10th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2006, Barcelona-Lloret de Mar, Spain, 11-15 September, 2006

EXPERIMENTAL INVESTIGATION OF SYNCHRONIZATION OF DOUBLE SPINDEL LATHE

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ABSTRACT
In the paper are shown results of experimental investigation of a lathe VENUS 350, manufacture by CBKO in Pruszkow (Poland). Such CNC lathe is equipped with two spindels. We have measured rotational speeds of both spindel, synchronization error and driven moments of motors, main and opposite. It made possibly to evaluate the process of synchronization.
Keywords: synchronization, CNC, lathe

1. INTRODUCTION
The modern CNC lathes are equipped very often with two spindels: main and opposite. Such feature should make possibly complete machining, it means machining first on the right of the workpiece then on the left side of the workpiece without stopping machine tool. The opposite spindel chuck the workpiece on the right side while the main spindle chuck the workpiece on the left side. So there is a short time when the workpiece is chucked on both sides. Of course spindels, main and opposite have to have strictly the same rotational speed. They should be synchronized. What is important in the point of view of productivity of the machine tool and quality of the workpiece? First the time of synchronization should be as short as possible. Second the moment of chucking the workpiece by the opposite spindel is important in the point of view of quality of the workpiece due possibly slip between chuck and workpiece (if the rotational speed of workpiece and opposite spindel differs). In the paper are shown results of experimental investigation of a lathe VENUS 350, manufacture by CBKO in Pruszkow (Poland). Such CNC lathe is equipped with two spindels. We have measured rotational speeds of both spindel, synchronization error and driven moments of motors, main and opposite. It made possibly to evaluate the process of synchronization.

2. CONCEPTION OF AUTOMATIC WORKPIECE RECLAMPING
In the last modern lathes and turning centers an idea of automatic workpiece reclamping called intercept spindel is used. The idea of such spindel seems to be not complicated. There are two spindels: main (M) and auxiliary (A) what is shown in Fig. 1. The main spindel rotates and a workpiece is clamped at a chuck. The second auxiliary spindel may rotates too, and has a possibility to move along the lathe axis. For that there is a special servo drives.

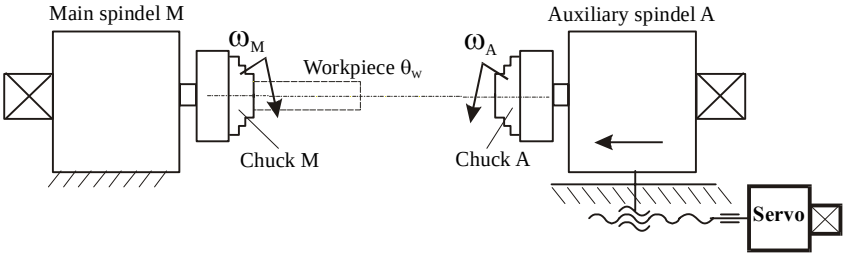

Figure 1. Conception of automatic workpiece reclamping using two spindels

Among others there are two main problems have to be solved if such conception work successfully:
- Coaxially between the axis of main spindel and direction of movement of the auxiliary spindel,
- Synchronization of rotating speed of the main and auxiliary spindels.

If the coaxially of both spindels is not enough the workpiece while reclamping may be destroyed. The coaxially of both spindels depends first of all on geometric accuracy of the machine tool. Newest lathes and centers belong to the high accuracy group of machine tools and in most cases there is no problem with coaxially.

More important is the second technical problem connected with synchronization of rotating spindels. Both spindels have to have the same speed at the moment of reclamping. It is a very hard condition because both drives of main and auxiliary spindels are independent and only CNC has an influence on actual speed of them. This problem is the main subject of our paper. We would like to present some results of investigation performed in CBKO Pruszkow (Poland), where such idea of reclamping was applied to the CNC lathe Venus 350 [1].

3. CONCEPTION OF AN ALGORITM OF SYNCHRONIZATION WHILE RECLAMPING WORKPIECE ON CNC LATHE

The mechanic and kinematics scheme of a system of synchronization while reclamping workpiece on CNC lathe is shown in Fig. 2.

