PATENT SPECIFICATION

Application Date: Oct. 5, 1922. No. 26,950/22. **210,486**
" " Oct. 13, 1922. No. 27,797/22.
One Complete Left: July 5, 1923.
Complete Accepted: Feb. 5, 1924.

PROVISIONAL SPECIFICATION.

No. 26,950, A.D. 1922.

Means for Preventing Breakage Due to Resonance in High Speed Machinery.

I, GEORGE CONSTANTINESCO, of "Carmen Sylva", Beechwood Avenue, Oatlands Park, Weybridge, in the County of Surrey, a subject of the King of Great Britain and Ireland, do hereby declare the nature of this invention to be as follows:—

The present invention relates to machines in which masses of metal rotate or oscillate at high speed; for example, the gear employed between turbines and the propeller in vessels driven by geared turbine installations.

In geared turbine installations, particularly in cases in which double reduction gearing is employed between a turbine and a propeller shaft, considerable difficulty has arisen owing to pitting and breakage of the gear teeth, although the normal stresses to which these teeth are subjected are apparently well within the limits allowable without over-stressing the metal. The cause of these breakages has hitherto been extremely obscure and breakages have usually been considered to be due to inaccuracy of cutting, quality of metal, or to excessive fatigue of the metal.

I have found, however, that the failure in many cases is due to high frequency vibrations of the teeth of the gears which at certain speeds of rotation are set into vibration at their natural frequency which may be in resonance with the impulses given by the teeth of the intermeshing wheels coming into contact as the gears rotate.

In a single reduction gear wheel the pinion is in direct connection with the shaft of the turbine and the gear wheel is fixed on the propeller shaft, this failure is less likely to occur, as in such case there is ample provision for the dissipation of the energy of vibration from the body of the wheel along the propeller shaft or to the shaft of the turbine, so that the energy of vibration may be dissipated and there is no storage of an excessive amount of energy in the vibration of the teeth of the gears.

On the other hand, in a double reduction gearing, the intermediate pinion and gear wheel are practically isolated for the supersonic vibrations because the only contact with radiating masses is on the bearings. The oil film maintained in the bearings acts as a most perfect insulator for very high frequency vibrations with the consequence that the energy of vibration due to supersonic vibration may continually increase if resonance should occur, as it will do in most cases at a given speed of rotation. The continually accumulated energy in the form of supersonic vibration ultimately results in damage to the teeth, because the increase of amplitude of vibration in the teeth results in alternating deformations of the metal beyond the elastic limit and also the high amplitude of the alternating velocity of vibration produces between the teeth impulsive pressures or shocks which may greatly exceed the surface resistance of the metal of the teeth, so that destruction of the surface occurs at the point of impact. This results in failure of the teeth which may be a clean breakage at the base due to the amplitude of the oscillation of the teeth and/or pitting and surface damage in the form of scaling; and pieces of hard steel may fly off owing to the excessive amplitude of the vibration and excessive relative velocity of impact.

The object of the present invention is to construct one or more of the gear wheels of a single or double reduction gear or other machinery in which a similar phenomenon occurs in such a manner that the energy of vibration is taken up in internal friction in the mass of the metal and carried away in the form of heat.

The invention consists in constructing a gear wheel or other body in which the vibrations occur in the form of laminations bolted together in such a way that the stresses produced on the laminations result finally in relative slip one over the other, so that the energy of impact in the moment of application of the stress is taken up in friction between the surfaces of the various laminations and dissipated in the form of heat, thus avoiding the occurrence of high frequency vibrations which may be termed supersonic energy in the material.

The invention further consists in constructing a member subject to intense vibration in the form of a number of thin laminations bolted together so that energy generated by shock between hard metallic surfaces is immediately converted into heat by friction between the laminations and providing means whereby the heat so generated by internal friction is carried away and over-heating avoided.

The invention also consists in constructing the intermediate gear wheel of a double reduction gear adapted to work at high speeds of a number of thin annular plates bolted together, the gear teeth being subsequently cut in the built-up structure so formed.

The invention also consists in the improved method and means for avoiding breakage in metal structures liable to resonance when running at high speeds hereinafter described.

In carrying the invention into effect according to one example as applied to the intermediate gear wheel in a double reduction gear between a turbine and a propeller shaft of a ship propulsion installation, the crowns of the intermediate pinion and gear wheel are constructed of a number of laminated annular plates of high tensile steel of say $^{1}/_{2}\,^{m}/_{m}$ to $3\,^{m}/_{m}$ thickness according to the size of teeth, firmly bolted together and double helical gears are cut on the wheel blank so formed in the ordinary manner. The surfaces of the laminations may be mechanically or chemically roughened to increase the friction or a layer of viscous or any friction increasing material in the form of a varnish not soluble in oil and which will not transmit vibration may be interposed between the laminations, for instance, the surfaces may be tinned or covered with very thin coating of lead, copper or other ductile metal or material.

It will be found that with a wheel so constructed the energy of vibration will be taken up by the friction between the plates; and by the provision of suitable cooling means, the heat so generated may be carried away and the tendency to breakage eliminated.

It will be seen that the invention is more applicable to members which are isolated in space from radiating masses such as the intermediate member of a double reduction gear, as in the case of the end members of such gear the vibration of the teeth can be transmitted either along the turbine shaft or along the propeller shaft and so dissipated without serious damage due to resonance.

