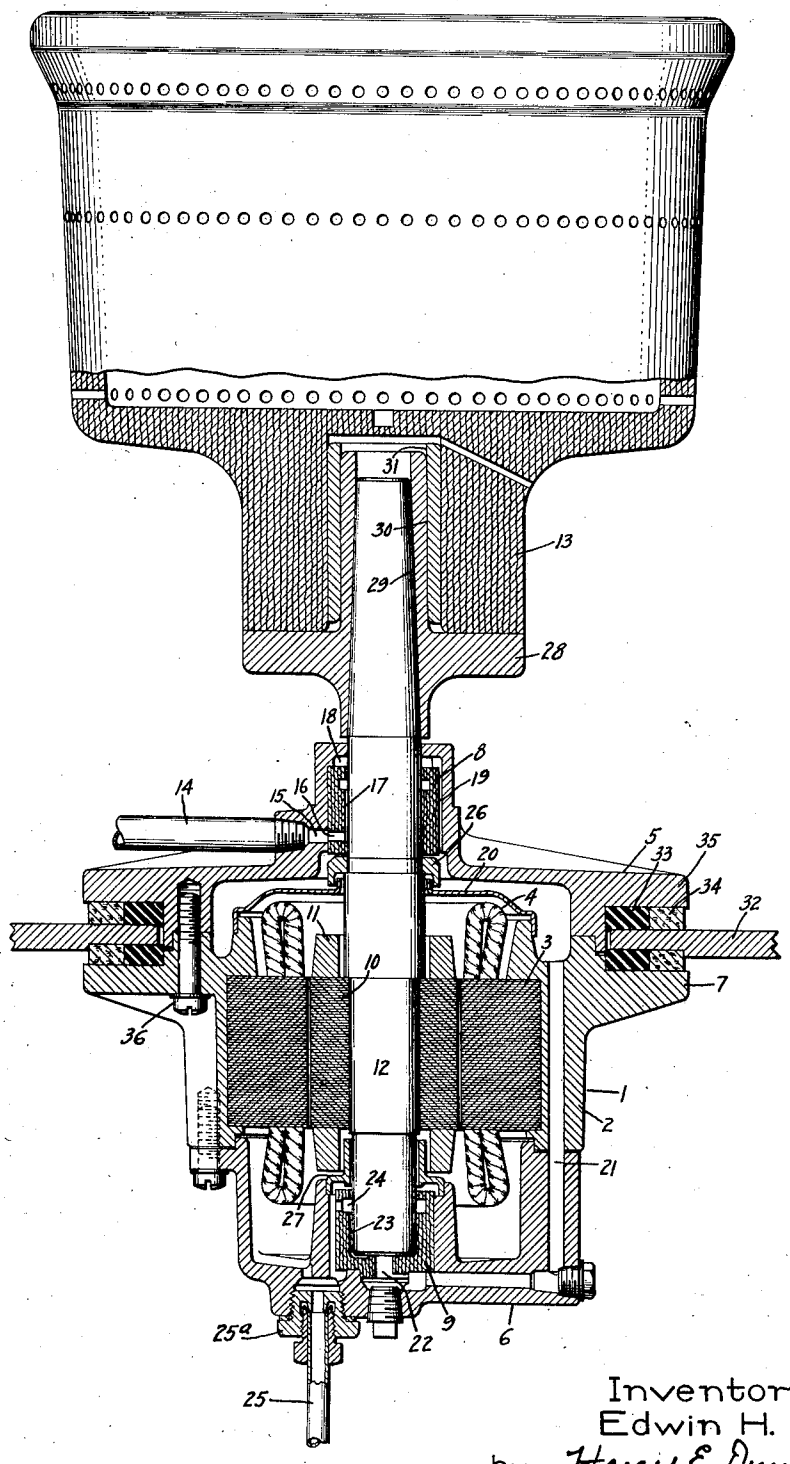
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SPINNING SPINDLE

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SPINNING SPINDLE

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22 Claims. (Cl. 117—27.6)

My invention relates to electric motor-driven spinning spindles for spinning artificial silk and the like of the type in which the spinning bucket is mounted on the motor shaft and driven thereby.

In motor-driven spinning spindles for spinning artificial silk which rotate at a high speed, there are certain speeds called critical speeds, at which the spindle shaft is distorted from the axis of rotation, and while rotating in the distorted position causes severe vibrating forces to be transmitted to the bearings in which the shaft rotates. The speeds at which the critical speeds occur depend upon the stiffness of the spindle shaft, the inertia of the stationary and rotating parts of the spindle, and the character of the mounting which is used to secure the spindle to the spinning frame.

