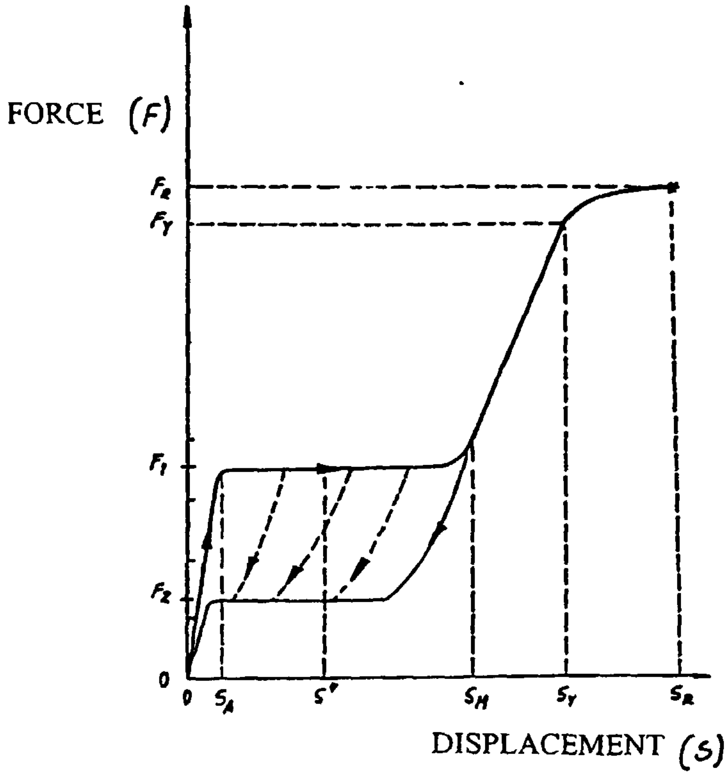


Fig. 1



AXIAL STRESS σ
0
0
ε_A
ε*
ε_M
ε_Y
ε_R
DEFORMATION PERCENTAGE (ε)

FIG. 2



FORCE (F)
F_R
F_Y
F_1
F_2
0
0
S_A
S*
S_M
S_Y
S_R
DISPLACEMENT (S)

