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Preizkusna raziskava sinhronizacije dvovretenske stružnice

Experimental Investigation into the Synchronization of a Double-Spindle Lathe

Jan Kosmol[1] - Krzysztof Lehrich[1] - Robert Jastrzębski[2]
([1]Silesian University of Technology, Gliwice, Poland; [2]Machine Tool Research and Design Centre, Pruszków, Poland)

V prispevku so prikazani rezultati preizkusne raziskave stružnice VENUS 350, izdelane v CBKO iz Pruszkowa (Poljska). RK stružnica je opremljena z dvema vretenoma. Merili smo vrtilne hitrosti obeh vreten, sinhronizacijo napake in pogonske navore motorjev, glavnega in nasprotnega. To omogoča ovrednotenje postopka sinhronizacije.

(Ključne besede: RK stružnice, sinhronizacija, vrtilne hitrosti, servopogoni, pogonski navor)

In this paper we show the results of an experimental investigation of a VENUS 350 lathe, manufacture by CBKO in Pruszkow, Poland. This CNC lathe is equipped with two spindles. We have measured the rotational speeds of both spindles, the synchronization error and the driven moments of the motors, main and opposite. With this information it was possible to evaluate the process of synchronization.

(Keywords: CNC lathe, synchronization, rotational speeds, servo-drives, moment of inertia)

0 INTRODUCTION

Modern CNC lathes are very often equipped with two spindles: the main spindle and the opposite spindle. Such a feature should make complete machining possible, as it means being able to machine first on the right-hand side of the workpiece and then on the left-hand side of the workpiece without stopping the machine tool. The opposite spindle chucks the workpiece on the right-hand side, while the main spindle chucks the workpiece on the left-hand side. This means that there is a short time when the workpiece is chucked on both sides. Of course the spindles, main and opposite, have to have exactly the same rotational speed, i.e., they should be synchronized. But what is important from the point of view of productivity of the machine tool and the quality of the workpiece? First, the time of synchronization should be as short as possible. Second, the moment of chucking the workpiece with the opposite spindle is important from the point of view of the quality of the workpiece due to the possibility of slip between the chuck and the workpiece (if the rotational speed of the workpiece and the opposite spindle differ). The paper shows the results of an experimental investigation of a lathe, manufactured in Poland. Such a CNC lathe is equipped with two spindles. We have measured the rotational speeds of both spindles, the synchronization error and the driven moments of the motors, main and opposite. This made it possible to evaluate the process of synchronization.

1 THE BASIC PROBLEMS OF SYNCHRONIZING A TWO-SPINDLE CNC LATHE

In the newest lathes and turning centers the idea of automatic workpiece reclamping, called the intercept spindle, is used. The idea of such a spindle does not seem to be complicated. There are two spindles: the main (M) and the auxiliary (A), as is shown in Fig. 1a). The main spindle rotates and a workpiece is clamped in the chuck. The second auxiliary spindle may rotates too, and it also has the possibility to move along the lathe axis.

There are two main problems to be solved if such a concept is to work successfully:

- Coaxiality, between the axis of the main spindle and the direction of movement of the auxiliary spindle,
- Synchronization of the rotation speeds of the main and auxiliary spindles.

If the coaxiality of both spindles is insufficient the workpiece may be destroyed during reclamping. The coaxiality of both spindles depends first of all on the geometric accuracy of the machine tool. The newest lathes and centers belong to the high-accuracy group of machine tools and in most cases there is no problem with coaxiality.

More important is the second technical problem, connected with the synchronization of the rotating spindles. Both spindles have to have the same speed at the moment of reclamping. This is a very hard to achieve condition because the drives of the main and auxiliary spindles are independent, and only the CNC has any influence on the actual speeds of the spindles. This problem is the main subject of our paper. We would like to present some results of an investigation performed in CBKO Pruszkow, Poland, where such an idea of reclamping was applied to the Venus 350 CNC lathe [1]. The mechanical and kinematic scheme for the synchronization system is shown in Fig. 1b).

What is important from the point of view of the synchronization of the two spindles?

- The rotational speeds ω_M and ω_A have to be the same at the moment of reclamping;
- The time of synchronization should be as short as possible, for reasons of productivity;
- Defining the moment of reclamping, which means to identify the time when the signal for clamping the chuck of the auxiliary spindle should be sent from the CNC to the chuck;
- What the signal controlling both drives should look like.

Both drives, from the main and auxiliary spindles, work as servodrives, which means that there are two encoders working as feedbacks and the CNC controller, which generates the signals ϕ_{Mgiv} and ϕ_{Agiv} as given values of the rotational motion of both spindles.

