An Approach to Super High-speed Ring Spinning Frame

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Abstract

This article summarizes our study made to obtain a super high-speed of 20,000 rpm in spindle revolutions of a ring frame, by improving the mechanisms of rotation parts such as spindle and ring, and by developing an advanced speed controller and speed regulator.

Our study for speeding up the spindle revolutions up to 20,000 rpm is as follows:

1) We have succeeded in developing a new spindle for ring frame, which can attain a speed of 20,000 rpm, putting the spindle vibration under restraint of the same level as in the conventional operation at 15 000 rpm.

2) All the bottlenecks of the rings and travellers usually encountered during the high-speed operation of spindle have been broken by improving their mechanisms.

3) We have developed a speed regulators provided with wider ranges of speed and also a speed controller with lemniscate pitches to cause no sudden changes in speed. The new equipment thus developed increases the efficiency of spindle and is effective in eliminating yarn ends-down.

KEY WORDS: RING FRAMES, OPEN-END SPINNING, SPINDLES, SPINNING RINGS, SPINNING TRAVELERS, SPINDLE VIBRATION, HIGH SPEED, SPINDLE SPEED, TENSION CONTROL, SPEED CONTROL

1. Introduction

Many trials have been carried out in many countries to increase the spindle speed (spindle revolutions) during spinning without increasing ends-down. Now the spindle speeds up to 17,000 rpm are available on the ring spinning system. On the other hand, such a high speed as 20,000 rpm has been made possible on the open-end spinning system without spindles. The speed on the open-end system may be further increased as the open-end spinning system is improved. If the gap in speed between the both systems should have been too great, the ring spinning frames would not be commercially payable sooner or later. If there is the feasibility, on the ring spinning system, for such a high speed as 20,000 rpm for example, the ring spinning frames could exist with the open-end spinning frames with uses suitable for the products produced, even if the speed of the open-end spinning frames should have been increased further to some degree. In other words, the ring spinning frames will not be replaced by the open-end spinning frames as the mule spinning frames were replaced by the current ring spinning frames. Now we have to foresee the feasibility for the high speed on the ring spinning frames.

Setting the goal for spindle speed on the ring spinning frames at the 20,000 rpm in maximum, this article tried to obtain this speed by improving the mechanisms of rotatable parts such as spindle and ring, and developing an advanced speed controller and speed regulator with the following results:

(1) The spindle vibration taken place at the speed of 20,000 rpm can be lowered down to that at the speed of 15,000 rpm by aid of the spindles trially developed by us.

(2) Though the rings have been supposed to be the most obstinate opposition to high speed, the spindle speed of 20,000 rpm in maximum can be obtainable by aid of the rings experimentally developed by us.

(3) The increase in ends-down can be prevented by aid of the double sheave speed regulator capable of the wider speed range and the stepwise speed-increasing type SS controller even if the average spindle speed is increased. This result suggests that the super high-speed ring spinning frame with 20,000 rpm in maximum may be possible in the meantime.

2. Spindle

It seems to have been thought that a super high speed may be obtainable, on ring spinning system, by use of HF and HA type inserts now available. As a matter of fact, these inserts fully help the ring spinning frames run without troubles if the spindle speeds are within the range of 15,000rpm to 16,000rpm. However, when the spindle speed exceeds 18,000rpm, there will take place the various problems on the ring spinning frames.

The problems on the spindles during the super-high speed operation are vibration, power consumption and increase of slippages.

Particularly, the increase of vibration will result in shortening the life of inserts. When the spindle speed should

be raised over 18,000 rpm, it is essential to prevent the increase of vibrations below 15,000 rpm. In view of this, our effort in this study should be centered mainly on development of a preventive means against the increase of spindle vibrations.

Fig. 1 Vibration of ordinary spindle

Fig. 1 shows the relation between spindle revolutions and spindle vibrations. If the spindle is operated with a bare bobbin or without a bobbin there is no problem concerning the vibrations even during the super high speed running. However, there will be an abrupt increase of vibrations when the spindle with full bobbin is operated at speeds of over 16,000 rpm. Fig. 2 shows relation between running time of spindle and the spindle vibrations. Fig. 3 shows running time and increased deformation phenomenon on bobbin. Fig. 4 shows the difference in vibration characteristics between spindle with unbalance weight and the spindle with a full bobbin. As is clear from these figures, when the spindle speed exceeds 16,000 rpm, it begins to lack anti-bending force of bobbin against the centrifugal force. As the spindle speed increases, the bending on bobbin increases, and in turn unbalance weight increases. They will result in increase of spindle vibrations.