FIG. 3

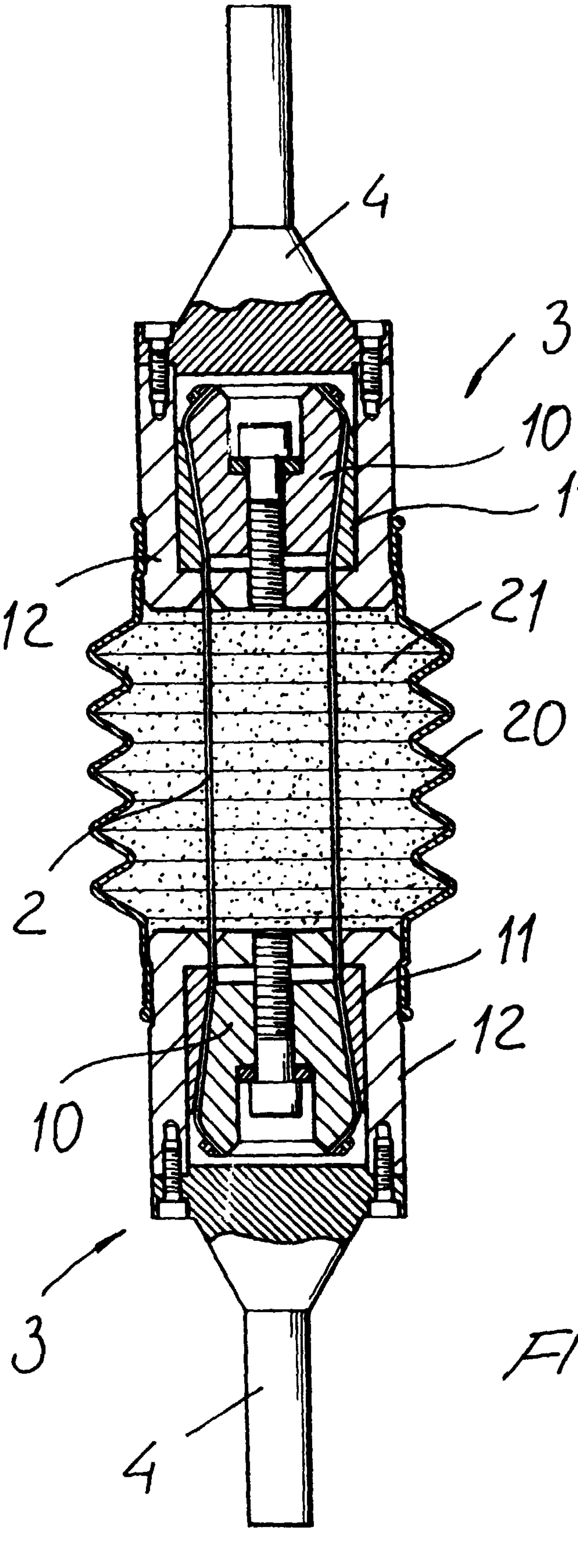


FIG. 4