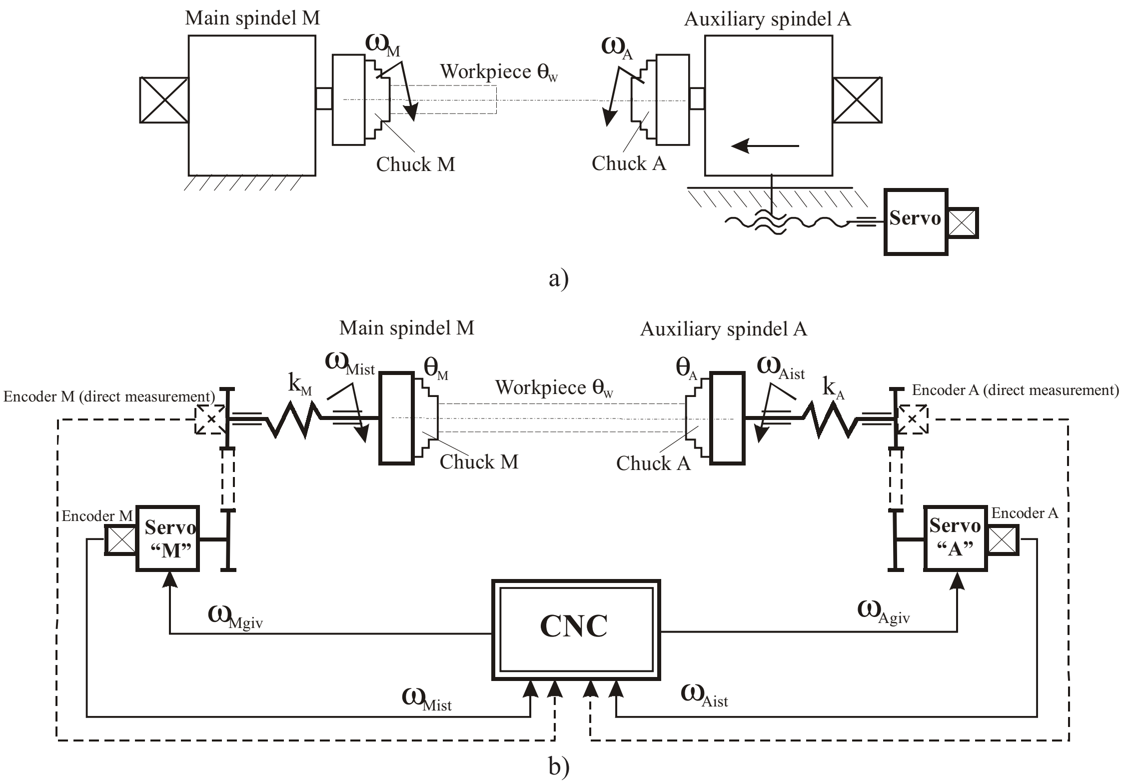

Fig. 1. *Concept of automatic workpiece reclamping using two spindles (a) and* the k*inematic scheme of the synchronization while reclamping the workpiece on the CNC lathe (b)*