In order to prevent exfoliation of the end laminations of the teeth, the last laminations can be made very stout, but with such a profile that they act only as maintaining flanges and do not take any direct load from the driving teeth.

It should be noted that when the laminations are arranged so that they bend under the application of the load, the relative slip between them will cause the transformation into heat of a certain amount of the energy of impact and from this it follows that helical gears laminated as above described will be more effective than parallel cut gears of the same size under the same load and speed. Therefore, whenever possible, the laminations should be arranged so that the plane of the laminations shall be inclined to the direction of impact.

Dated the 5th day of October, 1922.

W. GRYLLS ADAMS,
87, Victoria Street, London, S.W. 1,
Chartered Patent Agent.

PROVISIONAL SPECIFICATION.

No. 27,797, A.D. 1922.

A Method of Constructing Gear Wheels or the like.

I, GEORGE CONSTANTINESCO, of "Carmen Sylva", Beechwood Avenue, Oatlands Park, Weybridge, in the County of Surrey, a subject of the King of Great

Britain and Ireland, do hereby declare the nature of this invention to be as follows:—

The present invention relates to a method of constructing gear wheels and the like which are formed of a number of laminations in order to prevent failure due to high frequency or other vibrations of the teeth of the gear, or generally, vibrations due to the elasticity of the material which may, and frequently do, result in breakages when impulses occurring through the operation of the machinery coincide in frequency with the natural period of resonance of parts of the structure.

The invention consists in constructing a gear wheel or the like by stamping or otherwise forming a number of thin steel sheets, immersing these in a bath of molten tin, lead or other alloy, or galvanising them with a suitable metal, assembling the various plates so formed and subjecting them to pressure and heat in a suitable jig, cooling the blank so formed under pressure, and in the case of a gear wheel shrinking the ring so formed on to a wheel casting, bolting the whole together; and finally cutting the teeth in the known manner.

The invention also consists in the improved method of constructing a laminated gear wheel and in the improved gear wheel so formed as hereinafter described.

In carrying the invention into effect according to one example in which it is desired to produce a gear wheel of say 60 inches diameter, the outer ring of the gear wheel is formed of a number of sectors which may be $^1/_{16}$th of an inch in thickness, 3 inches in radial depth; and extending circumferentially through an angle of 45 degrees. These separate sectors may be stamped out of sheet-metal with suitable apertures for bolts which should be of rather smaller diameter than the final diameter intended. The sectors are then immersed in a bath of molten tin, lead, or other alloy, or may be galvanised by other suitable metal. The several sectors are then assembled in the form of a ring, the adjacent laminations overlapping each other across the width of the blank. Assembly is carried out in a special jig and the blank is then subjected to heat and pressure which causes the whole mass to bind together forming a solid body by reason of the melting of the jointing metal. The blank is then cooled under pressure and removed from the jig for machining. Holes are then formed parallel to the axis and riveting bolts inserted; and the blank is then machined on its inner diameter and shrunk on to a wheel casting which may be of cast iron, steel or other metal. The laminated mass is prevented from rotation on the wheel by a number of bolts parallel to the axis engaged half in the blank and half in the wheel body to take the drive and prevent slip. The teeth are now cut on the circumference of the wheel in the usual manner and finally circular flanges are bolted on to the sides. In such a wheel resonance under vibrations either of sound frequency or supersonic frequency is avoided.

Wheels constructed as above described are particularly suitable for intermediate gear wheels of double reduction gears rotating at high speeds such as are employed in geared turbine double reduction installations.

The method of construction, however, is applicable to many other purposes in which a laminated wheel or the like is required for the purpose specified.

Dated the 13th day of October, 1922.

W. GRYLLS ADAMS,
87, Victoria Street, London, S.W. 1,
Chartered Patent Agent.

COMPLETE SPECIFICATION.

A Method of Constructing Gear Wheels or the like.

I, George Constantinesco, of "Carmen Sylva", Beechwood Avenue, Oatlands Park, Weybridge, in the County of Surrey, a subject of the King of Great Britain and Ireland, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

The present invention relates to machines in which masses of metal rotate or oscillate at high speed; for example, the gear employed between turbines and the propeller in vessels driven by geared turbine installations.

In geared turbine installations, particularly in cases in which double reduction gearing is employed between a turbine and a propeller shaft, considerable difficulty has arisen owing to pitting and breakage of the gear teeth, although the normal stresses to which these teeth are subjected are apparently well within the limits allowable without over-stressing the metal. The cause of these breakages has hitherto been extremely obscure and breakages have usually been considered to be due to inaccuracy of cutting, quality of metal, or to excessive fatigue of the metal.

I have found, however, that the failure in many cases is due to high frequency vibrations of the teeth of the gears which at certain speeds of rotation are set into vibration at their natural frequency which may be in resonance with the impulses given by the teeth of the intermeshing wheels coming into contact as the gears rotate.

In a single reduction gear wheel the pinion is in direct connection with the shaft of the turbine and the gear wheel is fixed on the propeller shaft, this failure is less likely to occur, as in such case there is ample provision for the dissipation of the energy of vibration from the body of the wheel along the propeller shaft or to the shaft of the turbine, so that the energy of vibration may be dissipated and there is no storage of an excessive amount of energy in the vibration of the teeth of the gears.