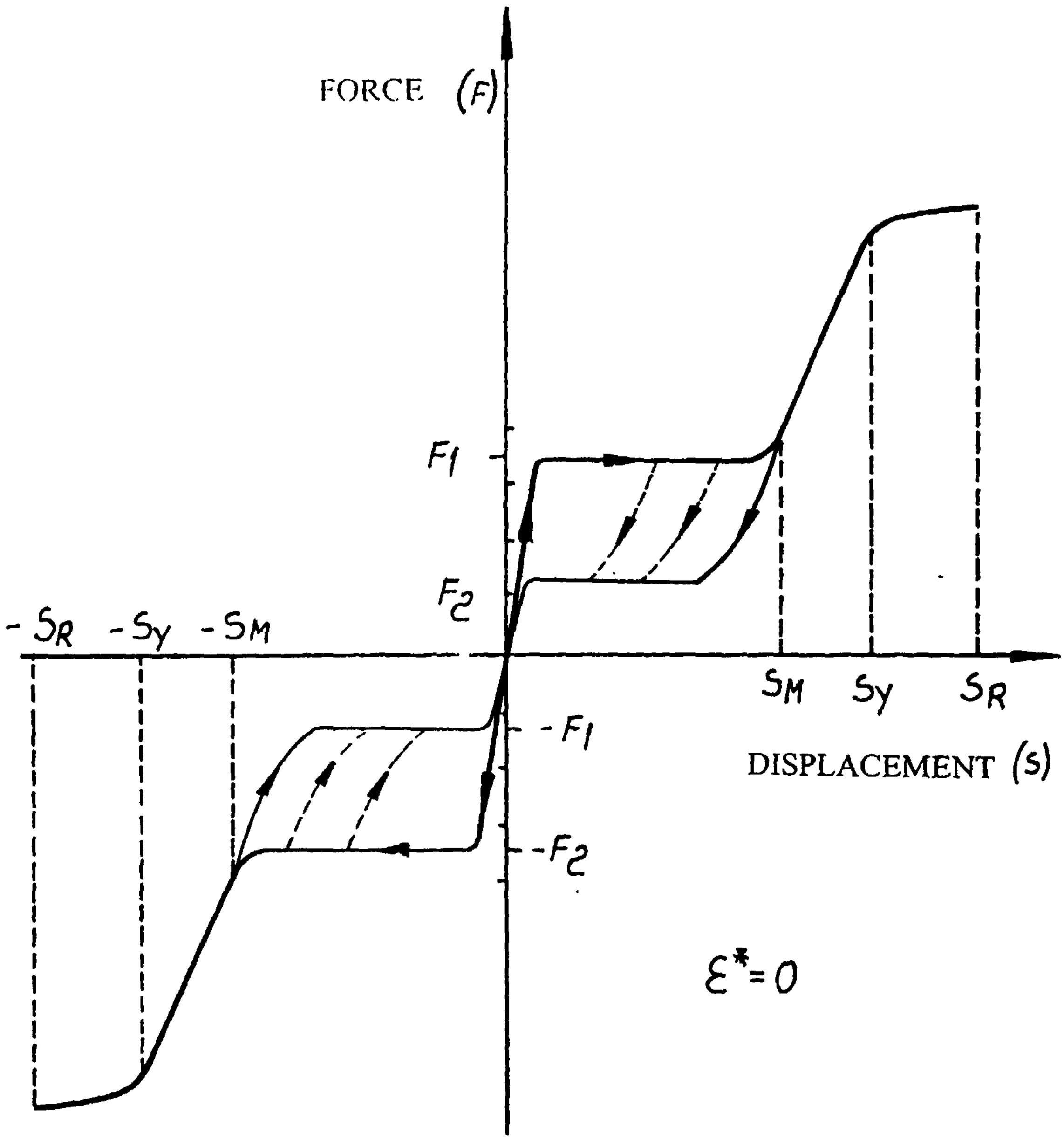


FIG. 5a

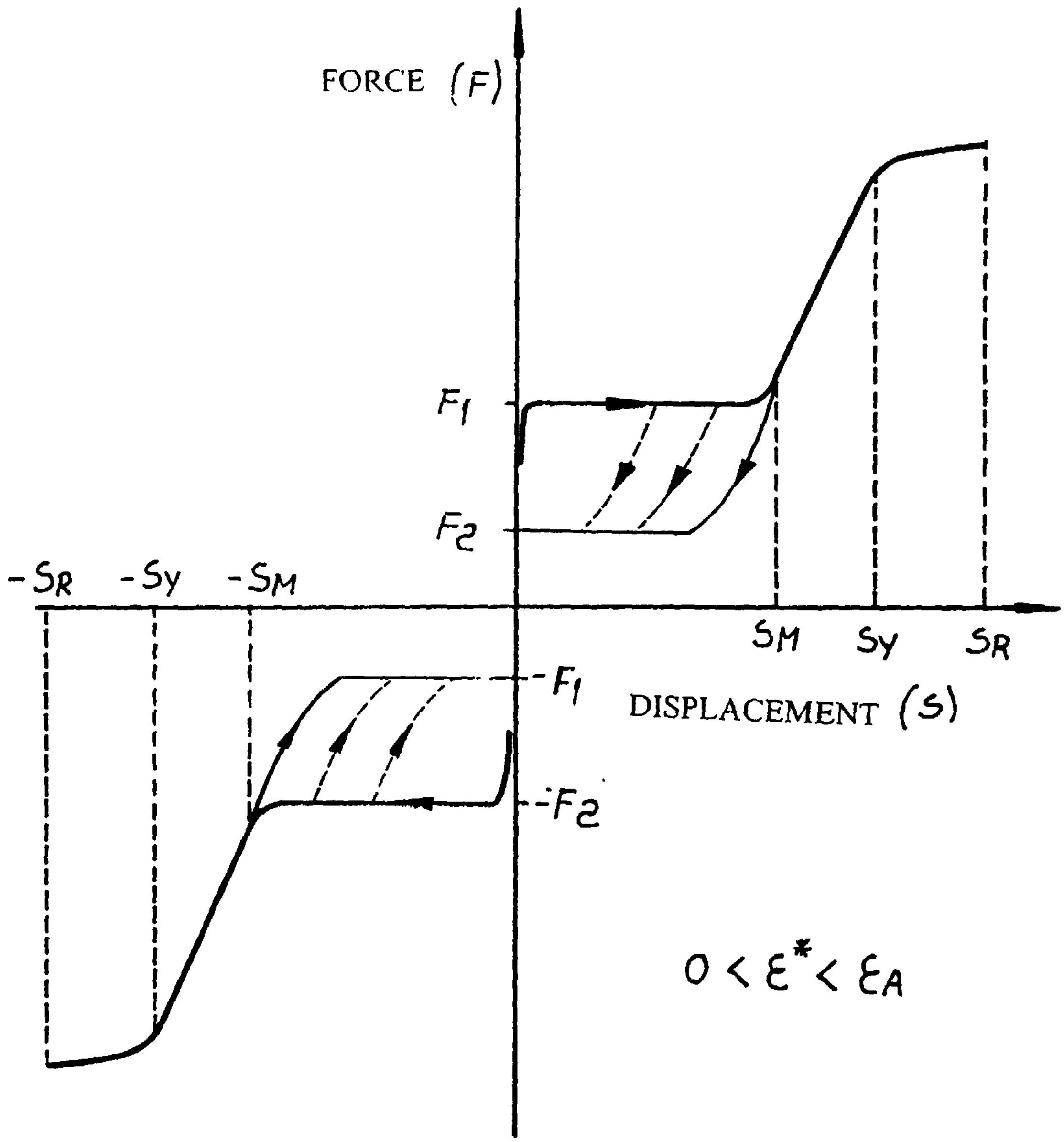


