

Combined Machine Tool for Stepped Shafts

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Abstract: The paper deals with a novel design of a combined machine tool in comparison with known contemporary analogues. It is designed for multifunctional machining of workpieces in one or two setups in collet and centre-to-centre design. Typical of this machine tool is the use of a bed with a trapezoidal cross-section with inclined longitudinal guides on both sides for the slides used for rough, fine and finish machining. With this design, the slides are spatially separated and lightly loaded. The material removal during roughing and finishing is separated from each other. The grinding slide and its guides are not subjected to additional thermal deflections caused by the high-temperature crisps produced during turning, and the slide for roughing and finishing is spatially protected against the influence of grinding powder. The bed meets the requirements for a thermosymmetrical design and allows internal cooling. The advantages of this arrangement from the design, technical and economic points of view are presented.

Keywords: combined machined tool; inclined guideways; multifunctional machining; trapezoidal bed

1 INTRODUCTION

The growing demands for accuracy and productivity in the roughing and finishing of chuck and center parts have led to the advent of so-called combined machine tools (CMT). In them, one or two setups are required for turning and grinding operations. This technology guarantees high productivity and dimensional accuracy, as well as mutual placement of surfaces machined on one side by eliminating setting errors. The main advantages of the processes and machines for combined machining are analyzed in [1-7]. Of particular interest are the multifunctional machine tools with inclined guideways, Fig. 1, manufactured by the company Index [8].

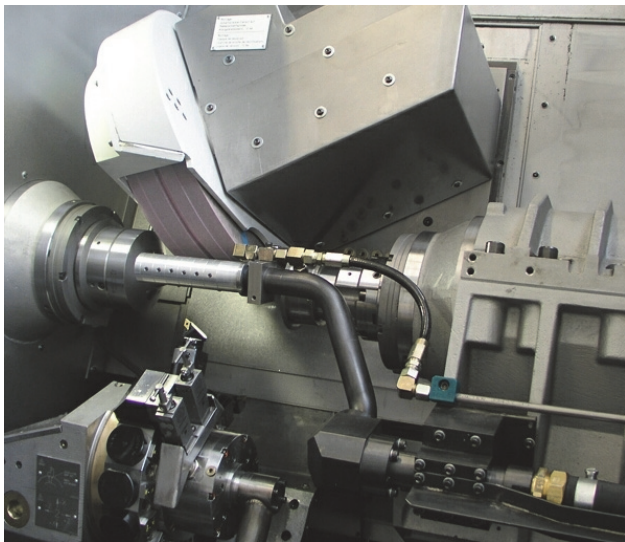


Figure 1 CMT Index G200 with inclined guideways [8]

The carriages for performing roughing and finishing operations (especially turning and grinding) are force separated and placed one above the other on an inclined or vertical surface on the bed on both sides of the machined workpiece. The hot chips produced during turning are discharged freely and do not affect the thermal deflections of the machine tool. The waste from grinding and dressing the grinding wheels falls on the turning carriage, its guides and the turret. This is a prerequisite for abrasive wear in the zones of sliding contacts. The abrasive powder, which is

not washed off by the coolant, gets between the contact surfaces for the cutting tools and their inserts.

Fig. 2 shows a possibility of horizontal arrangement [9] of a reconfigurable combined machine tool [10] with power separated slides for roughing and finishing. The design is based on the modular principle. Due to the design distance between the three longitudinal guides of the machine tool and the space between them, a relatively small amount of the chips and grinding waste falls into the area of the slides and their guides. This arrangement can also be considered as a vertical type [10] with horizontal (as in [8]) or vertical arrangement of the longitudinal guides. In this case, the hot crisps and grinding waste move down under their own weight.

Analysis of the layouts in Fig. 1 and Fig. 2 leads to the conclusion that the problem of separating the flow of chips and waste products from grinding and dressing is thus not completely solved. This leads to the requirement for an arrangement with optimum spatial and force separation of the slides for roughing and finishing operations on combined machine tools. In this context, the publications [11, 12] dealing with criteria for the selection and optimization of design options of technical systems are interesting.