To prevent this phenomenon, it is essential to reinforce

Fig. 2 Relation between running time and spindle vibration

Fig. 3 Running time and increased deformation phenomenon

Fig. 4 Difference in vibration characteristics between spindle with unbalance weight and the spindle with a wooden type full bobbin

bobbin or improve the spindle in mechanism so as not to produce the bending on the bobbin. As for the bobbin reinforcement there is a limit for the plastic material used. (This problem is being studied by bobbin makers). We try to deal with this from the point of spindle mechanism. Fig. 5 shows the spindle (USS) which was designed for the super-high speed operation by us. Fig. 6 compares the vibration characteristics between this spindle (USS) and conventional spindle (each with a full bobbin), from which it is found that there is a conspicuous difference between them especially when during the super high speed running.

Fig. 7 shows an example of spindle mounting via vibration-absorbing rubber used for longer life of bearings. Fig. 8 shows the load on the bearings is converted into the strain by use of strain meter.

In other words, the load on bearings at 15,000 rpm at the rigid mounting will be almost same as at 20,000 rpm at

Fig. 5 U. S. S. spindle

Fig. 6 Comparison in vibration characteristics between the U.S.S. spindle and conventional spindle

the flexible mounting

This kind of flexible mounting is employed for the large-sized spindles such as for doubling and drawing-twisting. In fine spinning process, the higher precision for the verticality and other problems at the mounting of spindle are more stringently required. For the spindle for 20,000 rpm, this method is not employed. This is a problem to be solved later.

Figs. 9 and 10 show the power consumption characteristics of USS spindle at the super high speed area and the relation between tape tension and slippage ratio.

To reduce the power consumption, the diameter of the wharve is needed to be made smaller. To prevent the increase of slippage ratio, it is necessary to make the tape tension less than 1.5 times of the conventional one.

Fig. 7 An example of flexible mounting of spindle

Fig. 8 Effect of flexible mounting of spindle

The USS spindle incorporating the above is featured as follows:

1) To prevent the increase of vibrations, an anti-bobbin bending means is incorporated into the running part of spindle.

2) To reduce the increase of the power consumption, HA 25C insert is used and the diameter of the wharve is made smaller from the conventional 23.8 mm ϕ into 20.2 mm ϕ .

3) To reduce the oil dirt and to reinforce the spindle, a steel bolster is used.

Fig.11 shows the outward look of USS spindle.

Fig. 9 Power consumption

Fig. 10 Slip ratio for each driving tape tension

3. Ring

Rings seem to have been the most opposition to the super high-speed operation. This chapter is to discuss the problems about rings. Fig. 12. shows maximum values of spinning tension in one chase at each stage of the beginning, half and end of bobbin build, respectively. The term "spinning tension" denoted in the later figures will be referred to as the maximum value in one chase. It is generally required to lower the spinning tension down to less than 1/4 to 1/5 times the strength of single yarn. Assume that the strength of cotton/polyester blended yarn, 45's is 200 g, and that the safety ratio is 4, then it is necessary to lower the spinning tension down to less than 50 g. Accordingly, it is understood from Fig.12 that the following spindle speeds—17,000 rpm (beginning of bobbin build), 19,500 rpm (half-built bobbin) and 20,000 rpm (full bobbin) — may suit the above conditions.

To make the ring run at the super-high-speed, it is necessary to reduce the friction resistance between ring and traveller and to lower the spinning tension, and at the same time it is necessary to use the higher anti-friction traveller.

Fig. 11 U.S.S. spindle

Fig. 12 Example of spinning tension at each stage of the beginning, half and end of bobbin build

Fig.13 shows comparison between the conventional high speed ring and USS ring developed for 20,000 rpm when the bobbin was half built.

As is clear from these results, USS ring is less likely to increase spinning tension at the super-high-speed area, compared with the conventional high-speed ring. Fig.14 shows the relation between running time of traveller and worn amount. Fig.15 shows a close-up view of traveller used for this experiment. It is understood that the square type traveller thinner in wire material and higher in efficiency of thermal dispersion is higher in anti-frictional consumption.

Fig.16 shows spinning tension between conventional high-speed ring and square type traveller. Fig.17 shows spinning tension between USS ring and square type traveller. From Fig.17 it is understood that the combination of

Fig. 13 Comparison between the USS ring and conventional ring

Fig. 14 An example of traveller worn amount

Fig. 15 Square type and elliptical type traveller

USS ring and square type traveller is less influenced by the increase of spindle speed.

Fig.18 shows the spinning tensions obtained with the various combinations between rings and travellers when the bobbin was 30% built. Fig.19 shows the spinning tensions obtained with the various combinations between

rings and travellers when the bobbin was half built. From the results, it is clear that the combination of USS ring and square type traveller is most suitable for the super high-speed operation.

