3.8 ACTIVE CHECK AND TECHNICAL DIAGNOSTICS OF CNC MACHINES

In order to reach the unattended operation of the production machinery in the right sense of the word, other specialized automation means have been developed and utilized which replace partly the operator's work in the remaining functions at the check of production accuracy and at the elimination of the factors influencing unfavourably production accuracy, at the supervision over the correct machine function and the state of tools (their wear, breakage) and finally at the identification of failure causes of the production machinery and at the protection against the machinery damage due to the originated failures.

Productive process

The variability of machining processes can brake the manufacturer in the competitiveness and profitability. It can cause the loss of time and inefficiency, it leads to high costs for the quality and to the need of the bigger quantity of employees and it results in late deliveries and in the bad check over the outputs. The productive process pyramid (Fig. 3.8.1) is the tool by Renishaw company, thanks to which it is possible to identify and to control the deviations and variabilities in the manufacturing company with the support of innovative technologies, proven methods and with the professional assistance [www-1].

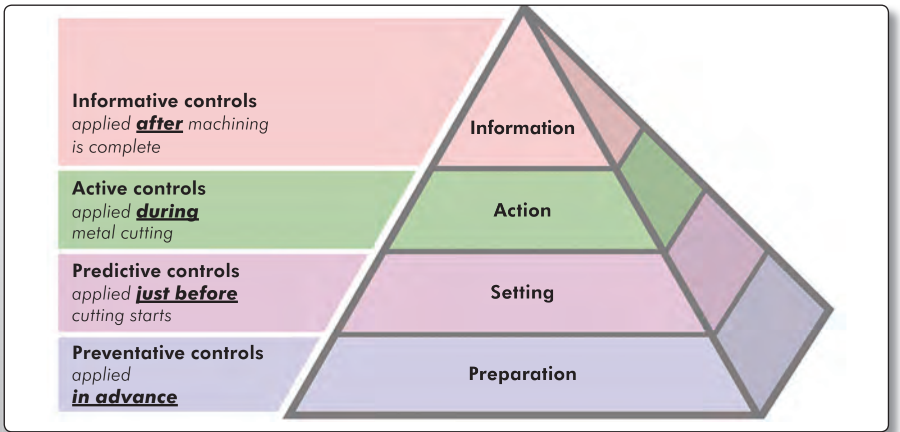


Fig. 3.8.1: Productive process pyramid [Renishaw]

The production preparation layer is aimed at stability of the ambient where machining shall take place. This layer includes optimization and monitoring of the machine output itself. This is the preventive measure which must prevent the possibility, that any unexpected influences may appear during machining which could cause random errors. The optimization of the machine state is the essential prerequisite for the production preparation which any production cannot be realized without. It is impossible to manufacture precisely with an imprecise machine. Based on the assessment of the machine parameters it is possible to reach such properties by means of calibration or repair which enable machining within the required values. The following factors can worsen the machining quality [www-2]:

- errors at position setting of the machine tool which are one of the most often reasons of the production of dimensional wasters and wasters having the poor quality surface treatment and which can be attributed to the geometric any dynamic errors and backlash errors inside the machine;
- errors originating even at a new machine due to the changes in the time period between the dispatching from the manufacturing plant and the first utilization in the factory;
- wear arisen due to the machine operation.

The correctly adjusted machine will evenly manufacture high quality workpieces with a smaller number of unplanned stops. This means more time for machining and bigger proactivity of service employees. Thanks to the regular checks of the state of all machines and by the determination of the sources of any errors it is possible to minimize the effort for maintenance and to focus on the valuable preventive work [www-2].

The process setting layer deals with the sources of variability, like the semi product location, the size of tools and the deviations at the machine are which can result in the manufacture of non conforming workpieces. This concerns the adjustment of parameters, the adjustment of the arrangement "machine – workpiece – tool", before machining is started [www-1].

The active feedback layer includes the operations and activities performed during machining. These measures create automatically the response to the material state, to the acute deviations from the expected dimensions or to other unexpected process states. This concerns the active check of parameters during machining [www-1].

Workpiece measuring during machining enables the following [www-3]:

- based on the determined values, to react on the deviations caused for example by the workpiece deformation, by the tool deflection or under the influence of thermal deformations;
- based on the determined values, to adapt automatically the current values of the coordinate system rotation, to update the machining parameters, to change the offset values in the tool tables and to branch the program run using the logic conditions with the target to get the perfect product.

