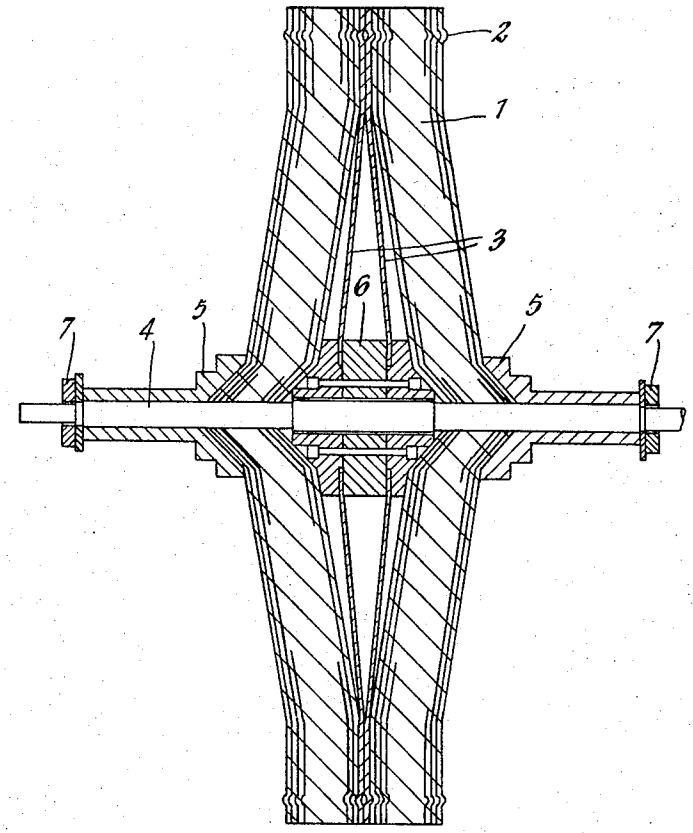
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FLYWHEELS

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FLYWHEELS

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ABSTRACT OF THE DISCLOSURE

Two sets of dished disc-like laminations having their coned sides facing are aligned and secured together by means which bears upon their control areas and maintains their marginal edges in pressure-bearing relation. The pressure-bearing related marginal edges sandwich a drive disc or plate between them, which drive plate is fixed to a shaft passing centrally through the laminated sets. The flywheel thus formed is prestressed to withstand greater loading incidental to operation.

This invention relates to disc type flywheels for use in energy storage systems in which the energy storage capacity is a function of the tensile stresses induced by centrifugal force.

It is usual for such high energy flywheels to be produced as unitary forgings in the smaller sizes and as unitary castings in the larger sizes, the former being subject to the disadvantages of internal discontinuities of the metallic structure which necessitates conservative stressing of the flywheel and, therefore, uneconomic use of the material. Where large flywheels have been built up by laminations of sheet or plate it has been found that the means used for clamping, securing, supporting and driving such built up flywheels cause stress concentrations which are a source of fatigue failures where such flywheels are used for cyclic storage purposes.

The object of the present invention is to provide a flywheel of laminated construction such that the plates forming the laminations are more evenly stressed over their full area and volume and are subject to the minimum concentrations of stress thus allowing more economic use of the material and greater safety in operation.

According to the invention I provide a flywheel comprising two opposed sets of laminations, each set being made up of a number of annular discs which are flat at their peripheries, slightly coned over their major area and more sharply coned at their central area, the said laminations being prestressed by axial pressure applied at least to the more sharply coned area of the outermost discs so as to put the dished areas of the discs into compression and the flat peripheral areas of the discs into tension.

At high speed of rotation the effect of centrifugal force causes radial and tangential tension stresses in the discs which are least at the periphery but increase towards the centre of the disc area where the stress normally reaches the critical maximum. However, the effect of the static prestressing becomes additive to the centrifugal tensions in the peripheral areas and reduces the higher or critical tensions in the intermediate and inner areas of the discs. The stress concentrations around the central hole may be partially diffused into an extra thickness of metal displaced into the more sharply coned areas around the hole.

In preferred forms of the invention driving forces are transmitted to and from the laminations to and from their mounting shaft through the medium of a plate or plates located between the opposed sets of annular discs, and such force transference is preferably by friction at flat peripheral areas of the discs and the plate or plates.

Circumferential ridges may be pressed or otherwise formed in the flat peripheral areas of the discs and driving plate or plates, which juxtaposed ridges assist in maintaining concentric location of the assembly.

The axially applied prestressing forces are conveniently derived through the medium of appropriately shaped collars slidable upon the flywheel shaft and moved towards one another by nuts engaging threads upon that shaft.

The collars themselves may serve as journal bearings for the laminated disc and driving plate assembly.

