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3,385,541

RESILIENT SUPPORTS FOR ROTATING MACHINE PARTS

Filed July 12, 1966

4 Sheets-Sheet 1

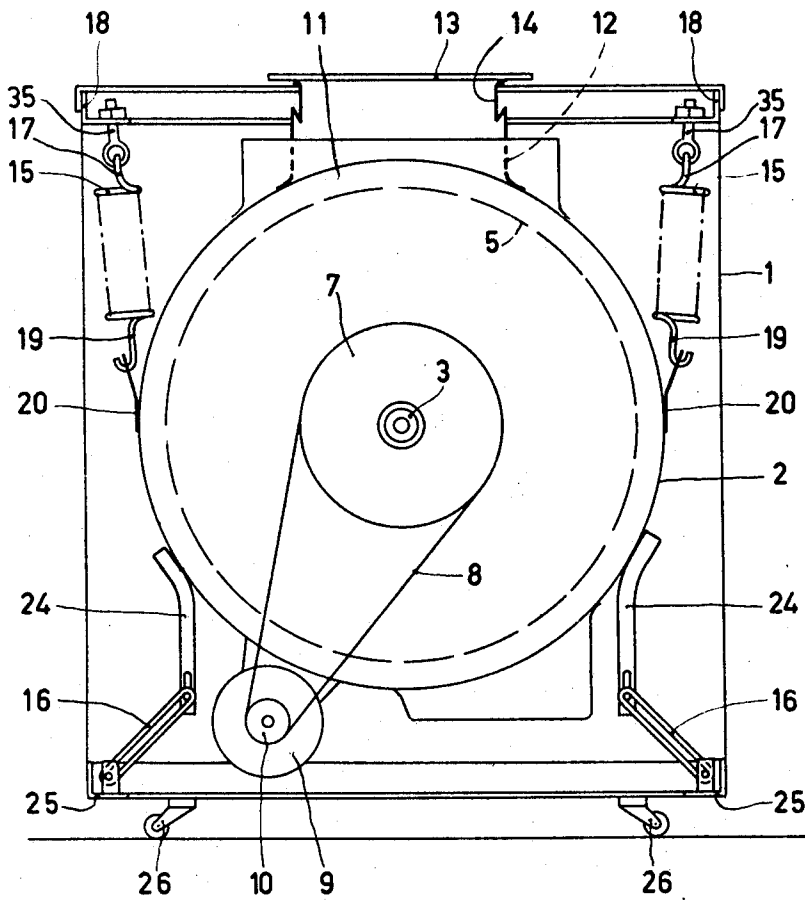


FIG. 1

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4 Sheets-Sheet 3

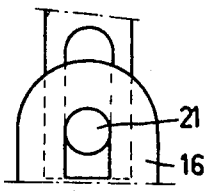


FIG. 3a

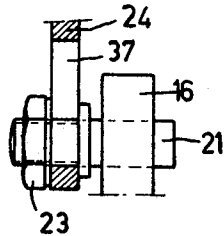


FIG. 3b

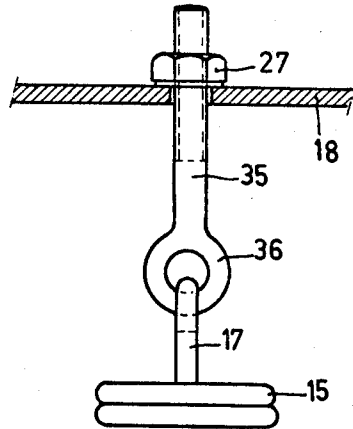


FIG. 4

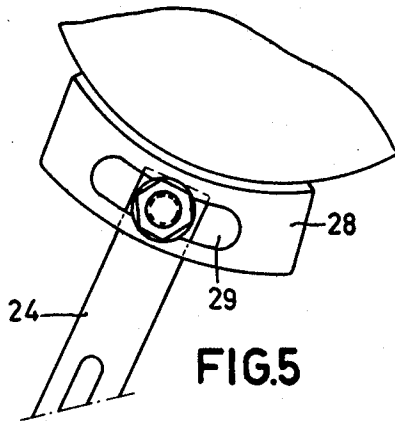