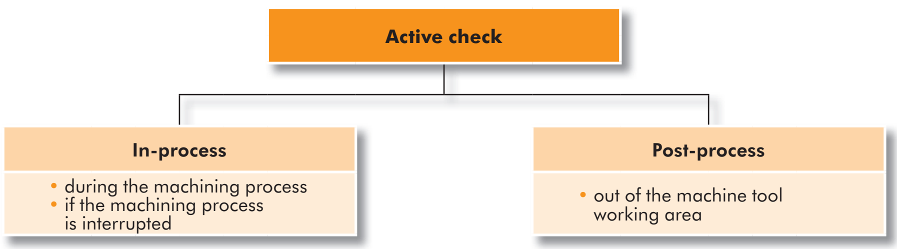


Fig. 3.8.2: Types of the active check at the CNC machine tool

Tool measuring during machining enables the following [www-3]:

- to check the tool presence and the tool position;
- to check the tool wear size;
- to check the wholeness and wear of the tool cutting edges.

The pyramid top, which is the layer of the ready workpiece check, represents measuring of the manufactured part and output information from measuring [www-1]. This is informative measuring after ma-chining is finished. Workpiece measuring directly on the machine enables the following [www-4]:

- to check the important workpiece elements directly on the machine, before the workpiece is released and manipulation is performed;
- to watch stability of the machining process.

Active check of machine tools

The main task of the active check arrangement is to eliminate automatically the influence of various factors which affect negatively the machining accuracy and the machine working capability. In addition to the above mentioned, the active checks having the modern concept contribute to another increase of manufacturing productivity, because the preparatory and secondary time is reduced. These benefits are reached by the active check utilization for "fine adjustment" of tools in their working position on the machine, for indication of wear and damage of tools and by utilization of the active check systems for measuring of the semi products chucked in the position for their machining on the machine. Based on the results obtained from these measurings, it is possible to perform the part program modification (to optimize the number and the size of roughing material removals – of "chips") [Borský 1992a].

Active check during machining (in process check)

In dependence on the location of the appropriate sensors, on the measuring ways and on the evaluation of measuring results as well as on the ways how correction interventions are done, the active check arrangements are divided into two essential types, i. e. the in process check and the post process check (Fig. 3.8.2). The in process active check arrangements work

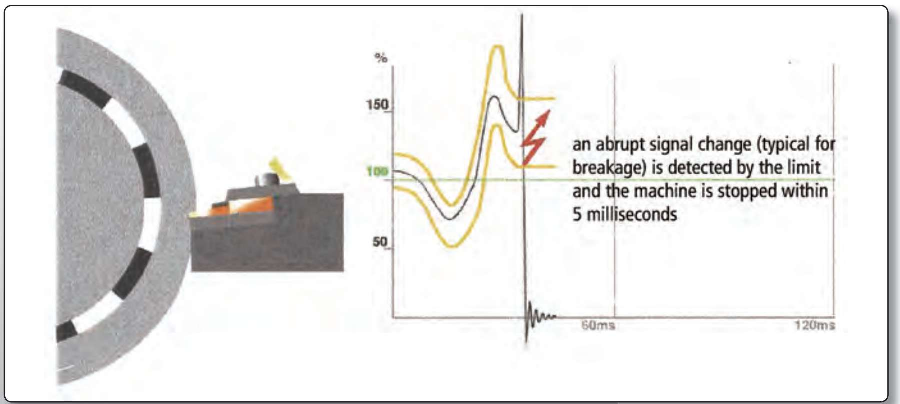
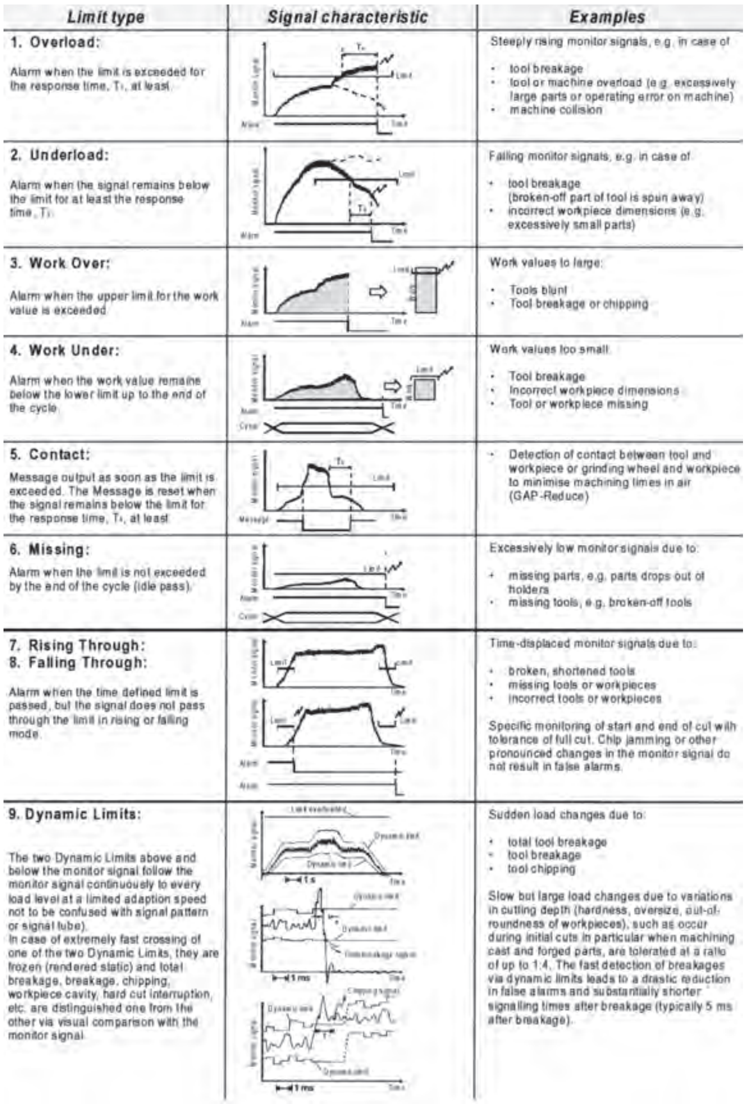