In a preferred construction, illustrated in the accompanying drawing, identical laminations forming the main body of the flywheel are formed from rolled and preferably cross rolled plate, which after being shear or flame cut into discs are die pressed, explosive-formed or swage rolled on a former so that except for an area round the periphery each disc **1** is slightly coned in a manner similar to what is known as the "Belleville washer." The centre of the disc is pierced and the metal "displaced" in piercing is dispersed in an area around the centre which is more sharply coned than the main body of the disc. To allow a number of such discs to be stacked, evenly supported at the thicker centre cone and at the flat periphery, a circumferential ridge **2**, which is preferably discontinuous, may be rolled or pressed into the flat periphery area of each disc. Such ridge, partially resting in the corresponding forming groove in the juxtaposed plate lamination when the discs are assembled together, assists the more heavily coned centre area in maintaining concentric location.

The thickness of the laminations is largely determined by compromise between a large number of thin laminations at a higher cost per ton of sheet stock, and a small number of thick laminations subject to higher forming and handling costs which themselves are dependent upon the method of forming adopted. Thus for hot pressing or flow turning the size of machine demanded by the lamination diameter would better suit the thicker plates around $.005x$ diameter; explosive forming would best suit laminations around $.0025x$ diameter; and spinning suit around $.001x$ diameter.

Thinner plates have the technical advantage that the concave/convex differential surface loads due to application of prestress deflection rate is low, allowing smaller diameter prestress tie rod. The thicker plates have the advantage that the greater peripheral "clutching" forces will allow higher energy transfer rates without inter-laminar slip and without any necessity to provide interlocking grooves.

The molecular structure of the steel laminations appears to be less affected by deterioration due to surface fatigue stresses, when the laminations are formed explosively rather than otherwise, and where possible this method of forming is to be recommended.

In building up the flywheel equal numbers of plate laminations are assembled to either side of the centre discs **3**, which are secured at least in the rotational sense to a shaft **4**, passing through the centres of the laminations. Where a single centre plate is used it is thin in the peripheral area corresponding to the flat peripheral area of the plate laminations and thickens towards its centre substantially to fill the space between the concave inner surfaces of the innermost laminations of the opposing sets but with a predetermined clearance, especially at the centre where a specified tolerance is maintained between the more heavily coned inner area of the lamination concavities and the matching hub of the centre plate. This alternative construction will be clear without illustration.

At each end of the shaft **4**, a collar **5**, shaped to match the inner convexity of the outmost lamination, is pulled up preferably through the intermediary of a unitary fitted sleeve by a nut **7** or other screw means, such that the laminations are deflected from either end until they lie all together and against the inner face of the hub **6** of

the centre discs, 3. The end collar sleeves serve as journal bearings for supporting the flywheel and are used for this purpose for truing and balancing the completed flywheel.

Preferably the drive is taken from an extension of the shaft through the intermediary of the centre plates 3, which at their periphery, form a multiplate clutch with the peripheries of the deflected laminations.

In the static condition the effect of the enforced deflection of the laminar plates is to prestress the inner Belleville dished area in compression resisted by the flat peripheral area in tension, with the junction between the two areas in slight bending.

In an alternative construction the centre hole of the plate laminations is punched out so that there is no increase of thickness of the more sharply coned central area of the laminations and this makes unnecessary the circumferential ridge and groove in the flat peripheral area of the laminations. The higher stress concentration around the central holes increases the fatigue factor or such that, where there is appreciable cycling of the flywheel speed and energy storage capacity, lower stresses and less economic use of the material follows. Also lower rates of energy release and acquisition will be permissible due to the pure friction transference of energy from the laminations to the centre plate without the keying assistance of the circumferential ridge/groove facility.

Where the driving discs are of low modulus light alloy, the radial strain movement of the high modulus inertia laminations, transferred frictionally to the driving discs, will correspond to a lower tensile stress of the lower modulus material; also the centrifugally induced tensile stresses in the small effective unsupported diameter of the driving disc allied with its lower specific weight ensures that the stresses at the centre of the driving discs where they are secured to or by the driving hub are low in relation to the fatigue limit.

I claim:

1. A flywheel comprising two opposed sets of laminations, each set being made up of a number of annular discs which are flat at their peripheries, slightly coned over their major area and more sharply coned at their central area, mounting means for holding said opposed sets of laminations in alignment with the coned sides thereof facing each other, said mounting means including mechanism engaging the central areas of said sets for maintaining peripheral portions of the sets in mutual pressure-bearing relation whereby to put the coned areas of the discs into compression and the flat peripheral area of the discs into tension.

2. A flywheel according to claim 1 wherein said peripheries of the discs are provided with circumferential ridges to assist concentric location thereof.

3. A flywheel according to claim 1 in which said collars are provided with cylindrical outer surface portions constituting journal bearings for the mounting shaft.

4. A flywheel according to claim 1 wherein said mounting means includes a flywheel mounting shaft projecting through the central area of the sets and said mechanism includes a pair of collars sandwiching said central areas of the sets therebetween and nuts on the shaft for displacing said collars toward each other.

5. A flywheel according to claim 1 wherein said mounting means includes a flywheel mounting shaft projecting through the central areas of said sets, and a plate fixed to said shaft and projecting radially therefrom, the marginal region of said plate being sandwiched between said peripheral portions of the sets.

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