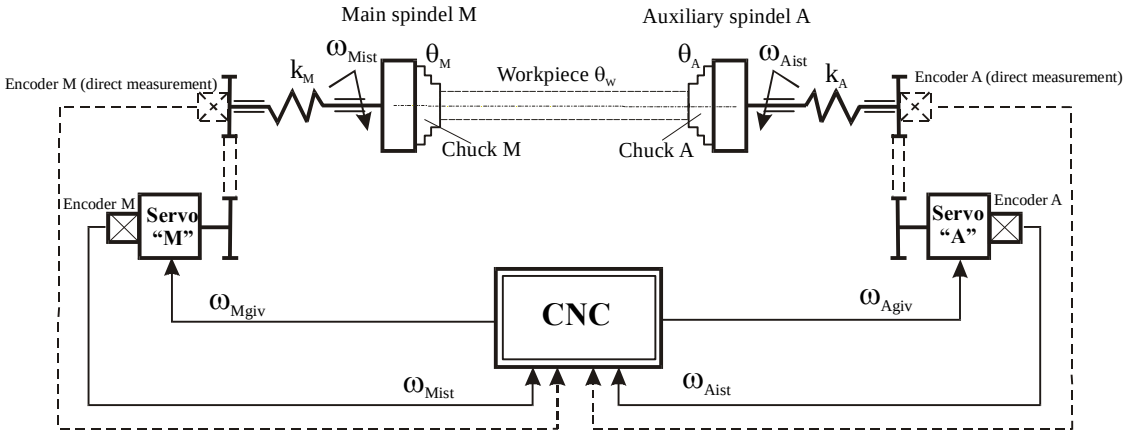

Figure 2. Kinematics scheme of synchronization while reclamping workpiece on CNC lathe

What is important in the point of view of synchronization of two spindles:
- Rotational speed 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, because of the productivity,
- Defining the moment of reclamping, what means to point the time when a signal clamping the chuck of the auxiliary spindel should be sent from CNC to the chuck,
- How the signal controlling both drives should look like?

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

The quality of synchronization process depends first of all on the time performance of ϕ_{Mgiv} (t) and ϕ_{Agiv}(t) signals, on the stiffness properties k_M and k_A of mechanical parts of kinematics chains of both spindels and on inertial moment Θ_M and Θ_A of chucks and workpiece. It means that a special schedule of time performance of all signals have to be implemented in the CNC controller of machine tools. Fig. 3 shows an example of such schedule we have used in our investigation.