Fig. 3.8.3: Measuring example of the turning cutting process [Prometec]



Limit type	Signal characteristic	Examples
1. Overload: Alarm when the limit is exceeded for the response time, T_1, at least		Steeply rising monitor signals, e.g. in case of • tool breakage • tool or machine overload (e.g. excessively large parts or operating error on machine) • machine collision
2. Underload: Alarm when the signal remains below the limit for at least the response time, T_1		Falling monitor signals, e.g. in case of • tool breakage (broken-off part of tool is spun away) • incorrect workpiece dimensions (e.g. excessively small parts)
3. Work Over: Alarm when the upper limit for the work value is exceeded		Work values to large: • Tools blunt • Tool breakage or chipping
4. Work Under: Alarm when the work value remaine below the lower limit up to the end of the cycle		Work values too small: • Tool breakage • Incorrect workpiece dimensions • Tool or workpiece missing
5. Contact: Message output as soon as the limit is exceeded. The Message is reset when the signal remains below the limit for the response time, T_1, at least		• Detection of contact between tool and workpiece or grinding wheel and workpiece to minimise machining times in air (GAP-Reduce)
6. Missing: Alarm when the limit is not exceeded by the end of the cycle (idle pass).		Excessively low monitor signals due to: • missing parts, e.g. parts drops out of holders • missing tools, e.g. broken-off tools
7. Rising Through: **8. Falling Through:** Alarm when the time defined limit is passed, but the signal does not pass through the limit in rising or falling mode.		Time-displaced monitor signals due to: • broken, shortened tools • missing tools or workpieces • incorrect tools or workpieces. Specific monitoring of start and end of cut with tolerance of full cut. Chip jamming or other pronounced changes in the monitor signal do not result in false alarms.
9. Dynamic Limits: The two Dynamic Limits above and below the monitor signal follow the monitor signal continuously to every load level at a limited adaption speed not to be confused with signal pattern or signal tube). In case of extremely fast crossing of one of the two Dynamic Limits, they are frozen (rendered static) and total breakage, breakage, chipping, workpiece cavity, hard cut interruption, etc. are distinguished one from the other via visual comparison with the monitor signal		Sudden load changes due to: • total tool breakage • tool breakage • tool chipping. Slow but large load changes due to variations in cutting depth (hardness, oversize, out-of-roundness of workpieces), such as occur during initial cuts in particular when machining cast and forged parts, are tolerated at a ratio of up to 1:4. The fast detection of breakages via dynamic limits leads to a drastic reduction in false alarms and substantially shorter signalling times after breakage (typically 5 ms after breakage).

Fig. 3.8.4: Signal types from the built in sensors [Prometec]

with the sensors located on the machine, the measuring is performed either directly during the cutting process or at its interruption and the appropriate correction data are generated by the CNC system for the workpiece which is just being machined.

The main feature of the post process active check arrangements is that the measuring is performed at the workpiece out of the machine working area, usually in the special measuring place (station) and the appropriate correction interventions are performed, when the immediately subsequent workpiece or another workpiece is machined.

