TRAVERSING MECHANISM OF YARN WITH THE ROD DRIVEN FROM BOTH ENDS FOR ROTOR SPINNING MACHINE

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Abstract
The present mechanisms for yarn traversing in the rotor spinning machine employs a driving mechanism for the rod from one end of the machine. Such a design puts high demand on the traversing rod, which is excessively loaded. The aim of this project is to reduce the stress and especially the longitudinal vibrations along the length of the rod. On the bases of analysis of the conditions it was designed a system based on the rod driven from both ends using two servomotors with crank mechanisms. Such an arrangement allows the suppression of the buckling loads. These loads excite radial vibrations in the rod and causes increased wear of supporting slide bearings. In order to analyze this structure a mathematical model is built. This model includes both the mechanical part as well as a model of the driver. It allows finding the optimal parameters of the system. The new design is expected to achieve higher speeds and thereby increase productivity of the machine.
Key words: Traversing mechanism, Rotor spinning, Servomotor, Crank mechanism, Mathematical model

1. Introduction

Rotor spinning machines serves for yarn production by so called open-end technology. After ring spinning it has the second largest share in the yarn spinning industry. Customer demand forces manufacturers to continually improve operating speed and productivity. It leads to assembling very long machines as can be seen in figure 1. One of the most limiting units is the yarn traversing mechanism. Therefore an attention is focused on the issue and this paper deals with the new design of such a mechanism.

Figure 1. Rotor spinning machine

The yarn traversing mechanism is part of the winding unit. The traversing motion of the yarn guide in combination with bobbin rotation ensures building a cross-wound bobbin. Because the spinning technology requires stationary draw-off speed, the bobbin rotation should be constant. Therefore the structure of the produced packages is fully dependent on the traversing motion. The optimal characteristic of the yarn traversing motion is shown in figure 2. It consists of sections with constant velocity and reversal movements. In order to obtain good structure of the bobbin the reverse motion has to be performed in a very small region. The sharp change in the velocity leads to severe dynamic load.

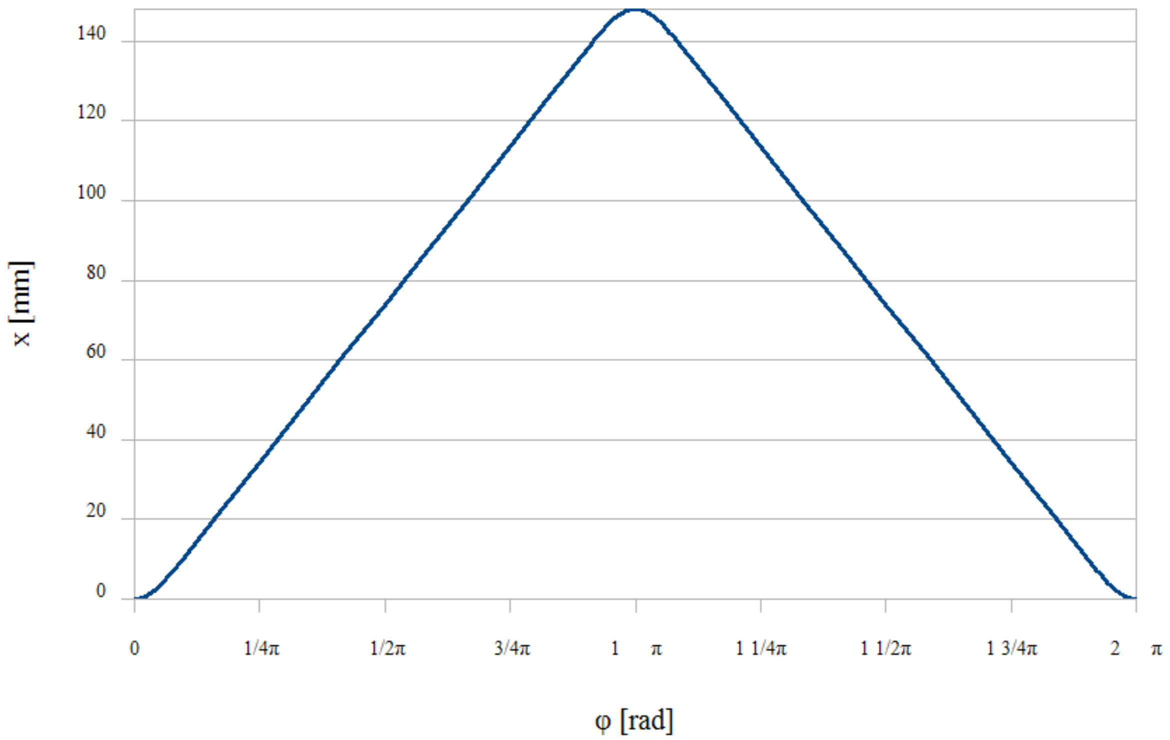

Figure 2. Yarn guide motion shape

In general practise to ensure the required traversing motion, the system consists of a centralized traversing mechanism. The motion is generated by the traversing mechanism on one side of the machine is consequently distributed among winding bobbins by mean of the traversing rods. A series of traversing rods is mounted along the whole length of the machine. In case of very large assemblies with over 200 winding units on one side of the machine, the length of the entire traversing rods can reach up to 50m.