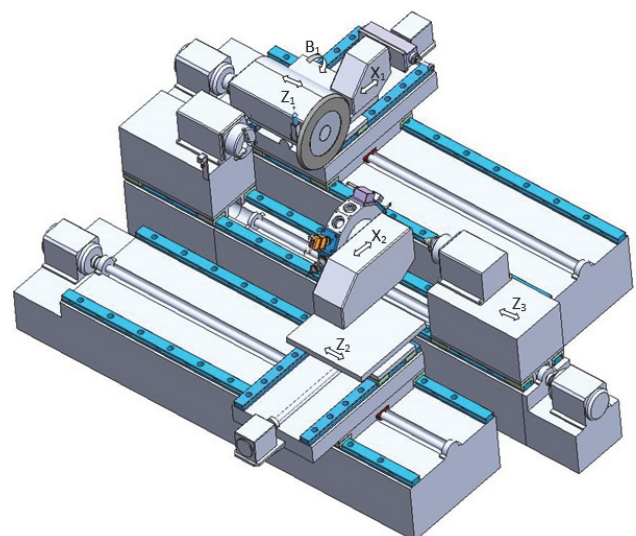


Figure 2 Horizontal layout of a combined machine tool [9]

Combined machine shown in Fig. 2 has two spatially and power-separated supports for turning (along the X_2 and Z_2 axes) and for grinding (along the X_1 , Z_1 and B_1 axes). The arrangement is suitable for processing chuck and center parts with different lengths by using the Z_3 axis.

2 NEW LAYOUT OF A COMBINED MACHINE TOOL

In the present publication, a new layout of a combined machine tool is presented - Fig. 3. Typical of it is the use of a bed with a trapezoidal cross-section with inclined guides arranged on both sides for force-separated slides for roughing and finishing operations. To facilitate access to the slides, for changing workpieces and for setting up new workpieces, the guideways can be slightly inclined with respect to the vertical plane or vertical, as in the Index C200 turning and grinding center [8].

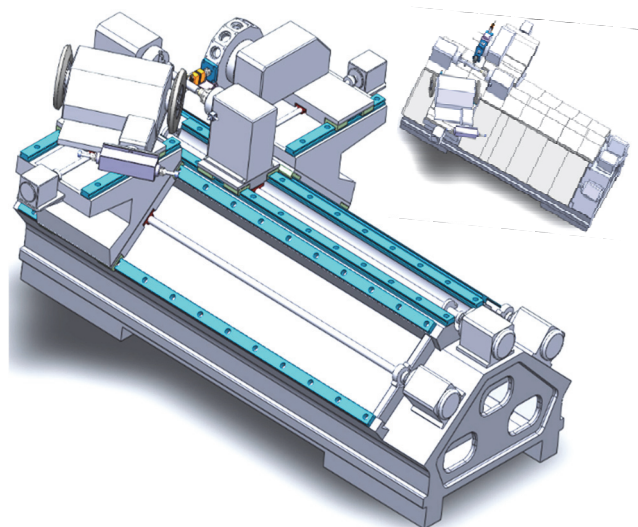


Figure 3 Combined machine tool with spatially and force separated carriages

This concept retains the advantages of the arrangements shown in Fig. 1, but the hot French fries and waste products from grinding and dressing are separated in different directions. The figure shows only one option of the modular layout with a bed of inclined guideways for machining chuck and center-to-center components in any sequence. If successive machining of stacks of workpieces of different lengths is required in the FMS, the tailstock (or the opposite spindle [10]) is automatically moved longitudinally on additional horizontal guides. Extendable V-shaped protective covers are provided for all guideways to prevent the ingress of French fries and grinding powder, as shown on the floor plan in the upper right corner of Fig. 3. They facilitate the separation of French fries from the waste products generated during grinding and dressing. For complete separation of the zones for roughing and finishing, additional design solutions can be implemented, such as vertical partitioning, etc.