On the other hand, in a double reduction gearing, the intermediate pinion and gear wheel are practically isolated for the supersonic or high frequency vibrations because the only contact with radiating masses is on the bearings. The oil film maintained in the bearings acts as a most perfect insulator for very high frequency vibrations with the consequence that the energy of vibration due to supersonic vibration may continually increase if resonance should occur, as it will do in most cases at a given speed of rotation. The continually accumulated energy in the form of supersonic vibration ultimately results in damage to the teeth, because the increase of amplitude of vibration in the teeth results in alternating deformations of the metal beyond the elastic limit and also the high amplitude of the alternating vibration produces between the teeth impulsive pressures or shocks which may greatly exceed the surface resistance of the metal of the teeth, so that destruction of the surface occurs at the point of impact. This results in failure of the teeth which may be a clean breakage at the base due to the amplitude of the oscillation of the teeth and/or pitting and surface damage in the form of scaling; and pieces of hard steel may fly off owing to the excessive amplitude of the vibration and excessive relative velocity of impact.

One object of the present invention is to construct one or more of the gear wheels of a single or double reduction gear or other machinery in which a similar phenomenon occurs in such a manner that the energy of vibration is taken up in internal friction in the mass of the metal and carried away in the form of heat.

Many proposals have been made to build up gear wheels from laminæ of steel or other metal having a softer damping material between them, the various laminæ being bolted to form a solid mass.

It has also been proposed to build up the solid mass of laminæ of steel or other hard metal with solder or softer metal between them, the whole mass being bound together under the action of heat and pressure, but in such case the laminæ have been arranged so that in the gear wheel formed the forces acting act parallel to the planes of separation between the laminæ so that there is no tendency for the laminæ to slip relatively to each other.

The present invention consists in building up a gear wheel or other mass of metal which is required to rotate or oscillate at high speed of laminæ of steel, bronze, copper or other metal having between them and amalgamated with them a thin layer of a metallic substance such as an intimately adhering solder or a metal more plastic than that of which the laminæ are formed, the intermediate material being such that it is capable of taking up energy by internal friction and/or molecular friction and converting it into heat; the laminæ being arranged so that under the stresses produced in the structure, there is a tendency for the adjacent laminæ to have a slight sliding motion relatively to each other, so that energy is taken up by internal friction and/or molecular friction, the oscillating motion being degraded into heat produced in the binding material.

In most cases the natural radiation will be sufficient to carry away the heat.

The invention also consists in constructing a gear wheel or the like by stamping or otherwise forming a number of thin steel sheets, immersing these in a bath of molten tin, lead or other alloy, or galvanising them with a suitable metal, assembling the various plates so formed and subjecting them to pressure and heat in a suitable jig, cooling the blank so formed under pressure, and in the case of a gear wheel, shrinking the ring so formed on to a wheel casting, bolting the whole together; and finally cutting the teeth in the known manner, the planes of the several laminæ being inclined to the direction of action of the forces acting on the wheel.

The invention also consists in an intermediate gear wheel of a double reduction gear adapted to work at high speeds; and constructed as above specified of a number of thin annular plates amalgamated and if desired bolted together, the gear teeth being subsequently cut in the built-up structure so formed so that the planes of the laminæ are inclined to the direction of action of the forces acting on the wheel.

The invention also consists in the improved method and means for avoiding breakage in metal structures liable to resonance when running at high speeds hereinafter described.

In carrying the invention into effect according to one example as applied to the intermediate gear wheel in a double reduction gear between a turbine and a propeller shaft of a ship propulsion installation, the crowns of the intermediate pinion and gear wheel are constructed of a number of laminated annular plates of high tensile steel of thickness say $^1/_2$ $^m/_m$ or even less for small teeth to 3 $^m/_m$ for very large teeth, according to the size of teeth, firmly bolted together and double helical gears are cut on the wheel blank so formed in the ordinary manner. The surfaces of the laminations may be mechanically or chemically roughened to enable them to adhere and therefore increase the internal friction and the surfaces may be tinned or covered with very thin coating of lead, copper, or other ductile metal.

Suppose for instance it is desired to produce a gear wheel of say 60 inches diameter, the outer ring of the gear wheel is formed of a number of sectors which may be $^1/_{16}$ of an inch in thickness, 3 inches in radial depth; and extending circumferentially through an angle of 45 degrees. These separate sectors may be stamped out of sheet-metal with suitable apertures for bolts which should be of rather smaller diameter than the final diameter intended. The sectors are then immersed in a bath of molten tin, lead, or other alloy, or may be galvanised by other suitable metal which is capable of forming an amalgam with steel. The several sectors are then assembled in the form of a ring, the adjacent laminations overlapping each other across the width of the blank. Assembly is carried out in a special jig and the blank is then subjected to heat and pressure which causes the whole mass to bind together forming a solid body by reason of the melting of the jointing metal. The blank is then cooled under pressure and removed from the jig for machining. Holes are then formed parallel to the axis and riveting bolts inserted; and the blank is then machined on its inner diameter and shrunk on to a wheel casting which may be of cast iron, steel or other metal. The laminated mass is prevented from rotation on the wheel by a number of bolts parallel to the axis engaged half in the blank and half in the wheel body to take the drive and prevent slip. The teeth which are at an inclination to the axis are now cut on the circumference of the wheel in the usual manner and finally circular flanges are bolted on to the sides. In such a wheel resonance under vibration either of sound frequency or supersonic frequency is avoided.

