AEDS 2004 WORKSHOP
11 – 12 November 2004, Pilsen - Czech Republic

MODERN METHODS OF MACHINING SCULPTURED SURFACES

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Keywords : Milling, programming, digitalizing, reverse engineering

1. Introduction

Computer development and very fast growing computerization of engineering production in the recent 50 years had also a great influence on requirements laid on machine tool design.
Level of computer usage in a production chain, design – operations planning – production, is often considered to be a product quality prove. Wide use of computer aided techniques in production planning as well as following their use in NC technologies often creates a base of today's company prosperity.
Modern machine tools are mostly equipped with some of the powerful CNC control systems today. But their productivity depends on quality of NC programmes prepared either manually or nowadays by using some of CAD/CAM systems available on the market. The aim of their use is to increase productivity of this part of production planning, sometimes in other cases, e.g. in mold and die making, generating of NC codes without their help would be almost impossible.
The main obstacle for their higher use is probably their high cost accompanied by necessity to prepare in any case a special software product called postprocessor.

2. Problems solved within the framework of the research project

At the beginning, all of the CAD/CAM systems available were evaluated. Great effort was devoted to the CAD/CAM system CIMATRON, currently used at the department. In the annual report a survey of all substantial orders and their use recommendations were presented. Realization works were focused on creating space models of simplier parts, developing their production strategies, NC programmes and finally on production itself. As the machining of sculptured surfaces requires a great number of data transfer a local combined DNC net between NC machines in the workshop and particular department workplaces was built. This can be used either for connecting older machine tools or for new machine centers (Fig. 1).

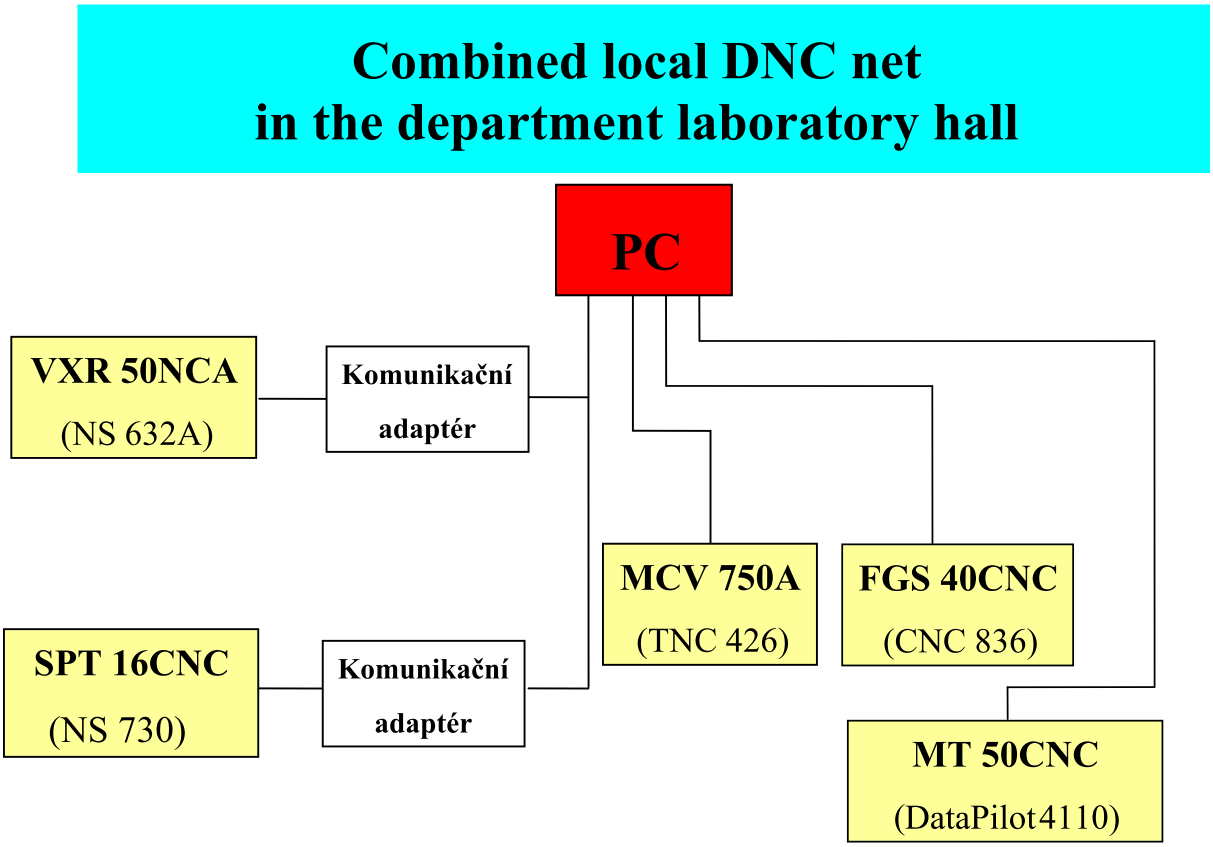


Figure 1. Local DNC net in the laboratory hall

This arrangement enables to transport a great number of NC programmes with thousands of information blocks. The largest NC programmes prepared were those for machining a crankshaft in 3 axes and for machining a rotary wheel of radial turbo- compressor in 5 axes (Fig.2, Fig.3)