The layout shown in Fig. 3 is a combination of a turning, drilling and milling center and a grinding machine with the following common features: bed, slide and counter-spindle, numerical control, various aggregates, etc. The cross section of the bed is an antiparallelogram. In view of a simpler machining, it can be composed of two symmetrical modules with inclined or vertical guides,

which are machined one after the other or simultaneously and then assembled.

The design of the saddle of the carriages, which travel along the guideways on the carriage body, also distinguishes the new installation. In its upper part, horizontal guideways are fixed, which allow the movement of the carriages in the transverse direction. This design variant retains the advantages of the horizontal arrangement shown in Fig. 2.

The modular variant of a CMT for machining components with stepped chucks and central holes, shown in Fig. 3, requires a total of 5 numerical axes: two for the carriage for roughing and three for the turret. For the production of batches of workpieces with central bore in FMS or the use of the counter-spindle for machining both sides of workpieces with chucks, a sixth axis is required for the automatic movement of the tailstock (or counter-spindle).

Depending on the requirements of different companies and production types, the presented machine tools can be reconfigured according to the modular principle to offer several options, the most important of which are described in [10 and 1]. The wheel head with two motor spindles and wheels with inclined profile for external grinding and two tools for internal grinding allows complete finishing of chucked parts on both sides in two settings. According to the modular principle, one or two turrets can be added to the compound turning carriage to perform procedures for roughing and finishing [9]. Spindles and tools for milling, drilling and other processes are fixed in their active positions [10].

The combined machine tool enables external, internal, longitudinal and face grinding of chuck and center-to-center workpieces on both sides. When using an equipment option with vertical longitudinal and transverse guides and a Y-axis, similar to the C 200 machine tool from Index, the technological features of the machine are extended for machining off-center surfaces and bores.

Installation of tools suitable for combination of turning and grinding in the turrets suitable for machining of hardened parts additionally increases the effect of combined machining by shortening the basic time for their production and achieving higher quality of machined surfaces.

The combined machine, shown in Fig. 3, differs from the arrangement in Fig. 2, mainly in the inclined longitudinal guides for the two supports. This solution greatly facilitates the two-way separation of waste products during turning, grinding and sharpening.

Fig. 4 to Fig. 7 show the main technological configurations of the new layout.

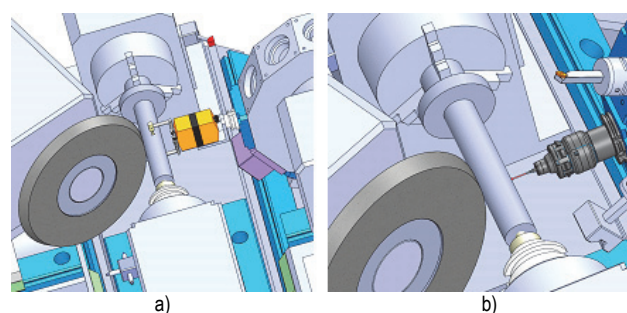
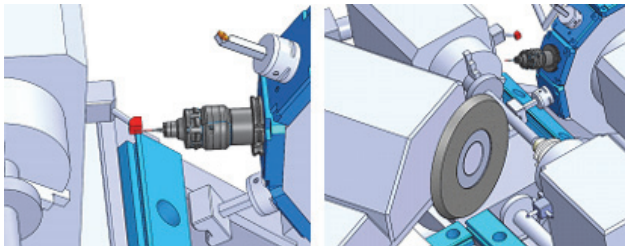