The commercial spinning of artificial silk and the like has been done at speeds between 5,000 and 10,000 R. P. M. Only a small amount of spinning has been done at 10,000 R. P. M. and the bulk of the spinning of artificial silk is at speeds in the vicinity of 7,000 R. P. M. In all the spinning spindles which have been successfully used for spinning artificial silk, the motor for driving the spindle has had a stationary member of large and heavy construction with the spindle shaft, on which the spinning bucket or other spinning device is mounted, supported in ball bearings and purposely made flexible so that the normal operating range would be between the speeds at which critical vibration occurs. The operating range has usually been between the first and second critical speeds of the spindle shaft. With motors of this construction and with the necessary high speeds of operation, it has not been feasible to make the shaft stiff enough so that the critical speed of the shaft would be above the normal operating range. A spinning spindle having a motor with a flexible shaft is shown in application Serial No. 701,478, filed Dec. 8, 1933, and assigned to the same assignee as the present invention.

In accordance with my invention, I propose to make the motor which drives the spinning spindle of improved construction so that it becomes possible to provide a spinning spindle which will operate at high speeds and in which the operating range is below the speed at which the critical vibration of the spindle shaft occurs.

An object of my invention is to provide a spinning spindle having an electric motor with a stator of low inertia and a spinning bucket mounted on the motor shaft in which the first critical speed of the motor shaft is above the normal operating range.

Another object of my invention is to provide a spinning spindle having an electric motor with a stator of low inertia, a spinning bucket mounted on the motor shaft, and sleeve bearings of synthetic resin.

Another object of my invention is to provide a spinning spindle having an electric motor with a stator of low inertia, a spinning bucket mounted on the motor shaft, and sleeve bearings lubricated by water or a water solution.

Further objects and advantages of my invention will become apparent as the following description proceeds, and the features of novelty which characterize my invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

For a better understanding of my invention, reference may be had to the accompanying drawing in which the single figure is a sectional view of a spinning spindle embodying my invention.

In the embodiment of my invention illustrated, the spinning spindle is driven by an electric motor having a stationary member 1, comprising a stator frame 2 and end frames 5 and 6. In order to make the stationary member light and of low inertia, the stator frame 2 is made from aluminum and is cast directly around a laminated field structure 3, having suitable windings 4, thereby holding the laminated field structure in place. A flange 7 is cast integral with the stator 2 and extends horizontally from the stator to provide a mounting for the motor. The end frames 5 and 6 are also made of cast aluminum construction in order to decrease the weight, and each of these end frames has a suitable bearing secured therein. The upper end frame 5 has a sleeve bearing 8 of fabric impregnated with a suitable synthetic resin such as a phenolic condensation product. The end frame 5 has an integral flange 35 extending horizontally to form a mounting for the spindle. The lower end frame 6 has a combined sleeve and thrust bearing 9 also made of fabric impregnated with a synthetic resin. The use of sleeve bearings allows the stator to be of light construction with low inertia. The sleeve bearings also allow larger clearances between the shaft and bearing than is possible with roller or ball bearings, and provide a simple and rugged construction.

The rotating member of the electric motor comprises a laminated core structure 10 having a cast squirrel-cage winding 11 therein and secured to a vertical shaft 12. The shaft rotates in the

bearings 8 and 9 and has a portion extending above the stationary member of the motor on which a spinning bucket 13 or other suitable spinning device may be mounted. The spinning bucket 13 is preferably frictionally driven by a clutch 28 having an inner tapered portion 29 frictionally engaging the tapered end of the shaft 12 and having an outer tapered portion 30 which engages a complementary portion 31 in the base of the bucket. The spinning bucket 13 is made of fabric impregnated with a phenolic condensation product. The inside diameter and inside depth are 7 inches and 4 inches respectively, and the total weight of the bucket is 4½ pounds.

