9.2 PRACTICAL KNOWLEDGE FROM DESIGNING OF CNC MACHINE TOOLS

The designing engineer can influence very significantly the resulting behaviour of the machine tool at machining by the selection of the appropriate building element of the machine tool assembly group. It is possible to come nearer to the real machine behaviour in the cutting process by the calculation modelling of mechatronic arrangements; however some properties can be find out only by testing. The following text describes the application of a few design elements to machine tools and their behaviour.

Influence of the clutch type on the behaviour of the feed axis

The clutch between the servomotor with the inserted gearbox and the ball screw shall transfer the rotary motion from the gearbox output onto the ball screw with the same angular velocity and with the same torque, if possible. When this function is performed, the important parameter is represented by the clutch backlash at the rotary motion transfer and the clutch torsional rigidity. The influence was compared which two different clutch types used to connect the gearbox output shaft with the ball screw had on the regulation of the machine tool axis. Measuring was made on the CNC horizontal boring and milling machine WFT 13 CNC equipped with the control system Fanuc 31iA (Fig. 9.2.1). The software Fanuc Servo Guide was used to read the values and to draw the graphical courses.

The comparison of the above mentioned properties was implemented on two following clutches having the different designs: EK2 450 clutch (Fig. 9.2.2) and BKL 500 clutch (Fig. 9.2.3).

Fig. 9.2.4 shows the graphical course of the position deviation at a jump change on the feed axis. Places A and B are marked on this course. The A zone gives the evidence about the torsional rigidity of the particular clutch, the B zone gives the evidence about its backlash. As it is obvious, the course of the position deviation shape in these zones is dependent on the torsional rigidity and backlash of the clutch.

Fig. 9.2.5 shows the detailed view of the A zone. This segment shows the graphical course of the position deviation (violet course) and of the position feedback from linear measuring (from the rule) – blue course. It is possible to see the zone in the graph, where the motion of the particular axis was not implemented despite the rotary motion of the servomotor. "Springing" of the whole arrangement including the clutch was performed all this time period. Because measuring of both axes was done independently on the same arrangement (the same machine, the same axis), it is possible to compare the influence of the clutch elasticity from this zone for both measurings. Nevertheless, the clutch flexibility value cannot be determined, because the flexibility of the whole arrangement is also reflected here. Because the arrangement was the same one for both measurings, it is possible to compare proportionally these zones for both measurings.

Fig. 9.2.6 shows the detailed view of the B zone. This view shows the graphical course of the position deviation (violet course) and of the position feedback from linear measuring (from the rule) – blue course. It is possible to see the zone in the graph, where the required position of the servo axis was stabilized in the stopped condition. The axis position was set in the required position with two overshoots during this time period. The shape and the size of this position setting is influenced dominantly also by the clutch backlash, in addition to the regulator adjustment and the position feedbacks. The bigger the clutch backlash is, the more demanding character the drive regulation necessary to reach the required position has and the worse quality this regulation has (it takes more time and there are more overshoots there). It is not possible to read the value of the clutch backlash influence on this position setting directly from the graph, because the "backlash offset" of the whole arrangement is reflected here, in addition to the clutch

Fig. 9.2.1: CNC horizontal boring and milling machine WFT 13 CNC [Fermat]

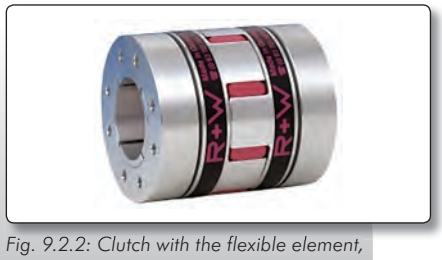


Fig. 9.2.2: Clutch with the flexible element, type EK2 450 elastomer B (64 Shore D) [R+W] [REM technik]

Fig. 9.2.3: Bellows type clutch, type BKL 500 v [R+W][REM Technik]