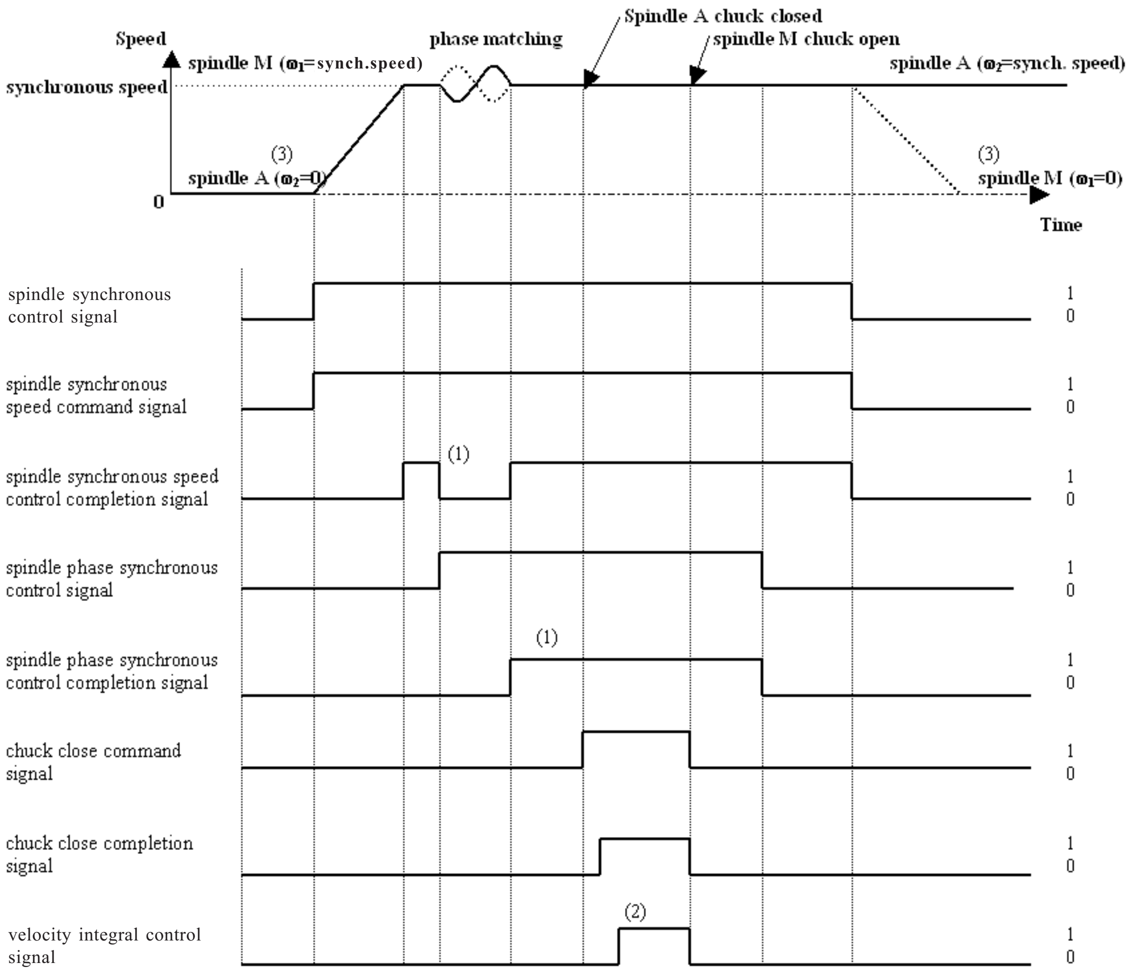

Fig. 2. *Scheme of time performance of the control signals*

The quality of the synchronization process depends first of all on the time performance of the ϕ_{Mgiv} (t) and ϕ_{Agiv}(t) signals, on the stiffness properties k_M and k_A of the mechanical parts of the kinematic chains of both spindles and on the inertial moments Θ_M and Θ_A of the chucks and the workpiece. This means that a special schedule of time performance for all the signals has to be implemented in the CNC controller of the machine tools. Fig. 2 shows an example of such a schedule that we have used in our investigation.

2 EXAMPLES OF EXPERIMENTAL TESTS

We made several experiments using a control algorithm like that in Fig. 2. During the investigation we measured parameters like the moments, M, of both servodrives, the rotational speed, ω, of both drives, and the synchronization error, ε, defined as the difference between the rotational speed of the main and auxiliary spindles. An example of the time performance of the measured parameters during the process of reclamping is shown in Fig. 3 and Fig. 4 (the rotational speeds of both servodrives are shown in rev/min, the moment, M, in Nm, but the synchronization error, ε , is in specific units).

We have made several experiments for different values of the rotational speeds and the time constants of the servodrives [1]. Fig. 3a) presents an example of the time performance of the rotational speed of the main spindle, ω_M, the auxiliary spindle, ω_A, the moment of the main servodrive, M, the synchronization error, ε, for the rotational speed of 1700 rev/min, and the time constant of the servodrives, 30 ms. Fig. 3b) presents another example of the time performance of the rotational speed of the main spindle, ω_M, the auxiliary spindle, ω_A, and the synchronization error, ε, for the same rotational speed of 1700 rev/min, but a longer time constant of the servodrives, 60 ms. Comparing the two it is clear that from the point of view of the synchronization error, ε, the time constant of 60 ms for the servodrives seems to be better than the time constant of 30 ms. For the time constant of 30 ms we can typically observe symptoms of overshoots, like the oscillation of the rotational speed of the auxiliary spindle (for the stationary state of a rotational speed of 1700 rev/min the rotational speed of that spindle reached, in a transient state, up to 2500 rev/min, which means 50% of the stationary state), the synchronization error reached up to 32,000 units and the moment of the auxiliary drive varied by ±100% of the maximum value. For the time constant of 60 ms we observed oscillations too, but these were much smaller. For example, the overshoot of the rotational speed of the auxiliary spindle did not exceed 25% of the rotational speed in the stationary state. The time of the transient state is about 3000 ms, in contrast to the 30 ms time constant, where the time of the transient state was about 50% higher (4500 ms).