FIG. 5

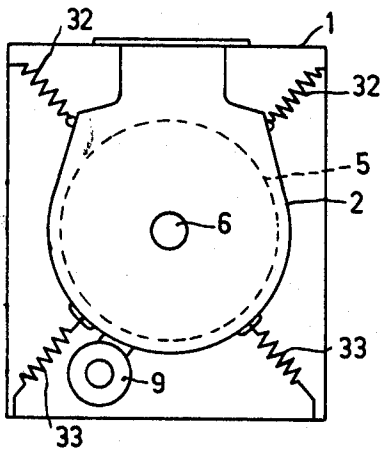


FIG. 6

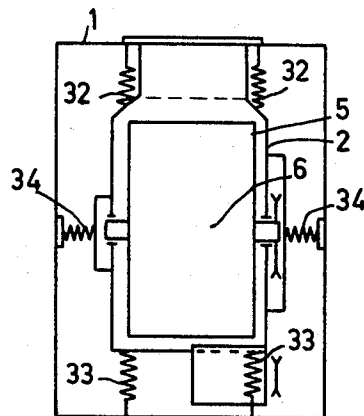


FIG. 7

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4 Sheets-Sheet 4

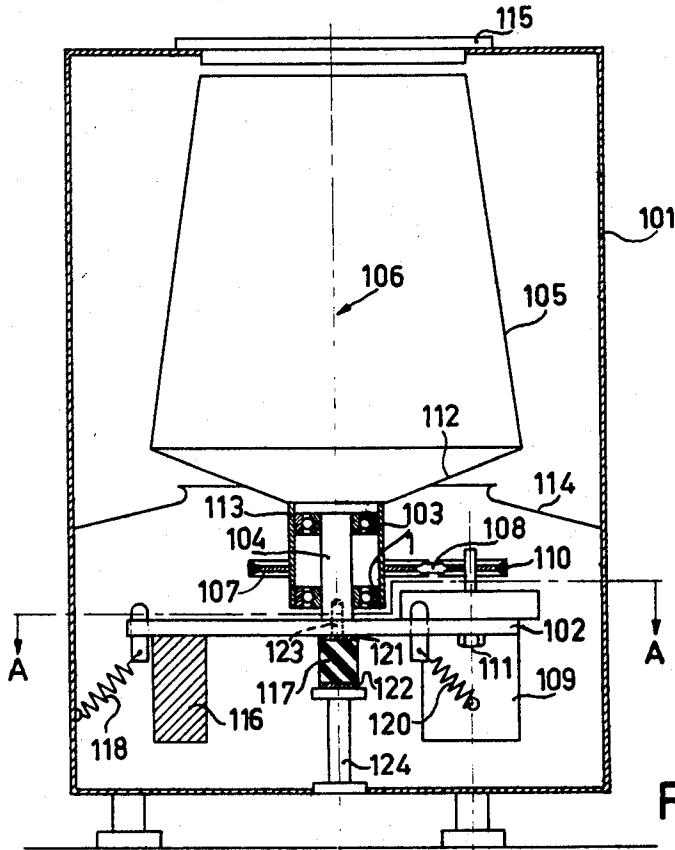


FIG. 8

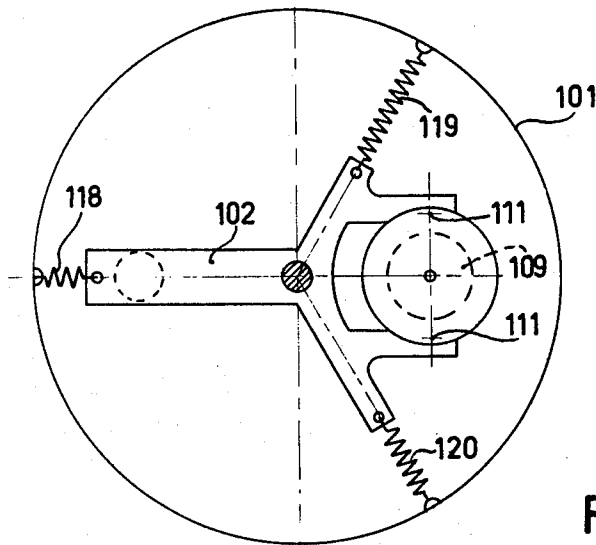


FIG. 9

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3,385,541
RESILIENT SUPPORTS FOR ROTATING
MACHINE PARTS

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 4 Claims. (Cl. 248-18)