Figure 4 Longitudinal grinding with active monitoring

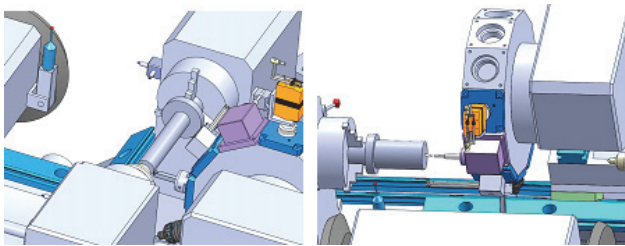
Fig. 4a shows a simulation example of the patented process for longitudinal grinding of rotary components with active monitoring and adaptive control of the process [10]. The new technology for longitudinal grinding using a scanning measuring probe [10] is visualized in Fig. 4b.

It is necessary to calibration of the measuring head, as shown in Fig. 5a. The patented method for longitudinal grinding of workpieces with low stability [10], in which they are supported by a vee block fixed in the turret of the counter slide, is shown in Fig. 5b.

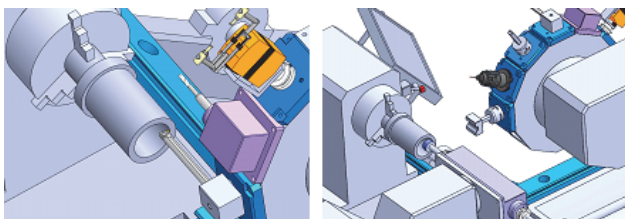


a) Calibration of scanning head b) Method of longitudinal grinding
Figure 5 Calibration of scanning head and method of longitudinal grinding

In the Figs. 6 and 7 are shown: turning, drilling, boring and internal grinding.



a) Turning b) Drilling
Figure 6 Turning and drilling of a chuck workpiece



a) Boring b) Internal grinding
Figure 7 Boring and internal grinding and dressing of grinding wheel

3 MAIN ADVANTAGES OF THE NEW LAYOUT

3.1 Specifications and Advantages of the New Layout from a Design Point of View

The advantages of the new arrangement in design terms are as follows:

- The feed drives of the slides for roughing and finishing are positively separated. This guarantees high dimensional accuracy and placement of the ground surfaces;
- The slide for finish machining is equipped with a motor spindle with two wheels with inclined profile for grinding both sides of external surfaces and adjacent surfaces of workpieces with center contact and chuck, and a motor spindle for internal grinding on both sides with two tools;
- Different design variants of the machine tool with inclined or vertical guideways can be configured

according to the modular principle [10] with one or up to four power-separated slides with different technological functions and tooling;

- The flows of the different types of chips from roughing processes and waste products from grinding and dressing are spatially separated. In this way, the arrangement provides additional protection of the guideways and slide for roughing against the penetration of abrasive powders, and protection of the guideways and slide for finishing against the hot French fries generated during turning;
- The overall dimensions of the machine tool are small due to the use of a bed with a trapezoidal or rectangular cross-section and inclined or vertical guideways;
- The layout is ergonomic, as access to components in the work area and on both sides of the bed is facilitated;
- A rotating column with a horizontal telescopic arm is provided for the machine tool control panel (not shown in the figures), which can be used on both sides of the bed;
- The distances between the rail guides are as long as possible due to the trapezoidal cross-section of the bed, which allows low reaction forces and deformations.

3.2 Specifications and Advantages of the New Layout from Technological Point of View

The advantages of the new arrangement in technological terms are as follows:

- Various processes can be carried out in one set-up, such as: Turning, drilling, boring, milling, plastic deformation, laser hardening, internal and external grinding, honing, polishing and others, using a variety of tools and equipment attached to the machine tool slides;
- With one setting, all internal and external surfaces of chuck parts arranged on one side can be machined coarsely, finely and finished. This enables high dimensional accuracy and mutual placement of surfaces;
- With a second setting, the use of a counter spindle enables coarse, fine and finish machining of chuck parts on both sides;
- The motor spindle with two wheels with inclined profile for external grinding enables successive external grinding on both sides of cylindrical surfaces and adjacent surfaces of chuck and center-to-center type components in two settings;
- The motor spindle with two grinding wheels for internal grinding on the turret grinding carriage enables successive two-sided internal grinding of stepped holes of chuck type components in two settings;
- In each setting, surfaces of chuck parts can be successively ground inside and outside, which ensures the coaxiality of machined surfaces;
- Roughing, fine and finishing operations of center to center and chuck type components, which is a prerequisite for very small allowances in grinding methods;
- Machining productivity is increased by reducing machining time due to the proximity of roughing, fine and finishing tools on both sides of the part;