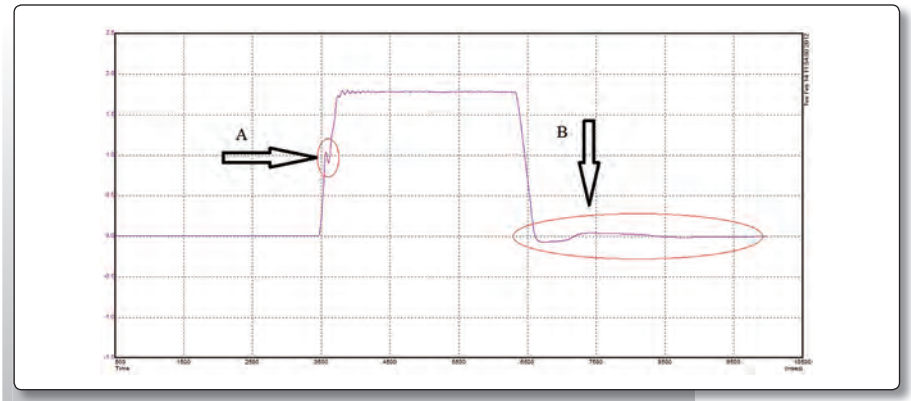


Fig. 9.2.4: Graphical course of the position deviation at a jump change [Fermat]

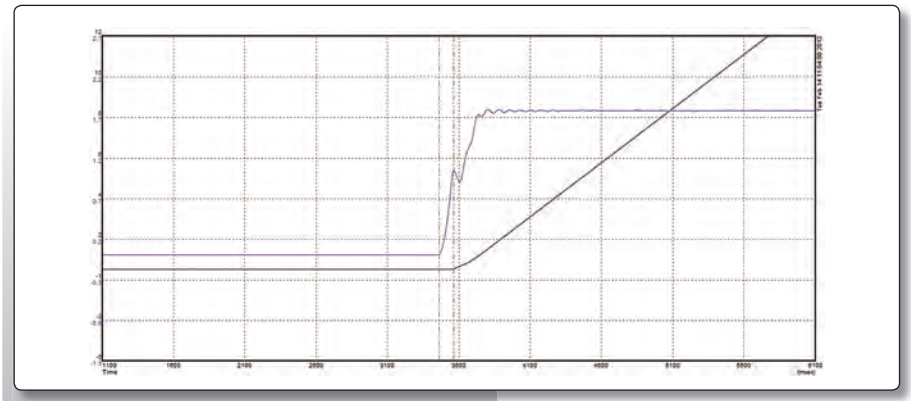


Fig. 9.2.5: Detailed view of a part of the A zone [Fermat]

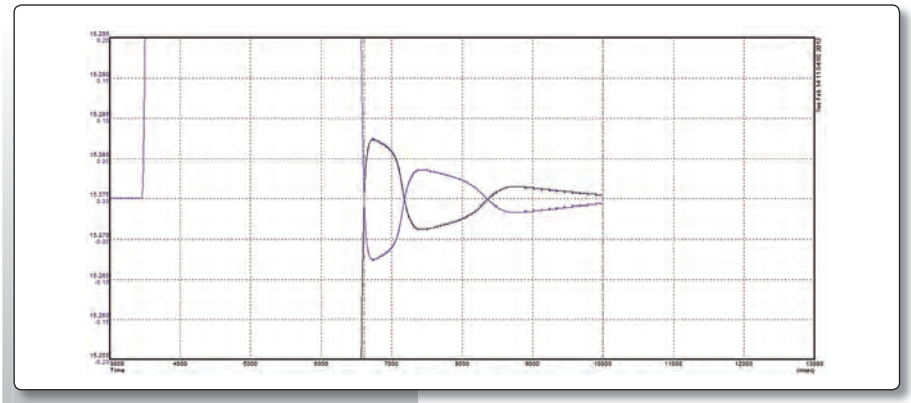


Fig. 9.2.6: Detailed view of the B zone [Fermat]

	Clutch EK2 450	Clutch BKL500
Zone A – "springing" size [-]	0,137	0,05
Zone A – "springing" time [ms]	106,42	89,53
Zone B – "position setting" time [ms]	2 060,81	1 054,05

Tab. 9.2.1: Comparison of the discussed axis properties for both clutch types [Fermat]

backlash. Because the arrangement was the same one for both measurings (the drive adjustment was identical too), it is possible to compare proportionally these zones for both measurings.

As it follows from the previous figures, the kind of the clutch used in the design (EK2 450 clutch, BKL 500 clutch) has the considerable influence on the course of the axis motion start from the static condition (so called axis tearing off) and on the subsequent final position setting at the motion to the required position (time of this position setting and number of overshoots of the required position). It was not possible to measure these properties directly, because their size and course are influenced by the adjustment of the regulation loop as well as by many other influences due to the mechanical properties of the particular machine. Because the measuring was performed on the same machine and on the same axis (but always with another clutch), it was possible to compare proportionally these properties. The resulting measuring values are given in Tab. 9.2.1.