ABSTRACT OF THE DISCLOSURE

A suspension system for rotatable drums of the type utilized in domestic washing/drying apparatus. A rotatable drum is suspended in a rigid framework by a plurality of spring and damping elements which co-act to define an elastic system having an elastic center positioned along the central axis of the drum and particularly at the center of mass of the total rotating system. The tension of springs which support the drum can be regulated thus permitting adjustment of the position of the elastic center of the elastic system.

The invention relates to a support for resiliently mounting a frame part which supports the bearings of a rotatable component, such as, a drum of a device for washing and spin-drying clothes with respect to a fixed frame part. The support comprises an elastic system consisting of a number of resilient elements arranged irregularly around the centre line of the said bearings, with the elastic system having an elastic centre.

In rotatable drum washing/drying apparatus, difficulties are often encountered when a part of the mass thereof becomes located eccentrically with respect to the axis of rotation as a result of the type of construction or the operating conditions, or forces and moments occur by other causes. For example, magnetic or electromagnetic forces which, on rotation rapidly vary their direction and are transmitted to the frame of the apparatus through the bearings. These periodic loads may easily result in unacceptable situations both as regards the use and the life of the construction particularly when the number of revolutions per minute is high.

In order to keep the forces and moments applied to the apparatus within permissible limits, a part of the frame supporting the bearings of the component to be rotated is resiliently secured in a given manner to the remaining part of the frame. As a result of this the rotating part, and the part supporting the bearings, are enabled to collectively approach a main axis of inertia such as the axis of rotation.

The resilient support of the part of the frame supporting the rotatable component must satisfy a number of conditions. First of all the support must be capable of supporting the static load as a result of the constructions own weight. In addition, the support must give the system low critical natural frequencies both for the translation vibrations as a result of the periodic forces acting in the direction of the axis of rotation and in directions at right angles thereto, and for the rotation vibrations as a result of the periodic moments operating in the same directions. Finally, the system must be dynamically stable at the various rotational operating speeds. A difficulty in this connection is that vibrations occurring in or about a given direction result in vibrations in or about the other directions so that the total vibration picture becomes very complicated. The requirements mentioned here determine the shape, the proportions, the type and the position of the elements of the resilient support. It is often neces-

sary for the elements to be provided irregularly around the centre line of the bearings of the rotatable components which means that the elements either cannot be all identical or cannot be loaded identically, or cannot all be arranged at equal mutual angles and/or angular distances around the centre line, or both.

According to the invention a rotatable washing machine drum is suspended in a rigid framework. The suspension assembly includes a plurality of spring and damping elements which support the drum in an elastic system having an elastic center along the central axis of the drum, preferably at the center of mass of the drum. The spring tension of the springs which support the drum can be varied thereby permitting the positioning of the elastic center along the central axis of the drum.

The elastic centre may be defined as the point of intersection of a system of elastic main axes which is a system of three axes which extend mutually at right angles and each have the property that a force acting in its elongation causes only a translation of the resiliently supported components in the direction of that axis and a torque acting about the direction of the axis causes only an angular movement about the direction of that axis.

When this condition is fulfilled a favourable condition is reached for the elastic system in that the number and the value of the periodic forces and torques on the resiliently supported components decreases, so that the vibration picture is simplified and its control facilitated.

A further improvement by a decrease of the number of excited degrees of freedom is obtained if it is ensured according to the invention that one of the elastic main axes of the elastic system coincides at least approximately with the centre line of the bearings of the rotatable component.

A further improvement with an even more extreme but otherwise analogous effect is obtained if one of the elastic main axes of the elastic system extends substantially parallel to one of the main axes of inertia of the resiliently mounted frame part, while it is of further advantage if also the two remaining elastic main axes of the elastic system extend substantially in parallel two by two with the two remaining axes of inertia of the resiliently mounted frame part.