4. Speed-variable Operation

To enable spinning under constant tension during one doffing with the use of the same ring and traveller on the current spinning frame, it is essential to apply the speed-variable operation effectively.

Fig. 16 Spinning tension in the combination of conventional high-speed ring and square type travellers

Fig. 17 Spinning tension in the combination of USS-ring and square type traveller

Fig. 18 Spinning tension obtained with the various combinations between ring and traveller (at the 30% built bobbin)

Fig. 19 Spinning tension obtained with the various combinations between ring and traveller (at the half-built bobbin)

Fig. 20 Speed-variable operation under constant tension

Fig.20 shows a speed-variable operation under constant tension diagram when the cotton/polyester blended yarn 45's was spun by use of USS ring and square traveller. If the generation of ends-down is completely correlated to spinning tension, it is required to vary the speed along the constant tension curve in Fig.20.

Fig. 21 End-down propensity of each case

Fig.21 shows end-down propensity of each case, that is,— (1) the constant speed operation of 20,000 rpm, (2) the constant speed operation of 18,000 rpm and (3) the variable speed operation along the 50 g constant tension curve in Fig.18. From these figures, even in the case of speed-variable operation under 50 g constant tension, the end-down at the beginning of bobbin build is made greater, compared with that after bobbin was half-built. Therefore, the speed revolutions at the beginning of bobbin build are needed to make the speed lower than when the speed-variable operation under constant tension is made.

Fig. 22 An example of speed-variable programs where the spindle speed of 20000 rpm operation in maximum is set

In Fig.22, the frame is set to lower the ends-down at the beginning of bobbin build taking the end-down propensity into account. The speed-variable curve capable of 20,000 rpm in maximum and end-down propensity are shown. Even in this case, there is a propensity that there are substantially more ends-down in the case of 30% bobbin build, compared with the other amount of bobbin build. When the number of ends-down exceed the control limit, it will be necessary to make the position of maximum number of revolutions reach the position of the 50% bobbin build.

5. Speed Regulator and Its Method

As previously mentioned, the ends-down on the ring spinning frames are likely to take place most particularly at the beginning of bobbin build and after the 50% bobbin build apt to decrease. Accordingly, to enable super high-speed operation by the use of the USS spindle and USS ring without the increase of ends-down, it is essential to employ the speed-variable operation effectively. Fig.22 shows an example of speed-variable programs where the spindle speed of 20,000 rpm operation in maximum is set.

From these figures, it is clear that: (1) it is needed to take the wider speed-variable range, compared with the conventional ring spinning frame with 15,000 rpm in maximum,

and (2) it is needed to make the speed-increasing curve more gradual.

Fig. 23 VPS fixed with motor shaft

As a means to attain this goal, we have developed a double -sheave type speed regulator (VPS) and a stepwise speed-increasing type speed controller.

(Double-sheave type speed regulator) This double-sheave speed regulator has made it possible to attain a much greater degree of 50% compared with the single-sheave type variable speed range (25%). Fig.23 shows the sheave at the motor side and Fig.24 at the tin-pulley side. The type and specifications are shown in Tables 1 and 2. The variable speed ratio Z for their combinations— if the variable speed ratio of motor-sided sheave is X% and that of tin-roller-sided sheave is Y%— is as follows:

Fig. 24 VPS fixed with tin pulley shaft

Table 1 Types of Vari-pitch Sheave

Belt type	Disignation	Pitch dia. variable (PD ϕ)	Out dia. (OD ϕ)	Max. hole dia. (d ϕ)	Number of belts	Variable speed ratio
C	6.5	167-224 ϕ	236 ϕ	48 ϕ	3-4	33 %
	7	178-234 ϕ	246 ϕ	48 ϕ	3-4	31 %
	8	203-259 ϕ	271 ϕ	48 ϕ	3-4	21 %

Table 2 Specifications of Vari-pitch Sheave

Belt type	Number of belts	A	B	C	L	Horsepower transformed
C	3	293	136	95	336.5	19 kW HP (25)
	4	334	177	115.45	377.5	22.5 (30)

$T_1' = [n(1 + t_1) - t_1] \text{ min} \dots$ Time required for reaching the maximum speed
 $T_1 = 25 \text{ min } (t_1 = 0 \text{ min, } 60 \text{ Hz})$
 $T_2 = 6\text{-}1/4 \text{ min } (60 \text{ Hz}) \dots$ Time required for reaching the minimum speed
 $t_1 = \text{Max. } 30 \text{ min} \dots \dots \dots$ Setting time of the timer