The bearing 8 and 9 are lubricated by water or a water solution which is brought to the bearings by an external circulating system. The water is led from the external circulating system to the bearing 8 by pipe 14 and flows through horizontal passages 15 and 16 to the inner bearing surface, through a vertical groove 17 in the inner surface of the bearing to a chamber 18 at the top of the bearing, through grooves 19 spaced around the outside of the bearing, over a baffle 20 extending from a point adjacent the shaft 12 to the stationary member of the motor, and through a passage 21 in the stator frame 2 and the end frame 6 to the sleeve and thrust bearing 9. The water lubricant flows into the bearing 9 through a passage 22, through a vertical groove 23 in the inner surface of the bearing to an outlet passage 24 at the top of the bearing, and out of the motor through a pipe 25 which is secured in an opening in the lower end frame 6 by a suitable coupling 25*a*. A sleeve 27 fitted in the end frame 6 and extending over the bearing 9 and around the shaft 12 prevents the flow of water upwardly along the shaft into the interior of the motor.

Due to the low viscosity of water, the bearing losses are low. The water also keeps the bearing cool and cools the motor during its passage over the baffle 20 and through the passage 21. A collar 26 is provided on the shaft 12 over the baffle 20 and prevents water from leaking into the windings of the motor. It is possible to mix a corrosion preventer with the water in order to prevent corrosion of the shaft and laminations, but I prefer to prevent corrosion by making the shaft 12 of non-corrosive steel and by placing a protective coating on the laminations. Equivalent water solutions may be used in place of water for lubricating the bearings; for example, a solution of 80% water and 20% glycerine is satisfactory. Water cooling of the motor allows the stator to be made lighter and with lower inertia.

The spinning spindle is secured to the spinning frame 32 by a composite member forming a resilient mounting which comprises an inner ring 33 of rubber or other material having low internal friction and a concentric outer ring 34 of cork or other material having high internal friction extending along each of the upper and lower surfaces of the spinning frame 32 coaxial with the spindle shaft. The lower rings extend between the lower surface of the spinning frame 32 and the flange 7 on the stator frame 2. The upper rings extend between the upper surface of the spinning frame 32 and the flange 35 on the end frame 5. The mounting may be constructed with the inner ring of cork and the outer ring of rubber. The motor is held in place by a clamping pressure exerted by bolts 36 between the stator frame 2 and the end frame 5. The resilient mounting is located so that the horizontal axis of the mounting coincide approximately with the center of oscillation of the spinning spindle throughout the normal running range. This axis is located between the two sets of shaft bearings and, in the embodiment illustrated in the drawing, is somewhat nearer the upper bearing.

It is important that the electric motor have a stator of low inertia in order that it may be feasible to make the shaft 12 of sufficient stiffness so that the operating range of the spinning spindle is below the speed at which critical vibration of the shaft takes place. With a stiff shaft, there is less chance for distortion of the shaft during abnormal operating conditions than in the case of the present flexible shaft motor. In the particular embodiment of my invention illustrated, the moment of inertia of the stationary member of the motor about an axis through the center of gravity of the stationary member of the motor and perpendicular to the axis of the shaft is equal to 0.085 lb. in sec.^{2}. I find that a satisfactory motor may be constructed if the inertia of the stator is less than 0.3 lb. in. sec.^{2}. The stiffness of the shaft 12 is calculated by considering the shaft as rigidly supported on knife edges at the center of the bearings 8 and 9 with a theoretically rigid extension on the shaft and by applying a force to the rigid extension at the center of gravity of the bucket. The ratio of the load applied to the deflection at the point of application of the load is a measure of the stiffness of the shaft and in the case of the shaft illustrated, is equal to 9,200 lbs./in. I find that it is important that the ratio of the shaft stiffness to the moment of inertia of the stator or stationary member of the motor be high, and in the case of the motor illustrated this ratio is equal to 272 in.$^{-3}$. It is also important that the ratio of the shaft stiffness to the moment of inertia of the stator and spinning bucket about an axis through the center of gravity of the spindle and perpendicular to the axis of the shaft be high. In the case of the spinning spindle illustrated, this latter ratio is equal to 40 in.$^{-3}$. I find that the spinning spindle will operate satisfactorily if the ratio of shaft stiffness to the inertia of the stator of the motor is greater than 70 in.$^{-3}$, or if the ratio of the shaft stiffness to the moment of inertia of the stator of the motor and the spinning bucket about the center of gravity of the spindle is greater than 20 in.$^{-3}$. By comparison, the stator of the present flexible shaft motor for driving spinning buckets has a moment of inertia of approximately 9 lb. in. sec.^{2}; the ratio of shaft stiffness to stator inertia is approximately equal to 1.1 in.$^{-3}$; and the ratio of the shaft stiffness to the inertia of the bucket and stator about the center of gravity of the spindle is approximately equal to .25 in.$^{-3}$. The ratios of shaft stiffness to moment of inertia are designated in terms of in.$^{-3}$, because, in practice, engineers find it more convenient to determine moments of inertia (J_w) in terms of weight (w) of a body, for which the equation is:

$$J_w = \Sigma w r^2$$

Similarly, the expression for shaft stiffness (S) may be expressed as:

$$S = \frac{F}{d}$$

where, F=force applied in pounds,
d=deflection in inches.