An improved embodiment is characterized in that the centre of mass of the resiliently mounted frame part without eccentric load of the rotatable part is located substantially on the centre line of the bearings of the drum components to be rotated. Also one of the main axes of inertia of the resiliently mounted frame part, without the eccentric load of the rotatable drum component, coincides substantially with the centre line.

Another embodiment has the elastic centre of the elastic system substantially coincident with the centre of mass of the resiliently mounted frame part when the rotatable drum component is not eccentrically loaded.

An optimum condition is reached if the two remaining elastic main axes of the elastic system substantially coincide two by two with the two remaining main axes of inertia of the flexibly mounted frame part. In this optimum condition the degrees of freedom of the resiliently mounted system in the direction of the said centre line of the bearings, and in two mutually perpendicular directions at right angles thereto, are fully separated from one another and consequently can no longer influence one another. In each of the three directions the said properties may be chosen to be so that the unavoidable vibrations have the least unfavourable effect.

An alternative embodiment of the invention is characterized in that the elastic centre is located approximately at the point of intersection of the said centre line with a plane which divides the contents of the rotatable drum component into two equal portions.

It has been stated above for the elastic centre and for the centre of mass that these must meet at least approximately certain requirements, notably that the points must be located substantially along the centre line of the bearings of the rotatable drum components. It is clear that the closer the said points approach the desired condition, the more favourable is the dynamic behaviour of the resiliently mounted frame part. However, in practice it is very difficult to actually reach this most desired situation. In connection herewith the practical requirement is imposed that the said points must be located at least within the area of a cross-sectional plane of the rotatable component determined by the circumference of the said component at right angles to the centre line of its bearings.

In this connection it is of advantage when the elastic system is constructed so that the elastic centre thereof is adjustable. According to the invention this can be reached by one or two or by a combination of two measures, namely in that the spring tension of at least one of the resilient elements is controllable in such manner that the elastic centre of the elastic system can be arranged at least approximately in the centre line of the bearings of the rotatable component, and in that at least one point of action of at least one of the resilient elements is controllable in such manner that the said elastic centre can be arranged substantially along the said centre line. In this manner, either the value, or the direction of the force which is exercised by at least one of the resilient elements, or both, can be controlled.

What has been said above for the elastic properties of the elastic system can be applied in an analogous manner to the properties thereof which determine the damping of the periodic movements of the resiliently mounted frame part. The elastic system may also be considered to be a damping system, and a damping centre and damping main axis may be defined in an analogous manner. So everywhere where an elastic centre and elastic main axes are mentioned, said expressions may be replaced by damping centre and damping main axes respectively to obtain similar advantages and prescriptions yielding analogous effects.

The periodic forces and moments occurring and the resulting vibrations are fully controlled by the measures and large forces therefore are not transmitted to the fixed frame part. For a domestic clothes washer and spin-drying machine this means, for example, that the frame need no longer be rigidly secured to the floor to secure a quiet position of the machine during operation but that the machine may be arranged, if required, on rollers or casters which greatly facilitates the use of the machine.

Other advantages of the invention will be apparent from the following description of a few embodiments with reference to the drawings, in which

FIGURE 1 is a rear view of a domestic clothes washer and spin-drying machine according to the invention, after removing a side wall.

FIGURE 2 is a side elevation of the same machine after removing a side wall,

FIGURES 3a and 3b show the connection of one of the resilient elements to the tub of the said washing machine in front and side view respectively.

FIGURE 4 shows a connection of a resilient element, the resilience of which can be controlled.

FIGURE 5 shows a connection of a resilient element of which a point of action can be displaced.

FIGURE 6 is a diagrammatic cross-sectional view at right angles to the axis of rotation of a similar machine in another embodiment.

FIGURE 7 is a diagrammatic cross-sectional view in the direction of the axis of rotation of still another embodiment of a machine of this type.

FIGURE 8 is a vertical cross-sectional view of a domestic spin-dryer for clothes which has a vertical axis of rotation; and

FIGURE 9 is a horizontal cross-sectional view taken on the line A—A of the machine shown in FIGURE 8.