The combination of extreme dynamic load and very long length makes the traversing rods one of the most stressed parts on the whole machine. In order to gain a good strength-to-weight ratio, they are made either from aluminium alloy or carbon composite. Subsequently they are combined into series so that the effect of thermal expansion could be minimised.

2. System with crank mechanism

In the beginning of the project, the traversing mechanism was originally designed as a cam mechanism. The cam mechanism has very stiff behavior that leads to dynamic load followed by increased wear and noise [1]. Despite optimization, the cam mechanism could no longer satisfy the increased demand for productivity. Because the cam mechanism has reached its limits, the new system with crank mechanism was developed and patented at the department of Textile Machine Design, Technical University of Liberec. The usage of the crank mechanism has an advantage that in case of constant velocity of the crank the difference between motion of crosshead and required motion is relatively small. However the motion of the crank is still varying and requires usage of servo drive. The stroke of yarn guide is set by the length of the crank to fixed value similar like in case of the cam mechanism. Although the traversing mechanism was replaced, the set of traversing rods remains without any change. The latest prototype with the crank mechanism is shown in figure 3.

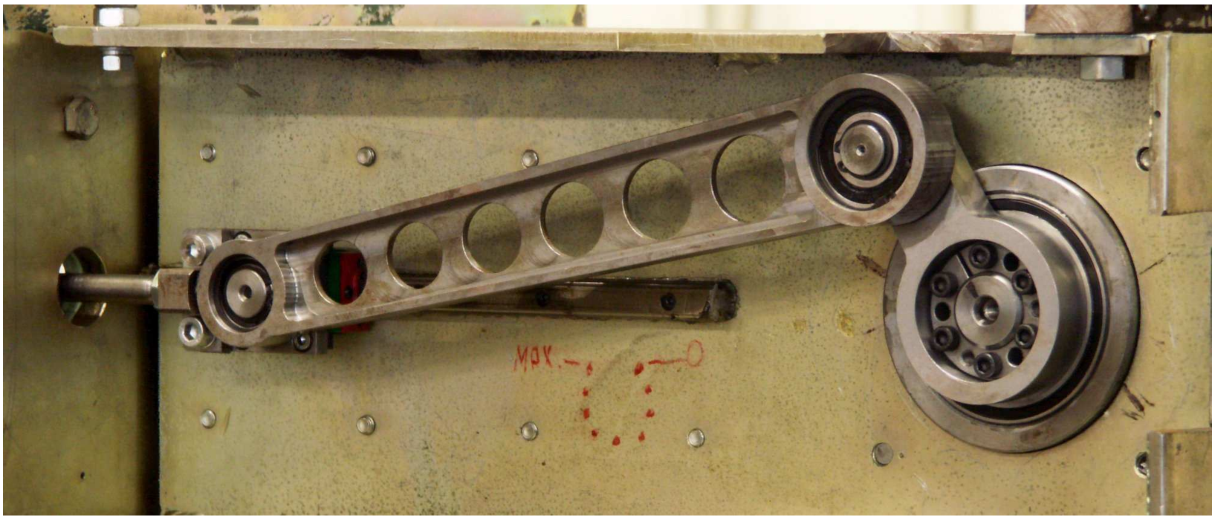

Figure 3. Crank mechanism

Besides using the prototype model for the verification of technical feasibility it is also used for performing numerous measurements. Figure 4 shows a record from measurement of traversing rod vibrations. First plot displays the vibration in axial direction while next two represent vibration in radial directions. The measurement clearly shows that the vibration level during the pushing phase is much higher than during the pulling phase. This confirms an assumption that the pushing phase causes buckling load on the traversing rod. The buckling is unwanted because it increases the friction in the slide bearings through witch the traversing rods are mounted. Thereby it increases the load on the rods and the wear of the bearings.

Figure 4. Measurement of vibrations – pulling and pushing phase

3. System with two drivers

After the accomplishment in the basic design with crank mechanism, various modifications of this mechanism were developed to further improve the system [2]. Among others, it was proposed a system with two servo drivers placed on both ends of the rod. It is especially intended for machines with extremely long traversing rods series. The schematic representation of such a configuration is shown in figure 5.