It will be found that with a wheel so constructed the energy of vibration will be taken up by the internal friction or hysteresis of the material between the plates; and by the provision of the suitable cooling means, the heat so generated may be carried away and the tendency to high frequency resonance and consequent breakage eliminated.

Referring to the accompanying diagrammatic drawings:—

Figure 1 is a side elevation of a pinion constructed according to the invention suitable for helical teeth;

Figure 2 is an end elevation of the same;

Figure 3 is a section through the rim of the wheel;

Figure 4 is a side elevation with the side plates of the wheel removed;

Figure 5 shows a method of forming the laminations when the teeth are cut parallel to the axis of the wheel;

Figure 6 shows one of the laminations;

Figure 7 is a side elevation showing laminations suitable for a bevel wheel;

Figure 8 is a section on the line 8—8, Figure 7;

Figure 9 is a plan of the bevel wheel;

Figure 10 shows a modified form of lamination suitable for a bevel wheel;

In the form of the invention shown in Figures 1 to 6, the portion of the wheel on which the teeth are cut comprises a number of annular discs *a* of steel, hard bronze, or other metal coated with solder or other suitable damping material which has considerable plasticity or hysteresis pressed together when hot as above described. The composite ring so formed is pressed on to the body of the wheel *b* and held in place by flanged rings *c c* held together by bolts *d d*. Each disc of the ring *a* is composed of a number of segments 1, 2, 3 *etc.*, the segments of the adjacent rings being staggered as indicated by the dotted lines 4 in Figure 4. With this arrangement, the teeth are cut at an angle to the axis as illustrated at 5 in Figure 2.

The separate segments of the disc *a* may also be arranged according to another figure as shown in Figure 5, in which case the teeth 6 on the wheel may be cut parallel to the axis as illustrated.

In applying the invention to a bevel wheel, the portion of the wheel on which the teeth are cut may consist of a tightly wound spiral forming a ring *g* Figure 8 with suitable damped material being employed as above described between the adjacent spiral. The ring thus formed is pressed on to a suitable hub *h* and held between a flange *k* and a plate *l* firmly bolted to the wheel hub by bolts *m*.

In this form of the invention suitable keys *n* should be provided on the face of the plate *l* to assist in the prevention of rotation of the ring *g* relatively to the hub of the wheel. The teeth of the bevel wheel are indicated by the lines *o*.

In the form of the invention shown in Figure 10 which illustrates another form of bevel wheel, the ring on which the teeth are cut is built up of a number of spiral segments 8 with suitable damping material between them, as above described.

In this form of the invention, the teeth may be cut as shown in Figures 7, 8 and 9. It will be obvious that many modifications of the invention are possible and that the wheels illustrated are only examples showing the method by which the invention may be carried into effect.

It will be seen that the invention is more applicable to members such as the intermediate member of a double reduction gear, as in the case of the end members of such gear a portion of the vibration of the teeth can be transmitted either along the turbine shaft or along the propeller shaft and so dissipated without serious damage due to resonance whereas the intermediate member is isolated from other masses by the oil film in its bearings.

In order to prevent exfoliation of the end laminations of the teeth the last laminations can be made very stout, but with such a profile they act only as maintaining flanges and do not take any direct load from the driving teeth.

It should be noted that when the laminations are arranged so that they tend to bend under the application of the load, the relative tendency to slip between them will cause the transformation into heat of a certain amount of the energy of impact and from this it follows that helical gears laminated as above described will be more effective than parallel cut gears of the same size under the same load and speed. Therefore, the laminations are arranged so that the plane of the laminations is inclined to the direction of impact. Figure 5 shows how the laminations should be arranged for teeth parallel to the axis. Such an arrangement is also suitable for helical teeth provided the angles of inclination of the teeth and laminations are different.

It should be noted that the steel laminæ are subjected to internal stresses below their elastic limit, the heat being generated chiefly in the intermediary material. In this way the non homogeneous structure obtained has high mechanical strength combined with considerable power of dissipating energy by internal and molecular friction.

The invention does not include cases in which bodies are built up from laminations bolted together without adhering firmly together. Such structures cannot take up internal shearing stresses, the laminæ simply acting individually as is the case with laminated springs or gear wheels built of plates bolted together, or does it include structures in which under this force acting there is no tendency to relative slip between the laminæ.

The strength of such bodies formed of a large number of laminæ is very much less than a similar structure solidly built. The difference in strength between the structure built up according to my invention and a solid body is negligible and since better quality of metal can be employed the strength may be even greater than would be the case of a solid structure provided the laminations are suitably arranged in view of the direction of the various stresses which have to be met.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. A method of constructing a gear wheel or the like in which vibrations occur by forming metal laminations amalgamated together in such a way that the stresses produced on the laminations result finally in a tendency of relative slip one over the other, so that the energy of deformation is taken up in internal friction and/or molecular friction of the material between the surfaces of the various laminations and dissipated in the form of heat, thus avoiding the accumulation of such energy in the form of high frequency vibrations.

2. A method of constructing gear wheels or the like according to Claim 1 by stamping or otherwise forming a number of thin steel sheets, immersing these in a bath of molten tin, lead or other alloy, galvanising them with a suitable metal,

assembling the various plates so formed and subjecting them to pressure and heat in a suitable jig, cooling the blank so formed under pressure and finally working the material to its final shape in the known manner.