The domestic clothes washing and spin-drying machine shown in FIGURES 1 and 2 comprises a frame 1 which consists of a bottom plate and a top plate and four upright side-walls which usually are manufactured from sheet steel, if required, reinforced by means of ribs, corner pieces, etc. In this frame is arranged a tub 2, likewise from sheet steel, for containing the wash-liquid. This tub comprises the bearings 3 for the shaft 4 of a cylindrical drum 5 in which the clothes to be washed are loaded which drum is preferably manufactured from perforated stainless steel plate. The centre line of the bearings of the shaft of the drum is denoted by 6. The shaft of the drum comprises a pulley 7 which is driven by a motor 9 through a belt 8 and a pulley 10 secured to the shaft of the motor. The motor is secured to the tub 2. The motor with the transmission mechanism coupled thereto is constructed for driving the drum at a speed of approximately 50 revolutions per minute during washing when the drum contains clothes and the tub is filled with wash-liquid, and at a speed which exceeds 800 revolutions per minute and preferably is 1200 to 1500 revolutions per minute during spin-drying when the tub is empty. The latter speed is required for removing sufficient liquid out of the clothes. In this embodiment the washing drum has an outside diameter of approximately 50 cms.

At its top side the tub 2 comprises an opening 11 for loading the washing. The drum 5 has a corresponding opening in its cylinder surface which opening can be closed by a cover (not shown). The opening 11 in the tub adjoins an opening 12 in the frame which can be closed by a cover 13. Between the tub 2 and the frame 1 a sleeve 14 of flexible material, for example, rubber, is provided around the opening 12 for sealing purposes.

The tub 2 to which the motor 9 is secured and in which the drum 5 is journaled is flexibly connected to the frame 1 in such manner that the forces and moments produced by the excentric load as a result of the presence of the washing in the drum 5 during operation, are not transmitted, or are transmitted only to a very small extent, to the frame 1. This flexible connection includes a number of resilient elements, namely four helical springs 15 and four rubber rings 16. The springs 15 and rings 16 together constitute an elastic system and are chosen to be so that the elastic centre of this system theoretically is located in point 30 which is the point of intersection of the centre line 6 with the transverse plane of symmetry 31 of the drum 5. One of the elastic main axes of the system coincides with the centre line 6. The calculation methods necessary to obtain this are considered known to those skilled in the art so that these need no further explanation here.

By means of screw-threaded members 35 provided with nuts 27 the upper ends 17 of the helical springs 15 are secured to a metal board 18 rigidly secured to the frame 1; the lower ends of said members are provided with eyelets 36 through which the ends 17 of the springs are threaded (FIGURE 4). Their lower ends 19 are formed into hooks which are threaded through holes in strips 20 welded to the tub 2.

The upper ends of the rubber rings 16 which have the shape of an elongated loop are slid onto pins 21 secured to metal strips 24 connected to the tub 2 in the manner as shown in FIGURE 3. The lower ends are slid in a corresponding manner onto pins 22 secured to a board 25 which forms part of the frame 1.

The frame 1 is placed on casters 26 which is possible by using the invention, since no or substantially no periodic inertia forces act upon the frame.

The springs 15 are arranged approximately in a vertical position. These springs carry the weight of the resiliently secured components. These springs are chosen to be as slack as possible so as to give the system the lowest possible natural frequencies. In this case a limit is im-

posed upon the natural frequencies to be reached by the static elongation of the springs. The additional elongation of the springs when the tub is filled with wash liquid and the drum with washing may in general not exceed a few centimeters. This means that a natural frequency in a vertical direction which is smaller than approximately 2 cycles per second, can substantially not be reached. In a horizontal direction, however, the natural frequency in this arrangement need not be higher than approximately 1 cycle/second.