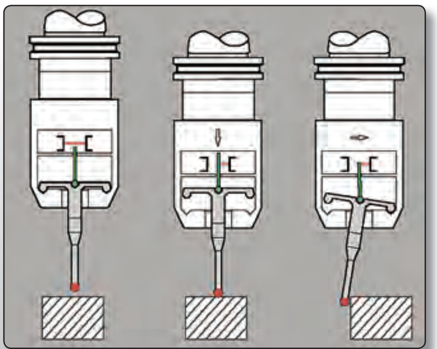


Fig. 3.8.5: Measuring mechanism of the workpiece measuring probe with optoelectronic signal generation [Blum]

Fig. 3.8.6: Measuring mechanism of the tool measuring probe with laser signal generation [Blum]

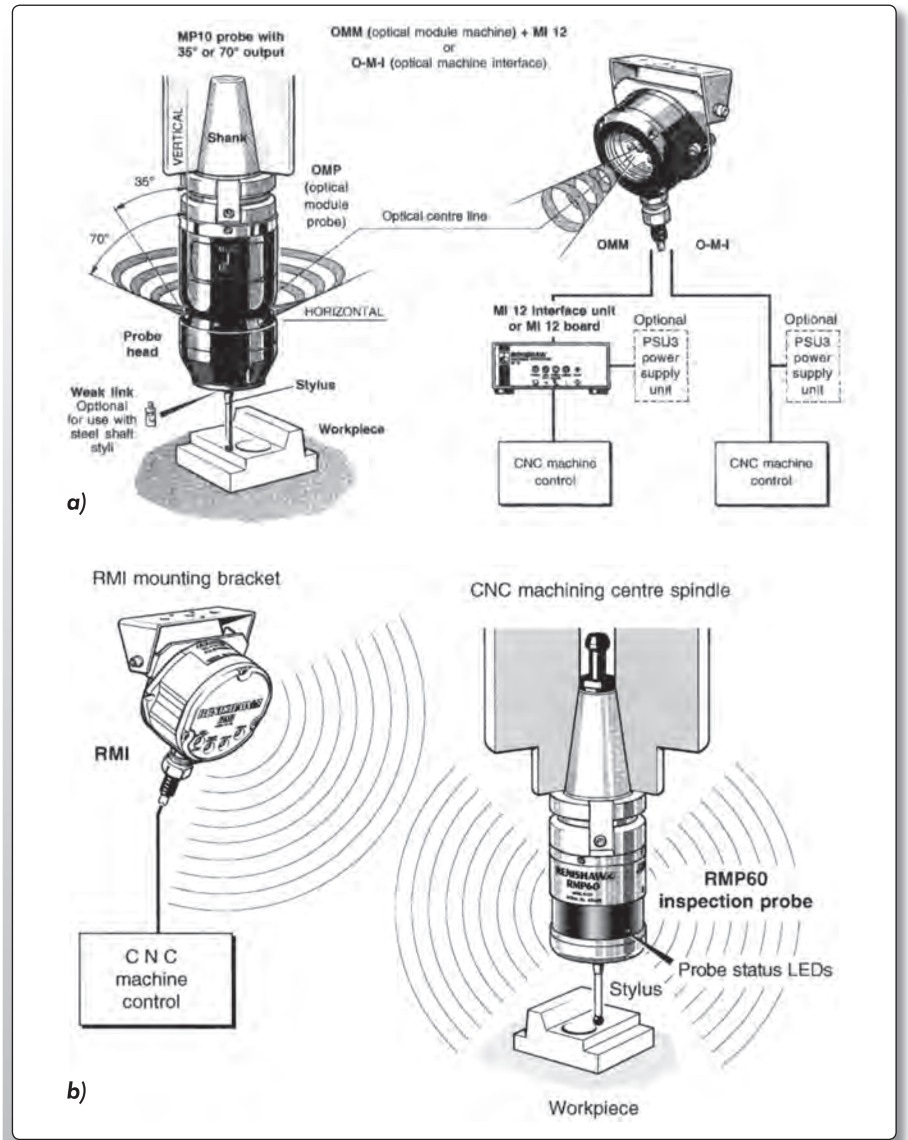


Fig. 3.8.7: Workpiece measuring probes – a) optical transfer, b) radio transfer [Renishaw]

The in process active check arrangements are divided into two groups according to their orientation and measuring way – into the active check arrangements, whose task is to monitor the state, adjustment and load of the cutting tools and into the active check arrangements, whose task is to provide the required working accuracy of the machine and the manufacturing accuracy.

The special monitors or the active check blocks realized within the CNC control systems (within the PLC part) are used for the active check of the state and load of the tools during machining. The immediate tool load values are obtained either from the measuring of the main feed drive power output or from the sensors installed on the machine (Fig. 3.8.3). One of the main disadvantages of this method is that the size of the sensed quantity(power output, torque, axial force) is usually influenced by disturbing effects (passive resistances, time constants of electrical elements, etc.). Therefore, the effort is to located these sensors as near to the cutting edge as possible; however, this is very difficult in the technical aspect [Borský 1992a].

The signals which can be obtained from the installed sensors are the following ones (Fig. 3.8.4): overloading, unloading, work