3. An intermediate gear wheel of a double reduction gear adapted to work at high speeds constructed according to the method claimed in Claim 1 of a number of thin annular plates; the mass being also bolted together and the gear subsequently cut in the built-up structure so formed.

4. The improved gear wheels constructed according to the method claimed in Claim 1, hereinbefore described and illustrated at Figures 1 to 6 of the accompanying drawings.

5. The improved bevel wheels constructed according to the method claimed in Claim 1, hereinbefore described and illustrated at Figures 7 to 10 of the accompanying drawings.

Dated the 5th day of July, 1923.

W. GRYLLS ADAMS,
87, Victoria Street, London, S.W. 1,
Chartered Patent Agent.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1924.

FIG. 4.

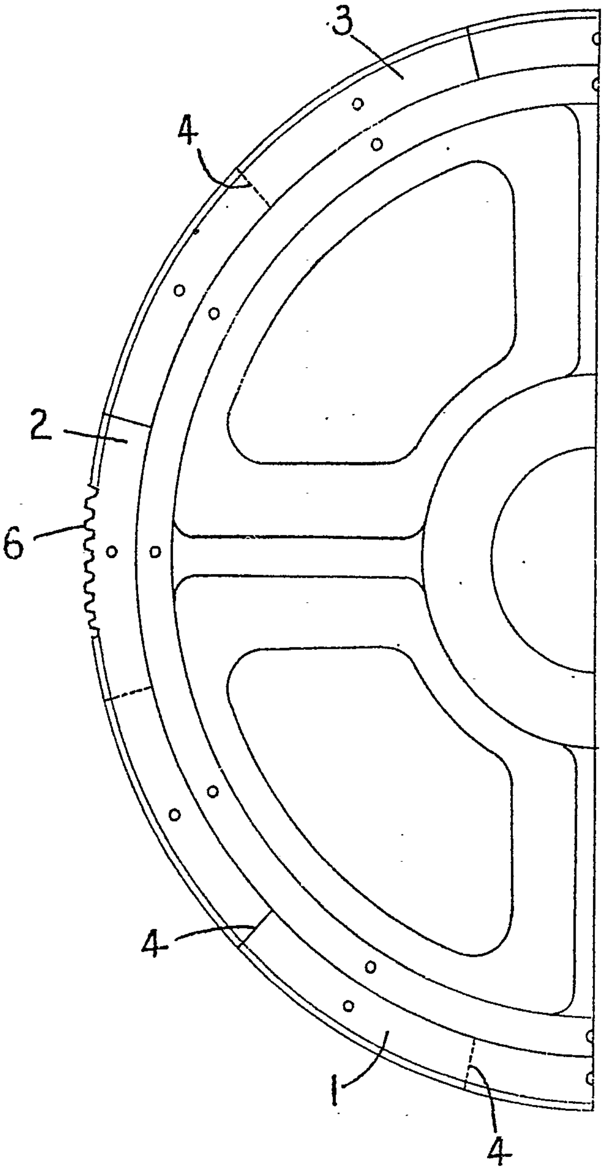
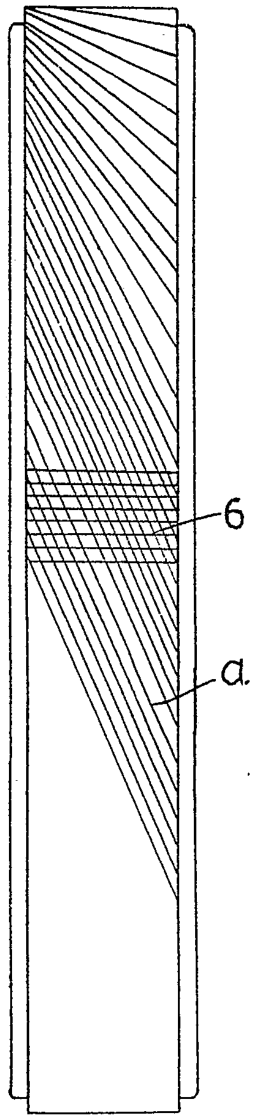
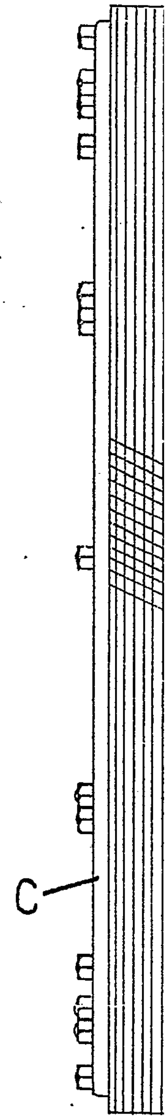


FIG. 5.



F



5.

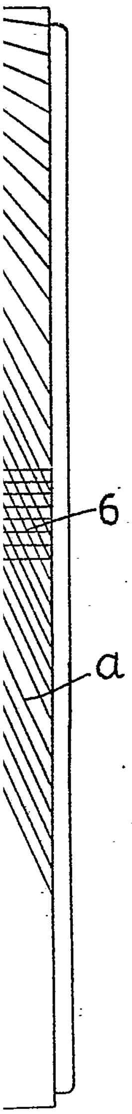


FIG. 2.