The rubber rings 16 in general do not contribute to carrying the weight of any structural component. These rings which are arranged at an angle of approximately 45° with the horizontal, first of all have the function of bringing the elastic centre of the resilient support in the centre line 6 and secondly they serve to damping the vibrations which occur when the drum 5 rotates at critical speeds. They are preferably manufactured from an elastomer, for example, butyl rubber, which has damping properties which are independent of the vibration frequency. As a result of this, the elements do not absorb too much energy at high frequencies, which would require an unnecessarily large motor power and would raise the temperature of the elements themselves too much.

The stress of the springs 15 can be controlled in a simple manner by displacing the nuts 27 as shown in FIGURE 4. The stress of the rings 16 can be controlled in a simple manner by displacing the pins 21 in the slots 37 of the strips 24 as shown in FIGURE 3. The connection point of the rings 16 to the tub 2 can be made adjustable in a simple manner as shown in FIGURE 5. For this purpose, the tub 2 is provided with corner pieces 28 comprising slots 29 through which bolts are inserted with which the strips 24 are secured to the corner pieces 28. These measures enable the elastic centre of the resilient support to approach the point 30 as closely as possible.

The centre of mass of the resiliently supported part of the machine, namely the tub 2 having journalled therein the drum 5 and secured thereto other components, such as, the motor and components which are not all shown, likewise lies in the point 30 while a main axis of inertia of the said mass extends along the centre line 6. The two remaining elastic main axes coincide with the two remaining main axes of inertia in directions horizontally and vertically at right angles to the centre line 6. The modes of calculation to obtain the end in view are likewise known to those skilled in the art, so that in this case also it is not deemed necessary to give any further explanation.

It is clear that in this embodiment the resilient elements 15 and 16 need not be regularly distributed around the centre line 6 as regards the value and the direction of the forces exerted by them. In this case it is ensured that the natural frequencies of the elastic system are different in two mutually perpendicular directions which facilitates the passing of those frequencies and restricts the motor torque necessary to rapidly pass the said frequencies.

Instead of the vertically arranged helical springs 15 it is of course also possible to use springs which are arranged at an angle as diagrammatically shown in FIGURE 6 (springs 32), while instead of the rubber rings 16 steel helical springs may be used, for example, the springs 33 in FIGURE 6. In addition it is possible to arrange resilient elements in the elongation of the centre line 6, for example, the springs 34 shown in FIGURE 7. In that case springs are preferably used which have a great rigidity in the direction of the centre line 6 and possibly a negative rigidity in the directions at right angles thereto, a result of axial pre-stress or torsional pre-stress. Both steel springs and rubber rings may be used for this purpose. This construction has particular advantage when the drum 5 has a large length in relation to its diameter and consequently a relatively large unbalance moment in a direction at right angles to the shaft is to be expected

as a result of unequal distribution of the load over the longitudinal direction.

The pre-stress and the resulting negative rigidity of one or both elements 34 located in the direction of the centre line 6 further has the advantage that this negative rigidity can compensate for the positive rigidity of the springs 32 and 33 so that a system can be obtained which has low critical natural frequencies at a small sag of the supporting springs as a result of the static load. In this connection it is still of advantage when the said prestress is made adjustable.

The invention may likewise be used advantageously in machines, in which the axis of rotation of the rotatable components is vertical. An example hereof is a domestic spin-drier for removing liquid from washing. For a satisfactory operation of such a machine the drum must preferably have a speed of at least 3000 r.p.m. when the drum has an average diameter of at least 25 cms. An example of such a spin-drier is diagrammatically shown in FIGURE 8, partly as an elevational view and partly as a longitudinal cross-sectional view, and in FIGURE 9 which is a cross-sectional view taken on the line A—A in FIGURE 8. In these figures 101 denotes a cylindrical sheet steel housing in which a steel plate 102 is resiliently supported. Said plate supports the bearings 103 which are arranged on a shaft 104 which is rigidly secured to the plate 102. Through a hollow shaft 113 the bearings 103 support a drum 105 in which the clothes to be centrifuged are placed. This drum is preferably manufactured from perforated stainless steel plate. The hollow shaft 113 is rigidly secured to the bottom 112 of the drum. The centre line of the bearings of the drum 105 is denoted by 106. On its outer circumference the hollow shaft 113 comprises a pulley 107 which is driven through a belt 108 by a pulley 110 connected to the shaft of the motor 109. By means of bolts 111, the motor 109 is suspended from the plate 102 which is bifurcated on one side. Around the drum, at the height of its bottom, an annular channel 114 is provided for conducting away the liquid removed out of the drum by the centrifuging, for which purpose an aperture (not shown) is provided in the housing 101.

