# Real-Time Monitoring and Control of Machining Accuracy in CNC Machining Centres

**Yunusali Khusanov Yuldashaliyevich**
Doctor of Technical Sciences (DSc),
Associate Professor
**O'lmasov Ahadjon Akramjon o'g'li**
(DSc) Doctoral Researcher
Fergana State Technical University
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**Abstract:** During machining operations on machining centres, there are a large number of internal and external factors that act on the technological system. The monitoring and control system developed for machining centres presented in this paper consists of 3D touch probes, a device for registering a contact between the cutting tool and workpiece, devices for measuring the geometric accuracy of the machine tool and for calibrating the touch probe in the spindle, parameterised CNC programmes, computer and software for data processing and database management.

During machining operations on machining centres (MC), the technological system is affected by many internal and external factors.

They generate errors that influence the cost, productivity, and most importantly, the accuracy of the machining operation. This type of control usually involves solving the following tasks:

- Inspection of the machined surfaces (Task A)
- Detection of the position and orientation of the blank material (Task B)
- Set-up of the cutting tools and their inspection after work (Task C)

The basic set for a MC includes TTP1 (Fig. 1), TPC (Fig. 1a), and MPM for solving tasks A and B. By mounting TTP2 to the body of the machine tool it is possible to solve task C as well. By adding TRS (Fig. 2) and MTC (Fig. 1b) to the typical basic system, it is possible to enhance it with minimal capital investment (this also includes TTP2). At the same time, on top of tasks A, B and C, listed above, together they can also solve the following new tasks:

• By using elements TTP1, MTC, TPC and PMP, it is possible to conduct servicing (planned or extraordinary, after a collision) control and diagnostics of some parameters of the geometric accuracy of the machine tool (Task D).

• With TTP1, TPC and PMP, it is possible to conduct continuous control of the geometric accuracy and thermal deformations of some of the parts of the machine tool by measuring the relative position of the datum surfaces of the table of the machining centre that orient the workholding devices (Task E).

• Using TTP2, TRS and PMP, the condition, integrity and thermal deformations of the cutting tool can be set and controlled both in its idle and working stages (Task F).

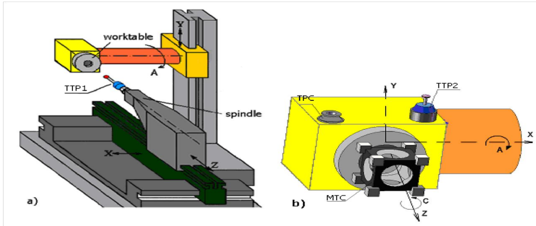


Fig. 1. Accuracy control system (a) basic; (b) extended.

Based on these formulated tasks, the system is divided into specialised, stand-alone blocks for solving each task (Fig. 4). Each block, in accordance with its function, possesses and uses the necessary databases that consist of dimensions, co-ordinates along the work axes and tolerances of the controlled parameters. They are loaded into the system in advance from an external source, but can be altered by editing or internal accumulation of the data.

After heavier collisions the control system may suggest that for recovering the functionality and geometrical parameters of the machine tool it needs to be serviced. The components used for the various tasks are:

- TTP1: this touch probe needs to have a spherical probe head. It is used in solving all tasks (except for cutting tool inspection) by contact co-ordinate measurement.
- TTP2: this touch probe with a cylindrical probe head is used for the set-up and inspection of the cutting edges of the cutting tool.
- TRS: touch registration system (Fig. 2).

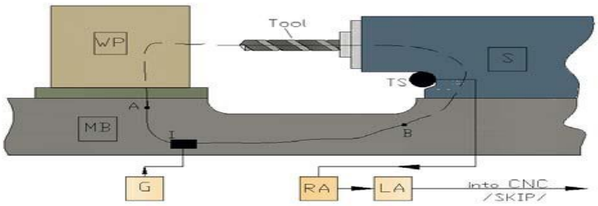


Fig. 2. Touch registration system (TRS).

The touch registration system includes a generator G of eddy-currents that are induced through an inductor I in points A and B in the body MB of the machine tool. When the cutting tool (a drill bit in Fig. 2) gets in contact with the workpiece WP a closed circuit is formed between the workpiece, cutting tool and machine tool body (this circuit is shown as a dashed line passing through the spindle unit S). As a result the touch sensor TS generates a signal which through a resonance amplifier RA and levelling amplifier LA is transformed as a SKIP signal for the CNC control system of the machine tool.

For each of the five blocks corresponding algorithms and programmes are developed. They can be activated manually or automatically. All blocks have a similar structure of the algorithm:

- Measurements, through which input information is gathered (green blocks); these are co-ordinates of points from the measured objects: for the machined part (block 1), for the work co-ordinate system and workholding device (block 2), for the machine co-ordinate system (scheme 3), and for the dimensions of the cutting tool (block 4).
- Analysis of the input data and comparison (yellow blocks) with data in the database (purple blocks).

Depending on the results from the comparison (YES/NO), a solution is generated either automatically by the system, or manually by the machine tool operator.

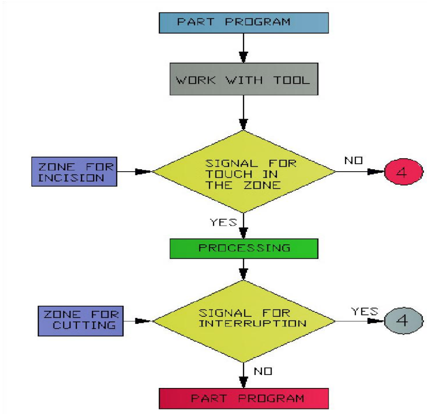


Fig. 3. Algorithm of the work of the touch registration system.

The functioning of the system block-by-block (Fig. 3) is easiest to be explained using examples:

After measuring the controlled dimension or a co-ordinate point of the machined part ($X_{wi}$, $Y_{wi}$.....$C_{wi}$), the result ($T_{xw}$, $T_{Yw}$.....$T_{Cw}$) is compared with the corresponding values ($T_{xi}$, $T_{Y}$.....$T_{C}$) in the database (block 1 in Fig. 3). If the measured deviation is within the given tolerance value (result 'NO'), the operation continues using the initial set-up values (exit TP). If the deviation is out of tolerance (result 'YES'), then using the algorithms through routes (2 3) and (2 →4) it is established if this deviation is due to the effect of thermal deformations of the technological system, cutting tool wear, displacement of the workholding device, or damage of the machine tool (route (2 3 5)). Depending on the amount of deviation and its source, the machining operation may continue without interruption after entering the necessary corrections into the system, or it may be stopped if the reason is displaced or damaged workholding device (Al1) or broken cutting tool (Al2), or the machine may require repairs.

When applied to a machining centre with CNC control, the developed system may have the following effects on the operation:

Low cost: the system only requires reasonably low investments; for example, the TRS and MTC systems only cost a couple of thousand euros.

High productivity: it is achieved with a low number (in most cases once-off) preparation work and measurements. Repeated work is only necessary when the MTC is re-installed on the table of the machine tool. The remaining preparation work is only performed once.

High reliability: it is achieved by the reduction of the scrap rate due to cutting tool breakage, and also by minimising human errors.

**Conclusions**

The developed system allows for complex control of accuracy and reliability of machining operations on four or five axis machining centres with minimum additional capital investment.

The shape, dimensions and types of the standard (reference) surfaces of the machine tool calibrator can be finalised individually by the operator, and its manufacturing is in the capabilities of small and medium-sized factories.

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