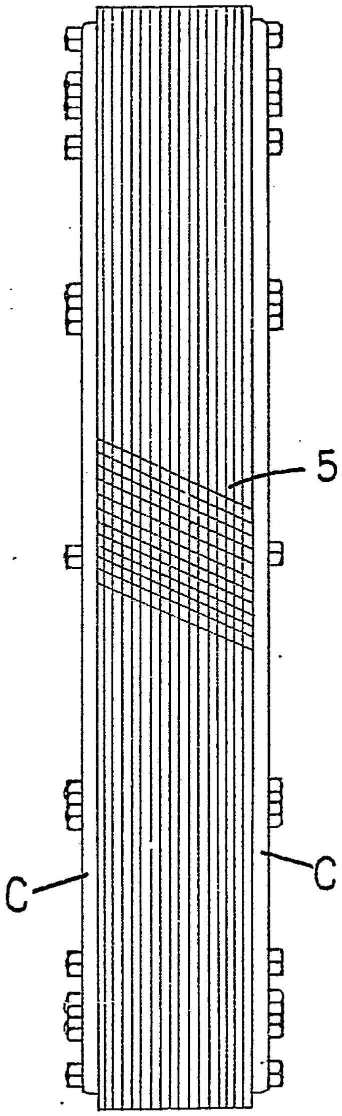


FIG. 1.

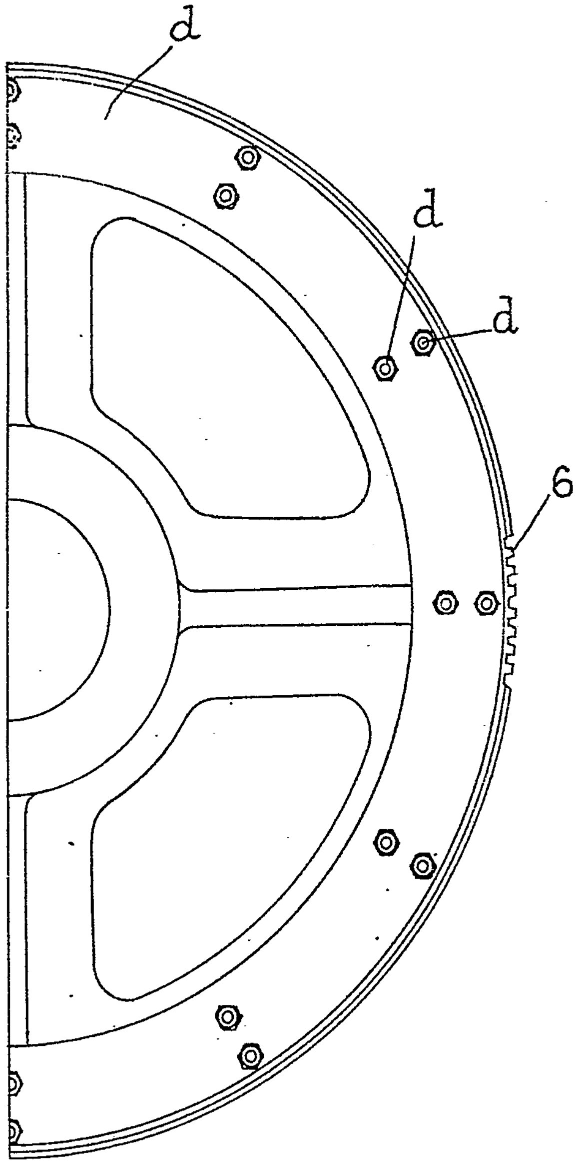


FIG. 4.

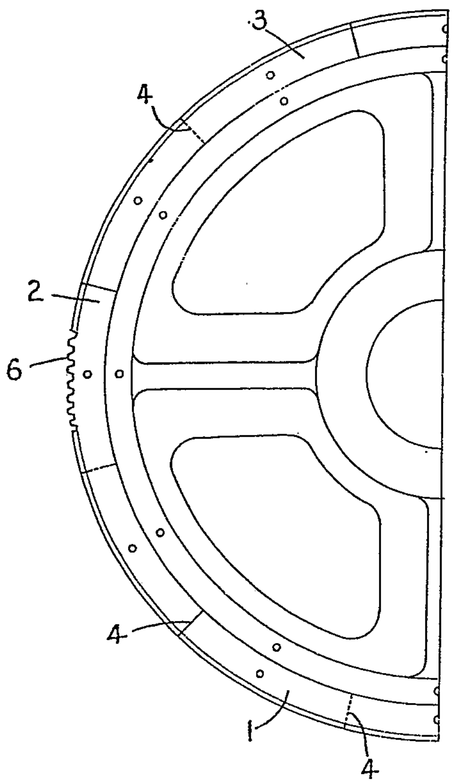


FIG. 5.

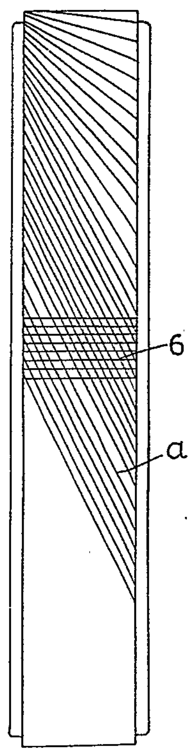


FIG. 2.