Then, the equation for the ratio of shaft stiffness to moment of inertia is:

$$\frac{S}{J_w}=\frac{\frac{F}{d}}{\Sigma wr^2}$$

Substituting, dimensional quantities gives:

$$\frac{S}{J_w}=\frac{\frac{\text{lbs.}}{\text{in.}}}{\text{lb. in.}^2}=k\ \text{in.}^{-3}$$

In the operation of the spinning spindle illustrated, at about 2,500 R. P. M. there are vibrations of the spinning spindle as a whole on the mounting. These vibrations may be called the critical vibration of the mounting. At this speed there is practically no distortion of the spindle shaft. There is no further vibration of the spinning spindle except that due to unbalance of the bucket until a speed substantially above 12,000 R. P. M. is reached. At this higher speed, which is above 15,000 R. P. M., the shaft 12 is subject to critical vibration. The spinning spindle therefore has a very wide operating range extending from about 4,000 R. P. M. up to 12,000 R. P. M. in which there is little vibration. This range is ample for the present practice in spinning artificial silk. If the ratios referred to above are made larger, preferably by decreasing the stator inertia, the upper limit of the speed of operation is increased. The lower limit of the speed of operation, which is dependent upon the mounting, remains substantially the same.

If the spinning spindle has small unbalance, which is not the usual case during normal operation, there is a tendency for the shaft to whip in the bearings; i. e., for the axis of rotation of the shaft to revolve about the center of the bearings. This tendency to whip has been corrected in the embodiment of my invention illustrated by the resilient mounting used to secure the spindle to the spinning frame. At high frequencies of vibration, the cushioning effect of the mounting is obtained almost entirely from the inner rubber ring 33. At lower frequencies of vibration, such as caused by whipping of the shaft, the vibrating forces act upon the outer ring 34 which is of cork or other material having high internal friction. The internal friction in the cork is sufficient to damp out these low frequency vibrations and effectively prevent whipping of the shaft.

Although I have shown a particular embodiment of my invention, I do not desire to be limited to the construction described, and I intend in the appended claims to cover all modifications which do not depart from the spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. A spinning spindle comprising an electric motor including a stationary member and a rotatable member having a vertical shaft extending from said motor, a water-lubricated sleeve bearing of synthetic resin between said shaft and said stationary member and above said rotating member, a baffle below said bearing and extending over said rotating member, means conducting water over said baffle for cooling said motor, and a spinning device adapted to rotate at speeds greater than 4000 R. P. M. mounted on the extended portion of said shaft and driven thereby.

2. A spinning spindle comprising an electric motor including a stationary member of small mass and a rotatable member having a vertical stiff shaft with the first critical speed thereof above the normal operating range of said spindle, said shaft having such stiffness and said stationary member such low moment of inertia that the ratio of shaft stiffness to the moment of inertia of said stationary member about an axis through the center of gravity thereof and perpendicular to the axis of said shaft is greater than 70 in.$^{-3}$, a spinning device adapted to rotate at speeds greater than 4000 R. P. M. mounted on and driven by said shaft, means including a sleeve bearing of synthetic resin for supporting said rotatable member within said stationary member, and means having its critical vibration below the normal operating range of said spindle for resiliently securing the same to a spinning frame or the like.

3. A spinning spindle comprising an electric motor including a stationary member having a horizontally extending flange and a rotatable member including a vertical shaft, a spinning device mounted on and driven by said shaft, and means having the critical vibration thereof below the normal operating range of said spindle and including a ring of resilient material of low internal friction and a ring of resilient material of high internal friction arranged between said flange and a spinning frame or the like for providing a mounting for said spindle.

4. A spinning spindle comprising an electric motor including a stationary member of small mass and a rotatable member having a vertical stiff shaft with the first critical speed thereof above the normal operating range of said spindle, a spinning device adapted to rotate at speeds greater than 4000 R. P. M. mounted on and driven by said shaft, means including a water lubricated sleeve bearing of synthetic resin for supporting said rotatable member within said stationary member and for providing a small radius of gyration to said stationary member, means including water lubricant for cooling said motor, and means having the critical vibration thereof below the normal operating range of said spindle for resiliently securing said spindle to a spinning frame or the like.