At its top side the drum comprises a loading port while the housing 101 can be closed at its top by a cover 115. The device further comprises a breaking mechanism which is actuated when the cover 115 is opened. To avoid drawing complexity said mechanism is not shown.

The assembly of the plate 102 with motor 109, shaft 104 with bearings 103 and drum 105 with hollow shaft 113 is resiliently supported by means of a rubber block 117 and three steel helical springs 118, 119 and 120. At its upper and lower side, the rubber block 117 comprises steel plates 121 and 122 secured thereto by vulcanisation, the upper plate 121 comprising a tap bolt 123 with which the shaft 104 is also secured to the plate 102. The rubber block 117 which has a rectangular or circular cross-section and is arranged in the centre line 106 of the bearings 103 engages with its lower side a support 124 which engages the bottom of the housing. The block 117 is preferably manufactured from butyl rubber for the same reasons as described in the first embodiment. The springs 118, 119 and 120 are chosen and arranged so that the flexible system has a natural frequency in a vertical direction of approximately and preferably not more than 10 cycles/second while in two directions, which are mutually at right angles, the natural frequencies at right angles thereto preferably are different, but do not exceed four cycles per second.

The springs 118, 119 and 120 are each secured to the plate 102 at one end and to the housing 101 and the other end. In this embodiment also the resilient elements are not regularly distributed around the centre line 106 as regards the value and the direction of the forces exerted by them.

The centre of mass of the flexibly supported system is

arranged along the centre line 106 by providing a balance weight 113 on the plate 102. If desired, the centre of mass may be provided within the rubber block 117.

The location of the flexible centre on the centre line 106 is determined by the value and the direction of the forces exerted by the springs 118, 119 and 120. The location of the elastic centre may be chosen to be so as to coincide with the centre of mass likewise within the rubber block 117. In this embodiment it can be reached that an elastic main axis and a main axis of inertia coincide with the centre line 106 and also the two remaining elastic main axes may be caused to coincide two by two with the two remaining main axes of inertia. For the practical realisation of the desired result in this case also the spring tensions of the springs 118, 119 and 120 may be made controllable or their connection points adjustable entirely in agreement with the first-described embodiment.

Although the invention has been described with reference to embodiments of clothes washer and spin-drying machines for domestic use, the use of the invention is not restricted to the said machines. Notably, the invention may advantageously be used in centrifuges for various industrial uses and, generally, everywhere where rapidly rotating eccentrically loaded machine components have to be used.

What is claimed is:

1. A suspension system for a rotatable drum apparatus comprising frame means, tub means, a cylindrical drum concentrically supported within said tub means and rotatable around the central axis of said tub means and said drum, means for elastically supporting said tub means and said drum within said frame means for movement in horizontal and vertical directions, said elastic means comprising a plurality of springs interconnecting said tub means and said frame means, and means for damping

horizontal and vertical movement of said tub means and said drum within said frame means, said damping means comprising a plurality of non load bearing elastic bands interconnecting said tub and said frame, said elastic means and said damping means defining an elastic system having an elastic center positioned substantially along the center line of said rotating drum.

2. A suspension system according to claim 1 wherein said elastic means further comprises a spring tension adjusting means coupled to at least one spring of said plurality of springs for adjusting the location of the elastic center of said elastic system.

3. A suspension system according to claim 2 wherein said spring tension adjusting means comprises a screw-threaded member having one end engaging said at least one spring and the other end passing through said frame, and a nut engaging said screw-threaded member for adjusting the length of said rod extending through said frame.

4. A suspension system according to claim 1 wherein said damping means further comprises a plurality of metal strips corresponding in number to said plurality of elastic bands, each of said metal strips having one end attached to said tub and the other end attached to one of said elastic bands.

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JOHN PETO, *Primary Examiner*.