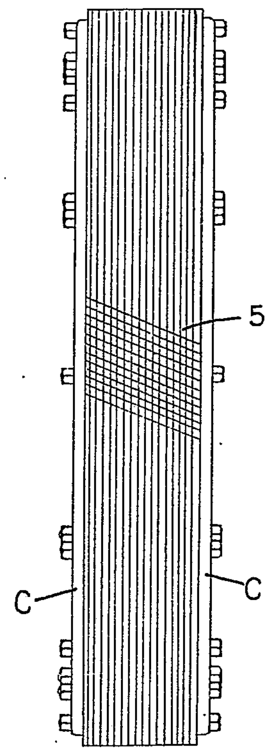
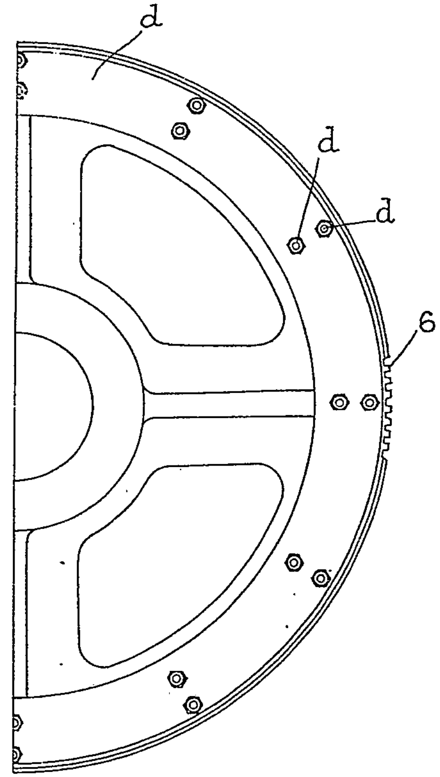


FIG. 1.



[This Drawing is a reproduction of the Original on a reduced scale]

FIG.8.

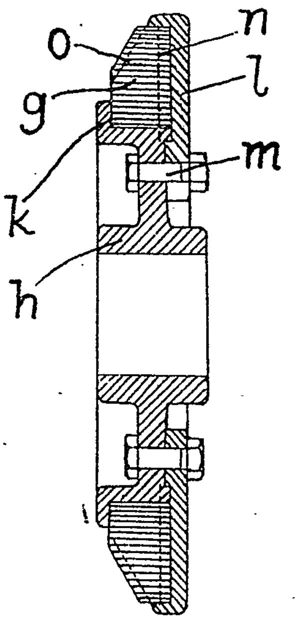
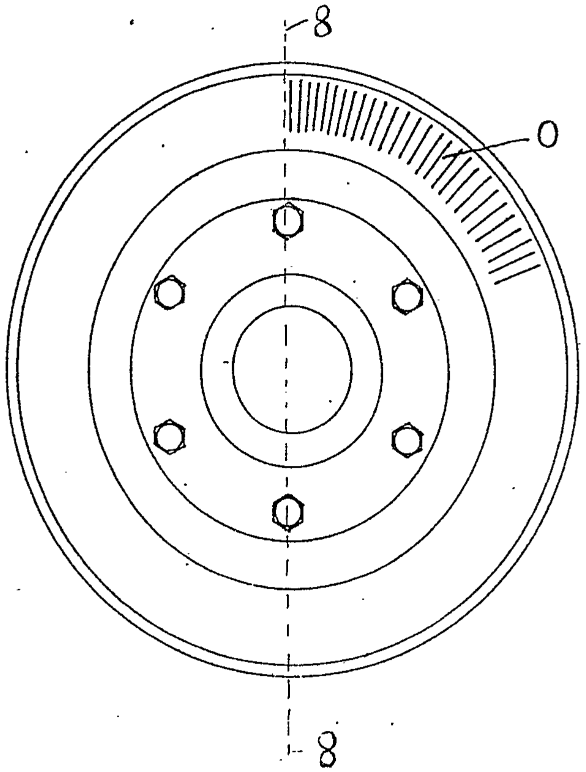


FIG.7.



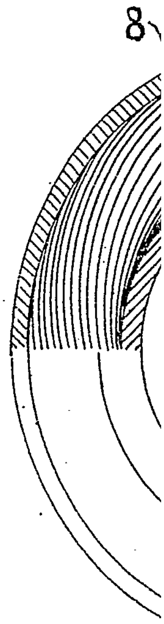
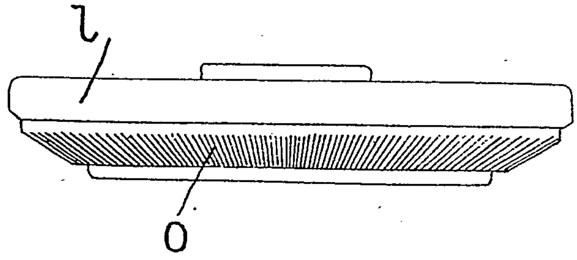


FIG.9.