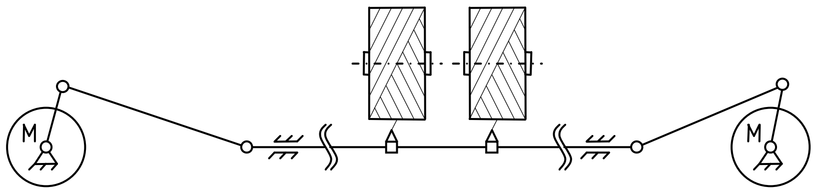

Figure 5. Double crank mechanism

The new design is based on the idea that enables the traversing rod to be driven from both ends. This way it should be possible to partially or totally eliminate the buckling load in the rods. However, the mechanism turns into statically indeterminate. The traversing rod is relatively stiff and even a slightest displacement can evoke a significant force. Therefore a precise control of the servomotors is essential.

In order to predict the behavior of the new design, a mathematical model was created. Because both mechanical and electrical parts are interacting with each other, the model has to simulate both of them together. As a best choice software Matlab and Matlab/Simulink was used. It contains a large library of mathematical functions and gives the user full control over the calculations. The overall structure of the main mathematical model in Simulink is displayed in figure 6. It is assembled from blocks with structures corresponding to the real configuration. The most important blocks are the models of servo drivers and model of the traversing rod.

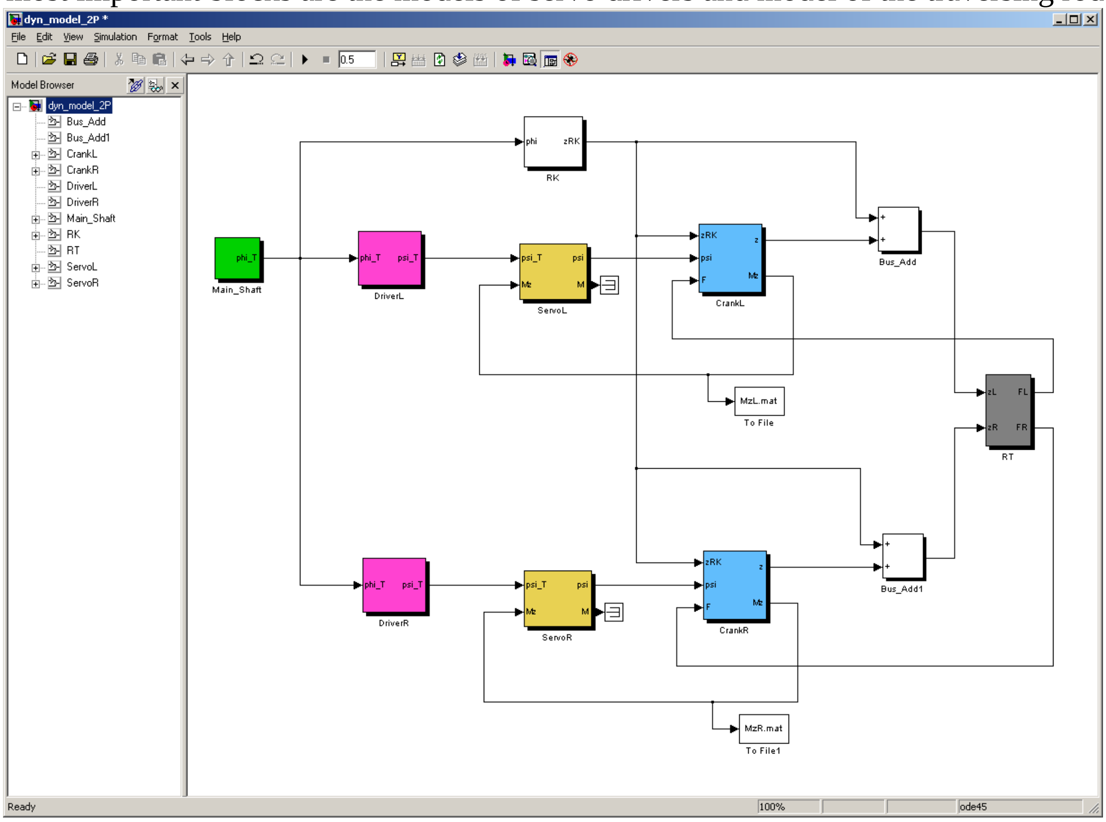

Figure 6. Mathematical model in Simulink

The model of traversing rod is realized by a final element method. Accordingly to one dimensional nature of the rod, the truss elements are employed. Even though truss elements in 1D do not contain information about radial displacement and therefore buckling, they are sufficient for our purposes.

The model of servo drive is assembled accordingly to the schematics published in the user manual. This approach enables us to use the mathematical model for optimization of the drive settings. The motor itself is described by means of the transfer function.