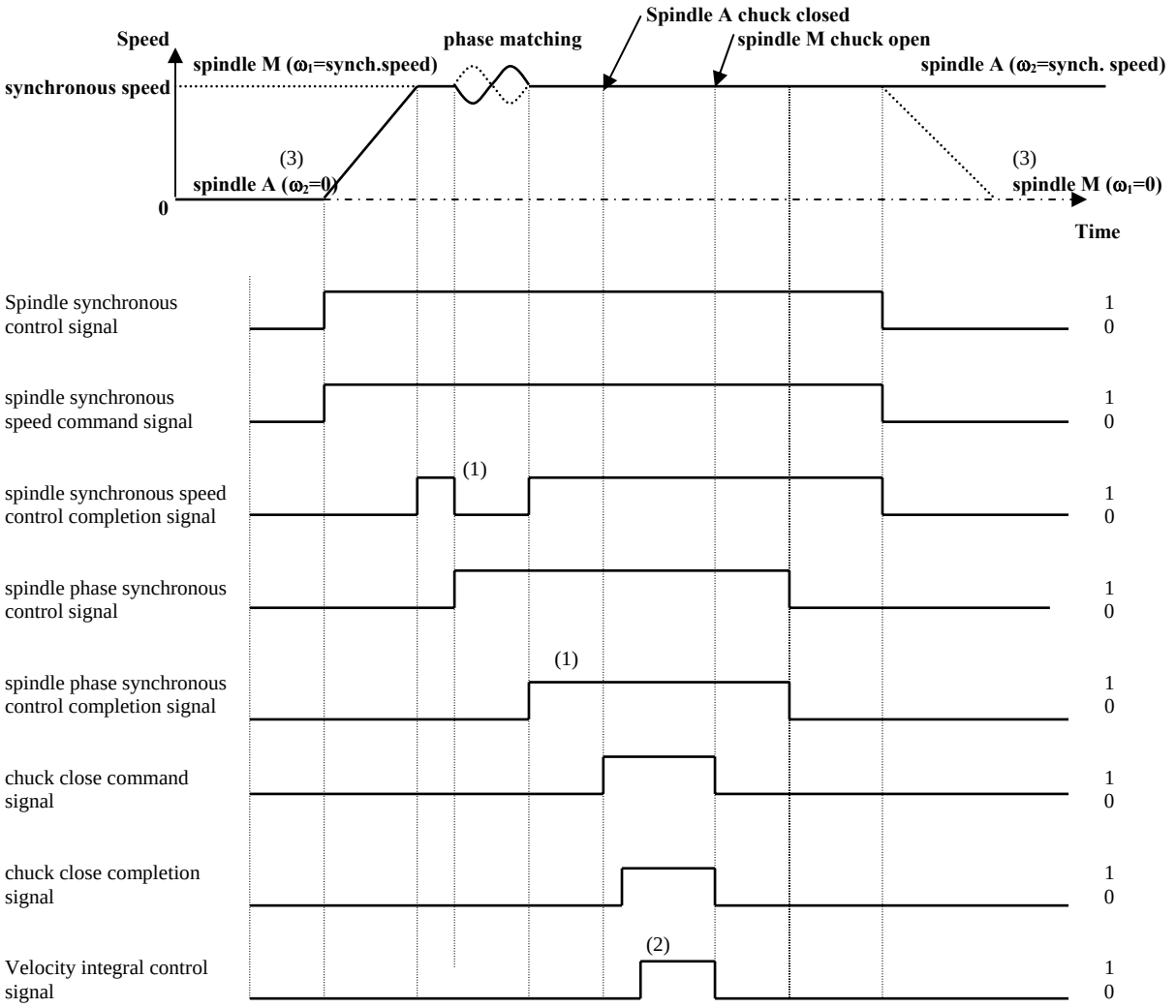

Figure 3. Scheme of control signal

4. RESULTS OF INVESTIGATIONS

We have done several experiments using an control algorithm like in Fig. 3. During investigation we have measured such parameters like: moments M of both servodrives, rotational speed ω of both drives and synchronization error ε defined as difference between rotational speed of main and auxiliary spindels. An example of time performance of measured parameters during process of reclamping is shown in Fig. 4.

We have done several experiments for different value of rotational speeds and time constants of servodrives. As a general conclusion of our investigation we can say that the problem of synchronization of both spindles during reclamping is complex and time of the process, precision and repeatability of reclamping, loading of the motors depends on many factors like:

- Rotational speed of spindles
- Time constants of both servodrives,
- Quality of encoders of both drives,
- Quality of the mechanical parts of both “C and “A” axis.

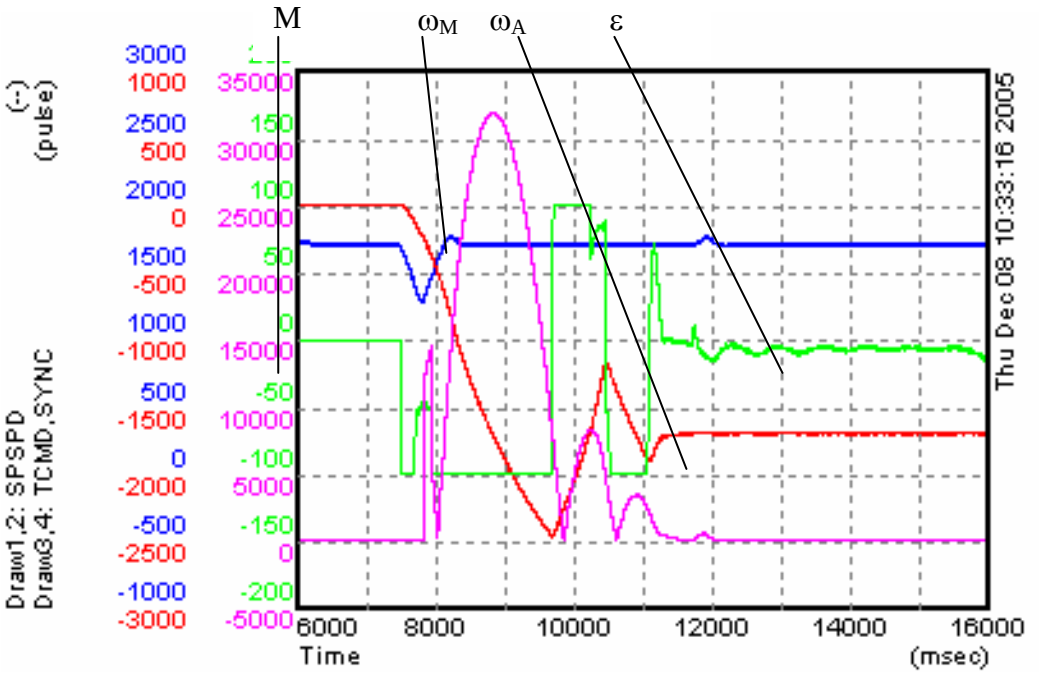

Figure 4. Time performance of rotational speed of main spindle (ω_M), auxiliary spindle ω_A, moment of main servodrive M, synchronization error ε for rotational speed 1700 rev/min and time constant of servodrives 30 ms

5. CONCLUSION

Performed investigation of process of synchronization of both spindels while reclamping allows us to such conclusions:

- If the rotational speed of synchronization while clamping is to high the loading of drives increases very much and time of the process grows longer (comparing loading of drive and synchronization error while reclamping and after finishing the process, we can say that they differs over 100-times)
- Because the CNC controller has restriction to the maximum value of the synchronization error, the process of reclamping may be broken if the real value of synchronization error exceeds the limitation value and the machine tool will be stopped
- Finding the appropriate values of time constants of servodrives and suitable encoders we are able to increase the rotational speed of reclamping or to decrease the time of synchronization.

Fig. 4 shows an example where the time constant of servodrives for the rotational speed 1700 rev/min was selected wrongly. We can observe typically symptoms of overshoots like oscillation of rotational speed of auxiliary spindel (the rotational speed of that spindel reached up to 3200 rev/min), the synchronization error reached up to 3200 rev/min and the moment of the drive varied +/- 100% of maximum value.

6. REFERENCES

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[2] Kosmol J. Servodrives of Numerically Controlled Machine Tools. Science-Technical Publishing House, Warsaw, 1998 (in polish).