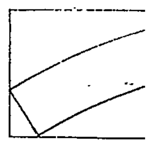


FIG.10

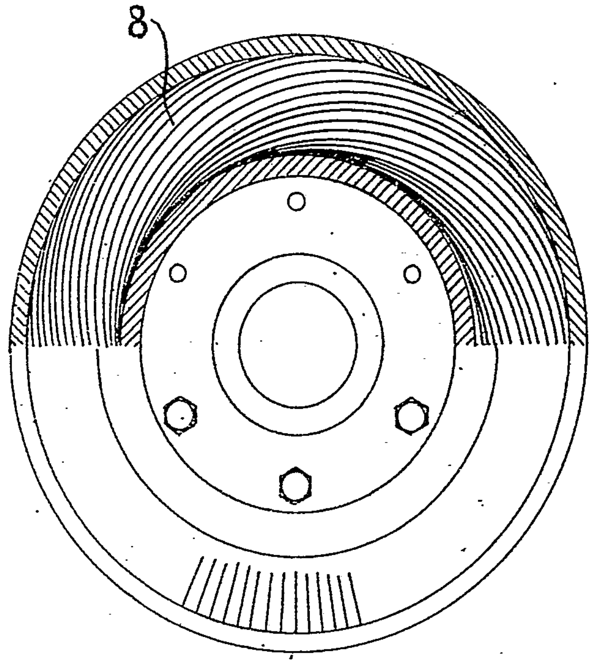


FIG.3.

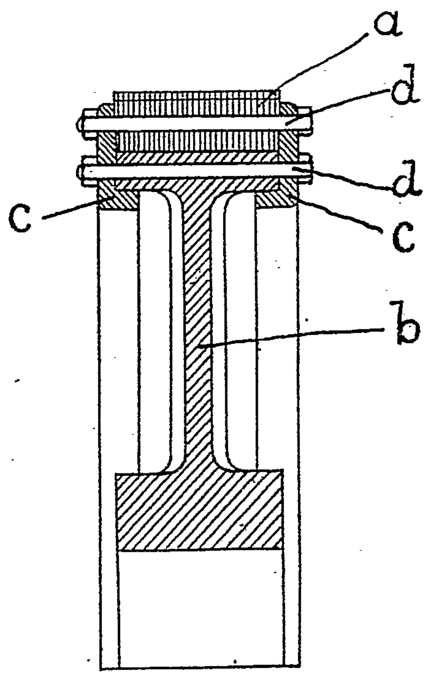
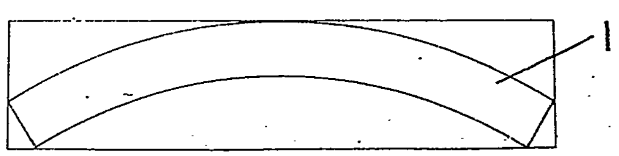


FIG.6.



Malby & Sons, Photo-Litho

FIG. 8.

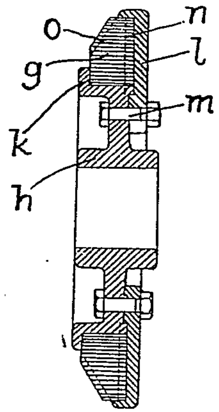


FIG. 7.

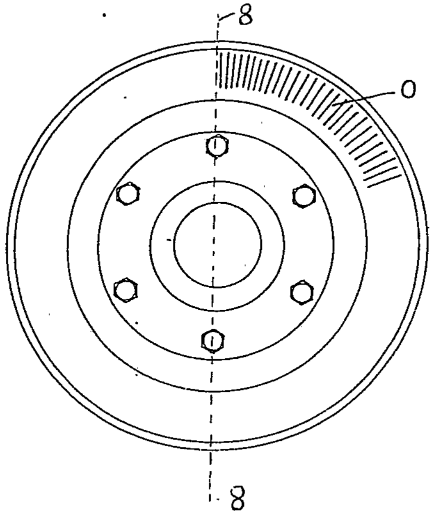


FIG. 10

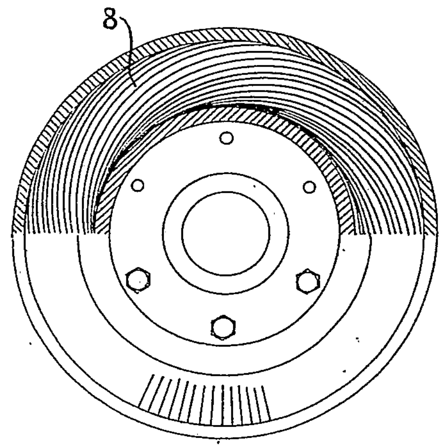


FIG. 3.

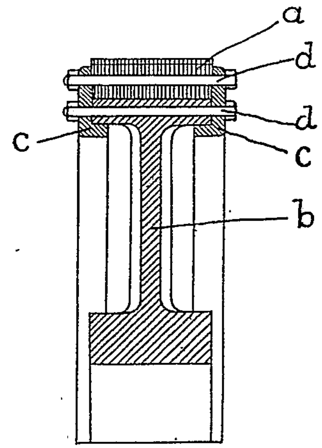


FIG. 9.

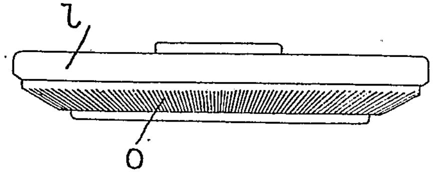
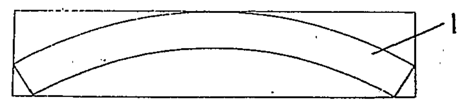


FIG. 6.



[This Drawing is a reproduction of the Original on a reduced scale]