Fig. 25 Stepwise speed increasing (1)

$T_1' = [n_1(1 + t_1) + n_2(1 + t_2) - t_2] \text{ min} \dots$ Time required to reach the maximum speed
 $T_1 = 25 \text{ min } (t_1 = 0 \text{ min } 60 \text{ Hz})$
 $T_2 = 6\text{-}1/4 \text{ min } (60 \text{ Hz}) \dots$ Time required for reaching the minimum
 $t_1 = \text{max } 180 \text{ sec} \dots \dots \dots$ Setting time of the timer
 $t_2 = \text{max } 30 \text{ sec} \dots \dots \dots$ Setting time of the timer

Fig. 26 Stepwise speed increasing (2)

$Z = (1 + X/100) \times (1 + Y/100) \times S$ (Slippage ratio)
 (Stepwise speed-increasing type speed controller) The conventional speed controller provides a comparatively abrupt speed-increasing curve. The conventional type SS controller is 25% per 25 minutes. To enable the gradual speed-increasing curve by extending the time required for increasing speed, stepwise speed-increasing type SS controller has been developed. The stepwise speed-increasing type SS controller is improved on the conventional SS controller and incorporates the speed-variable timer (Figs.25 and 26). It is possible to run it along the speed-variable program by using the double-sheave type speed regulator in conjunction with stepwise speed-increasing type SS controller.

(Fig. 27) An example of programming super high speed operation

T_1 : Time required to reach high speed from low speed when stepwise speed increasing method is not adopted.

T'_1 : Time required to reach high speed from low speed when stepwise speed increasing method is adopted

$$T'_1 = [n(t_0 + t_1) - 2t_1] + t_2 \quad \dots\dots\dots (1)$$

$$t_0 = T_1/25a$$

n ; Number of steps from low speed to high speed, calculated as $25a \times S/s$

s ; Speed variable range by sheave (%)

S ; Actual speed variable range by sheave(%)

a ; Number of teeth of switch cam for stepwise speed-increasing method

t_1 ; Time required by timer (1) for pause (max 18 sec)

t_2 ; Time required by timer (2) for pause (max 30 min)

T_2 ; Time required to reach low speed from high speed

$$T_2/T_1 = 1/4 \text{ or } 1/2$$

(Note) When stopping the frame at high speed (BS), it descends to middle speed and then stops at the suitable position for re-operation

Fig.27 shows another spindle speed control program. When we want to stop the frame that has reached the maximum spindle speed, we conventionally lowered the speed down to the minimum and stopped the frame. However, this stepwise speed-increasing type SS controller lowers the speed to medium degree and stops the frame. When restarting, the frame is designed to reach the maximum speed abruptly from the medium degree speed operation. Now,

we believe that this method is of the most ideal one for the super high-speed operation with the ring spinning frame. Figs.28 and 29 show the ring spinning frame built-in with the double-sheave type speed regulator and the stepwise speed-increasing type SS controller.

6. Conclusion

This series of studies summarizes the results obtained by ring spinning frame with 48 spindles each. In addition to improvements on spindle, ring & traveller, a new speed-regulator will be required for the super high-speed operation on the ring spinning frame. Since they are now avail-

Fig. 28 Double-sheave type speed regulator, stepwise speed-increasing type SS controller and tin roller brake

Fig. 29 Double-sheave type speed regulator, stepwise speed-increasing type SS controller and the roller and the roller brake

(1) 20,000 rpm (2) 18,000 rpm (3) 16,000rpm

Fig. 30 Apparent features of yarns

able, the approach to the super high-speed operation on the ring spinning frame will be realized. In this study, the experiments were made to spin cotton/polyester blended yarn 45's. From these experimental results, the maximum

speed will be limited in use for kinds and counts of the yarns and the bobbin length produced. The researches to widen the usage of this frame will be a problem to be solved later.

This study is anyway one step toward the super high speed operation of the ring spinning frame. To enable the 20,000 rpm operation to be obtained, the trials for preventing vibration on the frame and providing all the rotatable parts with bearings in addition to making the drafting parts into pendulum system and rollers into tin-pulley system will be required.

Table 3 shows the parts described in this paper, fitting of devices and targeted number of revolutions.

The double-sheave type speed regulator and stepwise speed-increasing type SS controller will be employed for other uses except the super high-speed operation, for example, at the plant where comparatively high frequent changes of counts are required or where the speed-change effect for the decrease of ends-down can not be obtained because of long lift on the conventional SS controller.

This report, we believe, will be helpful to change the conventional image toward the speed limitation of the conventional ring spinning frame.