If a design project is made, it is always necessary to select the correct solution considering the function of the machine tool. Therefore, it is also necessary to compare the advantages and disadvantages of each clutch.

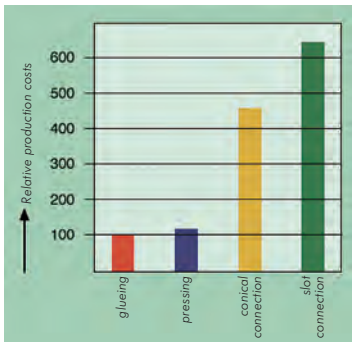
Type EK2 450

- *advantages:* relatively low price, it can be used for the connection with low dynamic stress
- *disadvantages:* at long term stress and the at maximum admissible utilization of geometric inaccuracies it is necessary to readjust the regulation loop parameters, which causes the problem with failure searching with possible axis oscillations

Type BLK 500

- *advantages:* good connection with higher dynamic stress, even at long term stress to the maximum admissible utilization of geometric inaccuracies it is not necessary to readjust the regulation loop parameters
- *disadvantages:* higher price, possibility of the bellows rupture (but it is possible to find the failure quickly at the same time).

As the measuring preset in Tab. 9.2.1 showed, if the clutch BKL 500 is used instead



The calculations are valid for series of 500 pieces. The costs for the assembly by glueing using Loctite are considered to be 100 %.

Fig. 9.2.7: Comparison of manufacturing costs form the most common assembly of cylindrical parts [www-1]

of the clutch EK2 450, the run of the given axis will be improved considerably.

Utilization of glued cylindrical parts

The chemical industry has developed and it is still developing glues which can be also used in the mechanical engineering. Many glues are specified to glue metallic parts. The utilization is also extended to glueing of belt pulleys, gears and other rotary parts on the shafts, without the utilization of splines, wedges and shaped joints. The glue is used to connect directly two rotary parts. It also transfers the torque. When this technology is introduced, it is possible to reach a cheaper and quicker solution. The commonly used hot pressed and cold pressed mountings or mountings with the tapered journal are economic, no unbalances arise and it is not necessary to make axial fixations. However, they also have their disadvantages. These disadvantages are represented by high manufacturing costs (Fig. 9.2.7) and stresses arise in the parts which can lead to their possible damage.

The shape and frictional load transfers are susceptible to the so called red corrosion caused by friction and stress. The reason can be seen in the micromotions also leading to the accelerated wear and possible failure. There are two ways of glued joints of cylindrical parts available – Fig. 9.2.8 [www-1]:

- glued sliding mountings – the parts are machined with backlash and the hardened glue transfers loading;

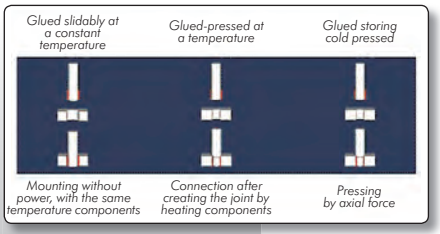


Fig. 9.2.8: Kinds of glueing of cylindrical joints [www-1]

Fig. 9.2.9: CNC boring and milling machine WFC 10 [Fermat]

- cold pressed/hot pressed glued mountings – loading is transferred by the hardened glue and by friction, thanks to matching with interference.

The advantages of the glued joint are the following ones [www-1]:

- it improves or replaces mechanical joints;
- it excludes origination of the frictional corrosion;
- it enables stronger and more rigid joints;
- it excludes backlash at splines and wedges;
- it excludes the need of other locking parts;
- it reduces the wall thickness necessary for loading capacity;
- it reduces requirements on tolerances;
- the parts can be dismantled by warming which reduces the glue strength;
- it enables to use different materials;
- it distributes stress uniformly in the parts and it reduces its peaks;
- it reduces the costs for machining;
- it balances automatically misalignments of bearings and sleeves;
- it connects hard and soft surfaces without their damage;
- it seals joints completely and it excludes corrosion.

Glueing is also used to attach the pinions on the drive shafts. This is the solution also in those cases, where it is not possible to transfer loading by the spline or by other couplings. For example, if it is necessary to increase the gear ratio in the limited areas, it is necessary to use the smallest possible pinion diameter. Then it is not possible to use here any connecting elements like the spline, or the costs would be increased considerably. This connection way was

Fig. 9.2.10: Original connection of the driving belt pulley with the servomotor by means of torsional rings Tollok [Fermat]