FIG. 5b

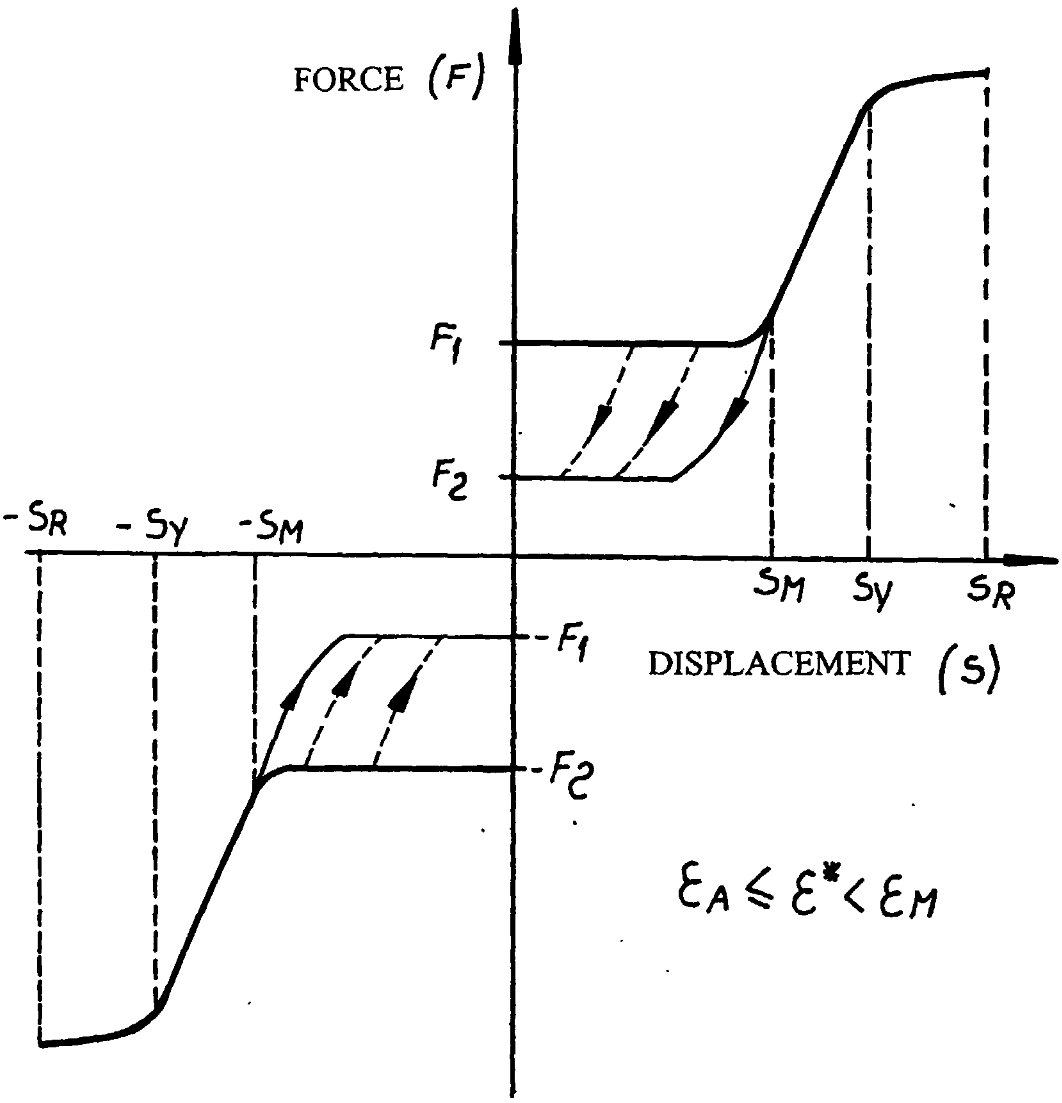