5. A spinning spindle comprising an electric motor including a stationary member of small mass and a rotatable member having a vertical stiff shaft, said shaft having such stiffness and said stationary member having such low moment of inertia that the ratio of shaft stiffness to the moment of inertia of said stationary member about an axis through the center of gravity thereof and perpendicular to the axis of said shaft is greater than 70 in.$^{-3}$, and a spinning device mounted on and driven by said shaft.

6. A spinning spindle comprising an electric motor including a stationary member of small mass and a rotatable member having a vertical stiff shaft, said shaft having such stiffness and said stationary member having such low moment of inertia that the ratio of shaft stiffness to the moment of inertia of said stationary member about an axis through the center of gravity thereof and perpendicular to the axis of said shaft is greater than 70 in.$^{-3}$, means including a sleeve bearing of synthetic resin for supporting said shaft upon said stationary member, and a spinning device mounted on and driven by said shaft.

7. A spinning spindle comprising an electric motor including a stationary member of small mass and a rotatable member having a vertical stiff shaft, said shaft having such stiffness and

said stationary member having such low moment of inertia that the ratio of shaft stiffness to the moment of inertia of said stationary member about an axis through the center of gravity thereof and perpendicular to the axis of said shaft is greater than 70 in.$^{-3}$, means including a sleeve bearing of fabric impregnated with synthetic resin for supporting said shaft within said stationary member, and a spinning device mounted on and driven by said shaft.

8. A spinning spindle comprising an electric motor including a stationary member of small mass and a rotatable member having a vertical stiff shaft, said shaft having such stiffness and said stationary member having such low moment of inertia that the ratio of shaft stiffness to the moment of inertia of said stationary member about an axis through the center of gravity thereof and perpendicular to the axis of said shaft is greater than 70 in.$^{-3}$, means including a water lubricated sleeve bearing of synthetic resin for supporting said shaft within said stationary member, means including water lubricant for cooling said motor and for lubricating said bearing, and a spinning device mounted on and driven by said shaft.

9. A spinning spindle comprising an electric motor including a stationary member and a rotatable member having a vertical shaft, said shaft having such stiffness that the ratio of shaft stiffness to the moment of inertia of said stationary member about an axis through the center of gravity thereof and perpendicular to the axis of said shaft is greater than 70 in.$^{-3}$, means including a water lubricated sleeve bearing of synthetic resin for supporting said shaft within said stationary member, means for supplying water lubricant to said bearing, means including a baffle below said bearing for conducting the water lubricant over said stationary member to cool the same, and a spinning device mounted on and driven by said shaft.

10. A spinning spindle comprising an electric motor including a stationary member having a horizontal flange and a rotatable member having a vertical shaft, said shaft having such stiffness that the ratio of shaft stiffness to the moment of inertia of said stationary member about an axis through the center of gravity thereof and perpendicular to the axis of said shaft is more than 70 in.$^{-3}$, a spinning device mounted on and driven by said shaft, and means including a ring of resilient material of high internal friction and a ring of resilient material of low internal friction arranged between said flange and a spinning frame or the like for providing a mounting for said spindle.

11. A spinning spindle comprising an electric motor including a stationary member of small mass and a rotatable member, a spinning device, and means including a stiff shaft for driving said spinning device, said shaft having such stiffness and said stationary member having such low moment of inertia that the ratio of shaft stiffness to the moment of inertia of said spinning device and said stationary member about an axis through the center of gravity of said spindle and perpendicular to the axis of said shaft is more than 20 in.$^{-3}$.

12. A spinning spindle comprising an electric motor including a stationary member having a horizontal flange and a rotatable member having a vertical shaft, a spinning device mounted on said shaft and driven thereby, and means having the critical vibration thereof below the normal operating range of said spindle and including a ring of resilient material of low internal friction and an adjacent ring of resilient material of high internal friction arranged between said flange and a spinning frame or the like for providing a mounting for said spindle.

13. A spinning spindle comprising an electric motor including a stationary member having a horizontal flange and a rotatable member having a vertical shaft, a spinning device mounted on said shaft and driven thereby, and means having the critical vibration thereof below the normal operating range of said spindle and including a ring of resilient material of low internal friction and a ring of resilient material of high internal friction arranged coaxially with said shaft between said flange and a spinning frame or the like for providing a mounting for said spindle.