4. System identification and verification

The results from the mathematical model would be unreliable if the input parameters are inaccurate. Therefore high attention was given to proper identification of those values. Some parameters were determined by the design, but most of them had to be measured. The main issue was identification of the mechanical properties of traversing rod and parameters of servo drive. The relevant mechanical properties of traversing rods are namely density, stiffness and damping. While density and stiffness can be determined easily with good accuracy, the measurement of damping is much complicated. The co-efficient of viscose damping has been determined experimentally by the method of exciting the distribution rod with an impact hammer [3]. For purpose of analysis, the carbon composite was assumed to be a homogeneous material.

The servo drive compared to the traversing rod is much more complicated system. Therefore determination of its properties poses a much more complex task. Parameters that are connected to driving unit can be simply read from its memory, however, parameters related to the motor itself has to be measured. The situation is additionally complicated because the behaviour of the motor depends on its load. For this reason a set of flywheels were designed to provide the desired load in the required range.

As mentioned above, for the description of the motor a transfer function is used. This method treats the motor like a black box. It describes relation between input and output, but it does not deal with internal states. The properties of linear transfer function can be displayed in a Bode plot. The Bode plot consists of two plots, one expressing magnitude and the other being phase. The Bode magnitude plot shows the amplification of the input signal depending on the frequency like plots in figure 7 while the phase plot shows the time shift.

The measurement of transfer function consists of exciting of the system on different frequencies and measuring its response. The Bode plot can be obtained as an FFT analysis of the response signal divided by FFT analysis of exciting signal. The quality of obtained results greatly depends on the selected exciting signal. For this reasons a pseudo random binary sequence (PRBS) was chosen as a source signal. The PRBS has a unique property that it excites the system on all selected frequencies with the same power. This provides the result of equivalent accuracy through the entire spectrum.

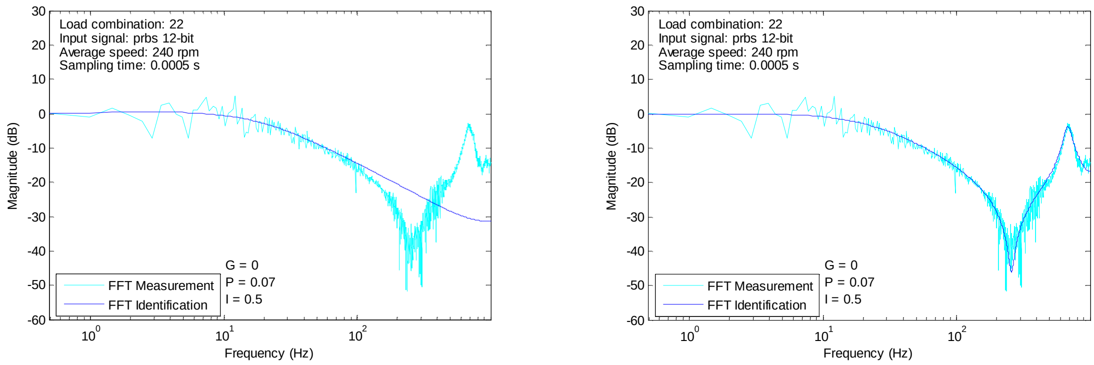

Figure 7. Bode plot of servo drive and its identification

After the excitement response of the system is measured, it is compared with mathematical simulation. In order to find the proper transfer function coefficients a multi-parametric optimization has to be performed, while the optimization criteria are set similarly to least square method. This method is time consuming and sensitive to initial conditions. This procedure has to be repeated for each setting at several different loads. The behaviour of coefficient upon the load is consequently determined by regression methods.

The model of the motor could be described by transfer functions of different degree. In case we need to describe the behaviour of the motor in the full measurable spectrum it is necessary to use transfer function of at least 5 degrees. The overall degree of the transfer function including driver is moreover increased by used PI regulator. The result of such identification can be seen in figure 7 on the right.

In our case, however, it is sufficient to describe the behaviour of the system only up to 100 Hz. This is because most of the energy is transmitted by low frequencies and the first natural frequency of the traversing rod is less than 60 Hz. In that case it is possible to describe the motor with transfer function of only second degree as it is shown in figure 7 on the left. Moreover all but one coefficient remains constant for different loads and the remaining one shows very strong linear regression according to the load.

The whole assembly is verified on the model with one servo drive [4]. This way it is verified not only the correct identification of parameters but the whole model structure especially the interaction between electrical and mechanical parts of the system.

4. Conclusion

On basis of analyses, a new system of yarn traversing was developed. It is based on two connected servo drives in a way that it enables to reduce the buckling load in the traversing rod. However the rigid connection of two motors puts high demands on their controlling. In order to predict and optimize the servo drive behavior, a mathematical model was created.

The new design has potential to increase traversing speed especially for long machines. And it is expected to improve the overall productivity of the rotor spinning machine

5. References

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