- The overall productivity is increased due to the significant reduction in the time for finishing of components in one setup, which is achieved by the reduced allowances for grinding;
- When using a combined machine tool with modular long bed, as shown in Fig. 3, the design leads to an increase in productivity in mass production when using four slides with different technological purpose and power separated drives [10]. An exemplary option for the latter is a combined machine tool with spatially separated 2 turning and 2 grinding slides, which allows simultaneous turning or grinding of two chuck parts in two setups;
- Small and uniform finishing allowances, spatial separation of the slides and separation of the waste products make it possible to apply the dry cutting or machining processes with minimum amounts of coolant;
- The wear of the grinding wheels is reduced due to small grinding allowances;
- The number of dressing operations between cycles is reduced due to the lower wear of the grinding tools;
- It is possible to apply the method of simultaneous longitudinal grinding and measurement of the machined surface with an active monitoring device or a scanning measuring head [10];
- Adaptive control [10] of the shape and dimensional accuracy of longitudinally ground components can be performed using the data from the active monitoring device or scanning measuring head;
- It is possible to apply the method of longitudinal grinding of components with low stability [10] using a traveling gib support in the turret on the opposite turning carriage;
- The degree of automation is increased;
- The programming is facilitated by the total synchronization of the emerging dimensioning between the successively executed methods for rough, fine and finish machining of the workpieces in each chucking with the tools from different slides, which is a prerequisite for achieving the maximum accuracy of the dimensions and the mutual placement of the surfaces. One machine tool is programmed, not two;
- Regarding the grinding possibilities, the machine can be configured both for centerless process with grinding wheel and regulating wheel and for RPM - synchronous non-circular grinding [13].

3.3 Specifications and Advantages of the New Layout from Economical Point of View

The advantages of the new arrangement in economic terms are as follows:

- Investment and production costs are reduced by using only one machine tool instead of two. The new layout is a combination of a turning, drilling and milling center and a numerically controlled machine tool for external and internal grinding with common slide or counter-spindle, bed, numerical control, various units, etc. This is a prerequisite for a significant reduction in investment;
- The working area required for one and the same production job is reduced because only one machine

tool with trapezoidal or rectangular bed is used, not two;

- Tooling costs for grinding and dressing tools are reduced, as well as coolant costs, since finishing allowances are reduced;
- Only one operator operates the machine tool.

4 CONCLUSION

This paper presents a new layout of a combined machine tool for roughing, fine and finish machining of workpieces in collet and centering machine design in one or two setups. It can be used to realize the following processes: a) longitudinal grinding with active monitoring and adaptive control of the diameter accuracy and the shape of the machined surfaces; b) longitudinal grinding of workpieces with low stability when supported by a movable prismatic support fixed in the turret on the opposite slide. The equipment has a trapezoidal or rectangular bed as a cross-section and two inclined or vertical longitudinal guides. Spatially and power-separated cross slides for roughing and finishing operations are attached to them. The shape of the trapezoidal or rectangular bed separates the flows of hot chips from turning and waste products from grinding and dressing. The machine tool can be equipped according to the modular principle with two to four slides with different technological objectives, actuated by spatially and power separated drives. The presented new layout of a combined machine tool for roughing, finishing and finishing is compared with similar known modern machine tools and its advantages are analyzed in design, technological and economic terms.

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