14. A spinning spindle comprising an electric motor including a stationary member having a horizontal flange and a rotatable member including a vertical shaft, said shaft having the first critical speed thereof above the normal operating range of said spindle, a spinning device mounted upon and driven by said shaft, and means having the critical vibration thereof below the normal operating range of said spindle and including a ring of resilient material of low internal friction and an adjacent ring of resilient material of high internal friction arranged coaxially with said shaft between said flange and a spinning frame or the like for providing a resilient mounting for said spindle.

15. A spinning spindle comprising an electric motor including a stationary member having a horizontal flange and a rotatable member having a vertical shaft, a spinning device mounted on said shaft and driven thereby, and means having the critical vibration thereof below the normal operating range of said spindle and including a member having a composite arrangement of resilient material of low internal friction and a resilient material of high internal friction arranged between said flange and a spinning frame or the like for providing a mounting for said spindle.

16. A spinning spindle comprising an electric motor including a stationary member having a horizontal flange and a rotatable member having vertical shaft, said shaft having the first critical speed thereof above the normal operating range of said spindle, a spinning device mounted on and driven by said shaft, and means having the critical vibration thereof below the normal operating range of said spindle and including a ring of resilient material arranged between said flange and a spinning frame or the like with the horizontal axis of said means in substantial coincidence with the normal center of oscillation of said spindle for providing a mounting for said spindle.

17. A spinning spindle comprising an electric motor including a stationary member having a horizontal flange and a rotatable member having vertical shaft, said shaft having the first critical speed thereof above the normal operating range of said spindle, a spinning device mounted on and driven by said shaft, and means having the critical vibration thereof below the normal operating range of said spindle and including a ring having a composite arrangement of resilient material of low internal friction and a resilient material of high internal friction arranged between said flange and a spinning frame or the like for providing a mounting for said spindle, the hori-

zontal axis of said last mentioned means being in substantial coincidence with the normal center of oscillation of said spindle.

18. A spinning spindle comprising an electric motor including a stationary member of small mass and a rotatable member including a vertical stiff shaft, said shaft having the first critical speed thereof above the normal operating range of said spindle, a spinning device mounted on and driven by said shaft, means including water lubricated sleeve bearings of synthetic resin adjacent each extremity of said rotatable member for supporting said rotatable member within said stationary member and for providing a relatively small radius of gyration to said stationary member, and mounting means having the critical vibration thereof below the normal operating range of the spindle and having the horizontal axis thereof in a plane located between said sleeve bearings for resiliently securing said spindle to a spinning frame or the like.

19. A spinning spindle comprising an electric motor including a stationary member and a rotatable member including a vertical shaft, said shaft having the first critical speed thereof above the normal operating range of said spindle, a spinning device mounted on and driven by said shaft, means including water lubricated sleeve bearings of synthetic resin adjacent each extremity of said rotatable member for supporting said rotatable member within said stationary member, and means between said sleeve bearings and including a composite ring of resilient material of high internal friction and resilient material of low internal friction for providing a mounting for said spindle.

20. A spinning spindle comprising an electric motor including a rotatable member having vertical stiff shaft and a stationary member of small mass having a moment of inertia about an axis through the center of gravity thereof and perpendicular to the axis of said shaft of less than 0.3 lb. in. $sec.^2$, said shaft having such stiffness that the ratio of shaft stiffness to the moment of inertia of said stationary member about an axis through the center of gravity thereof and perpendicular to the axis of said shaft is more than 70 $in.^{-3}$, and a spinning device mounted on and driven by said shaft.

21. A spinning spindle comprising an electric motor including a rotatable member having a vertical stiff shaft and a stationary member of small mass having a moment of inertia about an axis through the center of gravity thereof and perpendicular to the axis of said shaft of less than 0.3 lb. in. $sec.^2$, a spinning device mounted on said shaft, said shaft having such stiffness that the ratio of shaft stiffness to the moment of inertia of said spinning device and said stationary member about an axis through the center of gravity of said spindle and perpendicular to the axis of said shaft is more than 20 $in.^{-3}$.

22. A spinning spindle comprising an electric motor including a stationary member and a rotatable member having a vertical shaft extending from said motor and adapted to operate above 4000 R. P. M., means including a sleeve bearing for supporting said shaft, said extended portion of said shaft being adapted to rotate a spinning device driven thereby, and means for supplying water to the surfaces of said stationary member of said motor and to the surfaces of said bearing to cool said stationary member and to cool and lubricate said bearing.

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