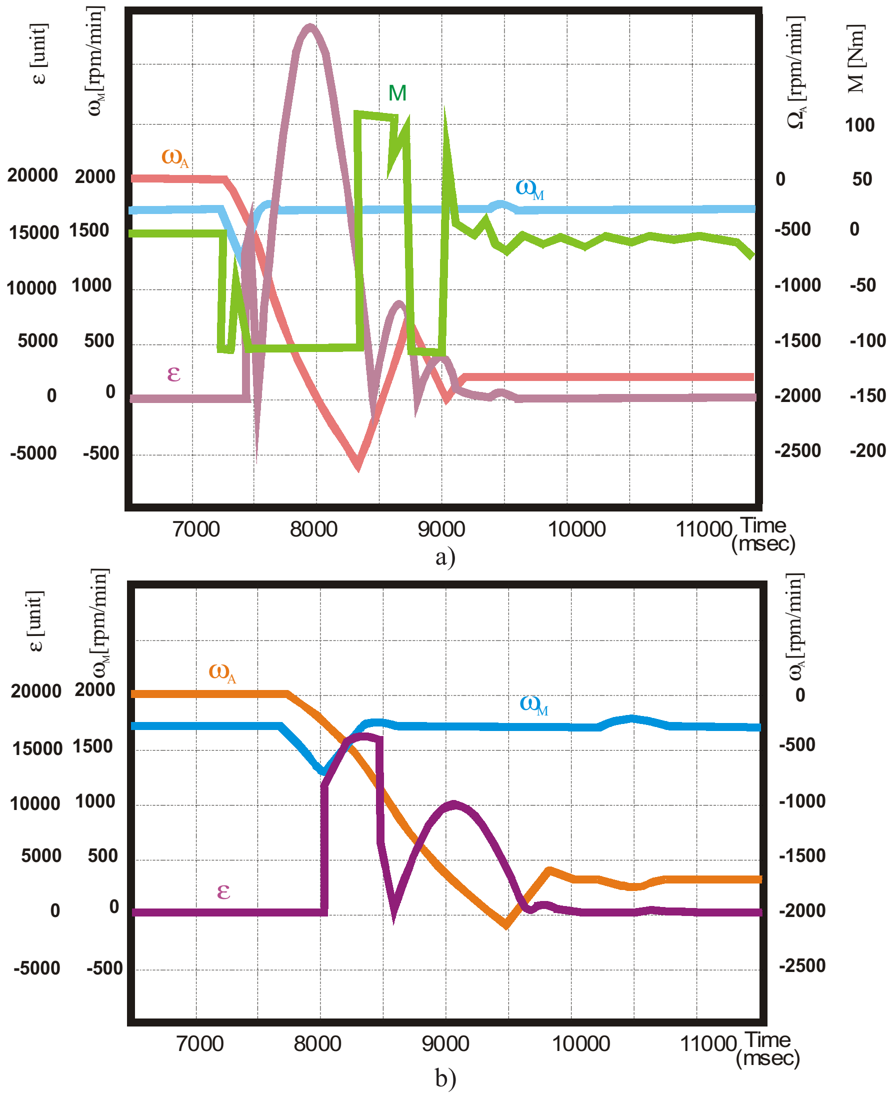

Fig. 4. *Time performance of the rotational speed of the main spindle, ω_M, the auxiliary spindle, ω_A, the moment of the main servodrive, M, the synchronization error, ε, for a rotational speed of 1700 rev/min: a) time constant of 30ms, b) time constant of 60 ms*

As a general conclusion from our investigation we can say that the problem of synchronizing both spindles during reclamping is a complex and time-consuming process, and the precision and repeatability of the reclamping and the loading of the motors depends on many factors, like:

- the rotational speed of the spindles
- the time constants of both servodrives,
- the quality of the encoders in both drives,
- the quality of the mechanical parts in both the “C and “A” axes.

3 SUMMARY

Our investigation of the synchronization of both spindles while reclamping allows us to make the following conclusions:

- If the rotational speed of the synchronization while clamping is too high the loading on the drives increases a great deal and the time for the process increases (comparing the loading of the drive and the synchronization error while reclamping and after finishing the process, we can say that they differ by a factor of over 100).
- Because the CNC controller has a restriction on the maximum value of the synchronization error, the process of reclamping may fail if the real value of the synchronization error exceeds the limitation value and the machine tool is stopped.
- By finding the appropriate values for the time constants of the servodrives and suitable encoders we were able to increase the rotational speed of reclamping or to decrease the time of the synchronization.

5 REFERENCES

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Authors’ Addresses: Jan Kosmol
Krzysztof Lehrich
Department of Machine Technology
Silesian University of Technology
Gliwice, Poland

Robert Jastrzębski
Machine Tool Research and Design Centre
Pruszków, Poland

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