FIG. 5c

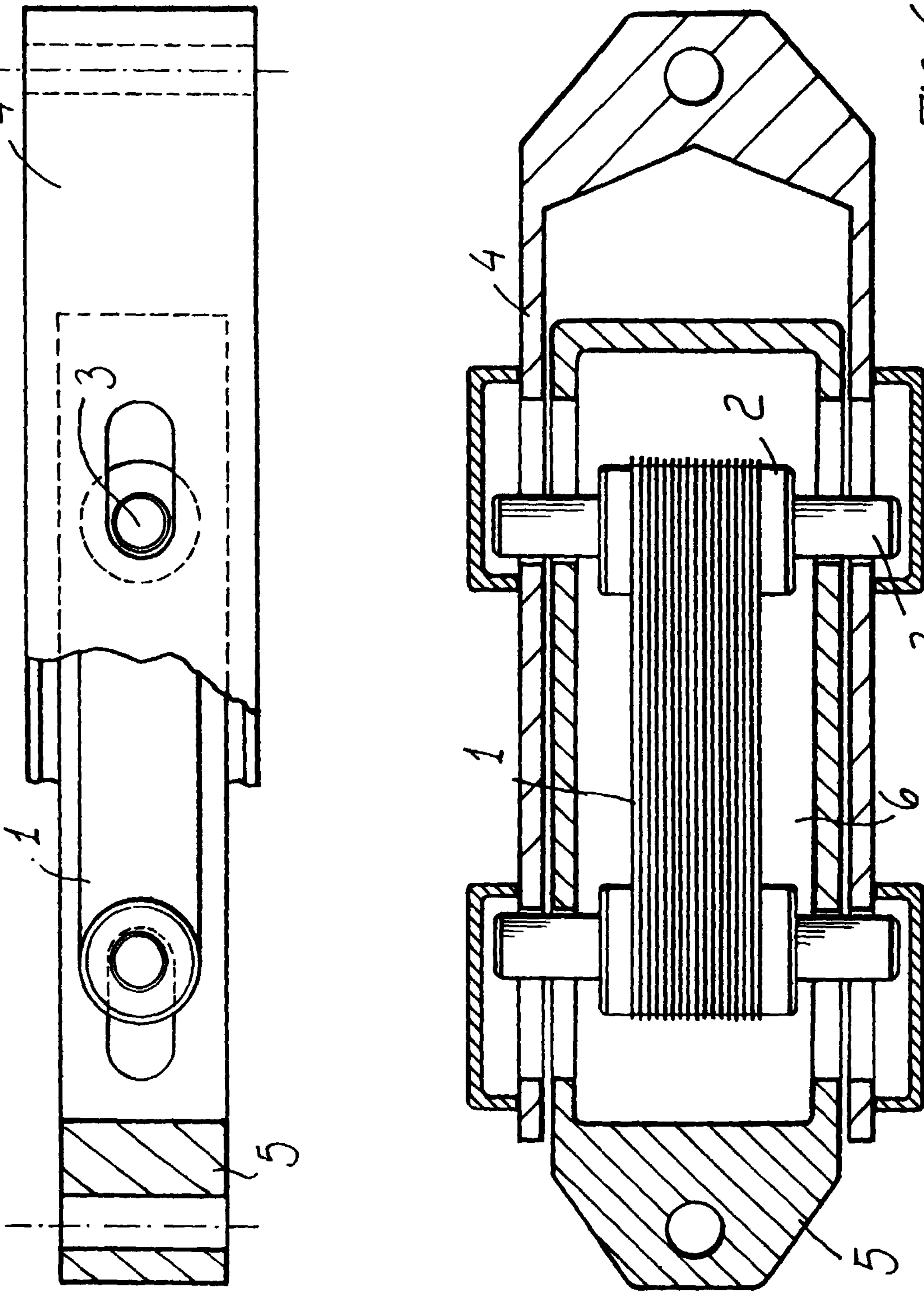


FIG. 6