Figure 2. Milling of a die cavity

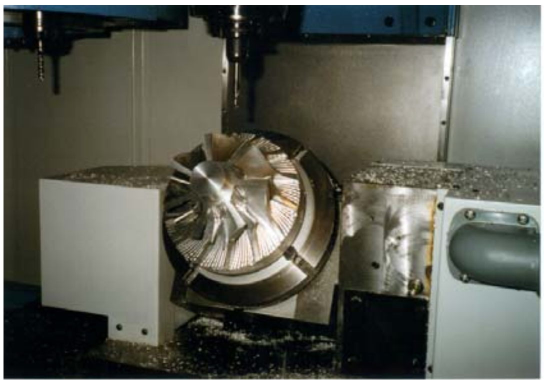


Figure 3. Milling of a rotary wheel of a radial Turbo-compressor

The results obtained were followed by works focused on verification of the NC programmes. For these works software NC SIMUL was used verifying several of them.

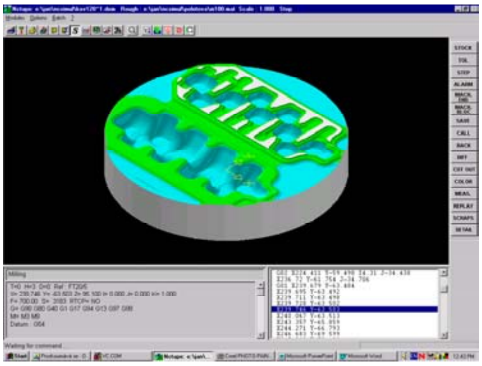


Figure 4. NC SIMUL
Final stage of machining

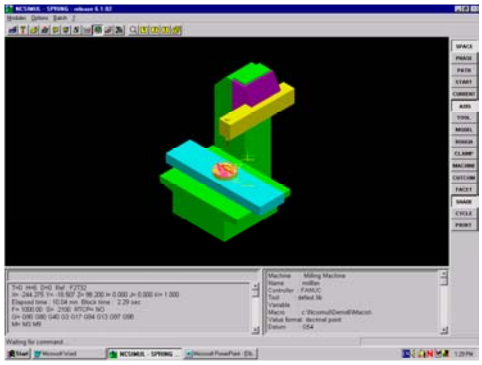


Figure 5. NC SIMUL
simulation of the whole machine

As shown on Fig 4 it is possible by using this software to visualize the machined part in its particular stages of machining and on basis of machine technical data to create the virtual model, its kinematics as well as its main and auxiliary motions. Bv means of

Figure 6. Reading of a model surface by means of an analogy probe SP 2

To make the NC programming more effective some of the department employees were chosen for training in running the analogy probe RENISHAW SP 2. Another RENISHAW software product TRACECUT was bought to process digitalized data obtained from the milling center MCV 750 NC A with the probe RENISHAW SP 2.
As a start in reverse engineering research a comparison study of model surfaces by means of a contact and analogy probes was carried out. Two softwares for digitalized data evaluation, software SUSA by Heidenhain Co and software TRACECUT were compared.

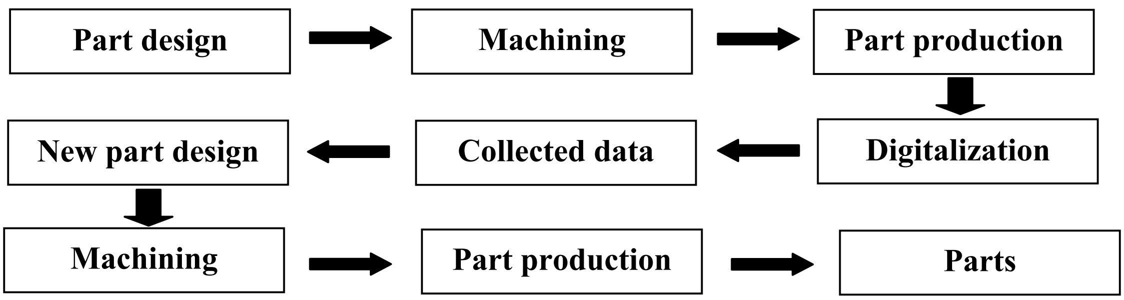


Figure 7. Shape and dimension checking procedure

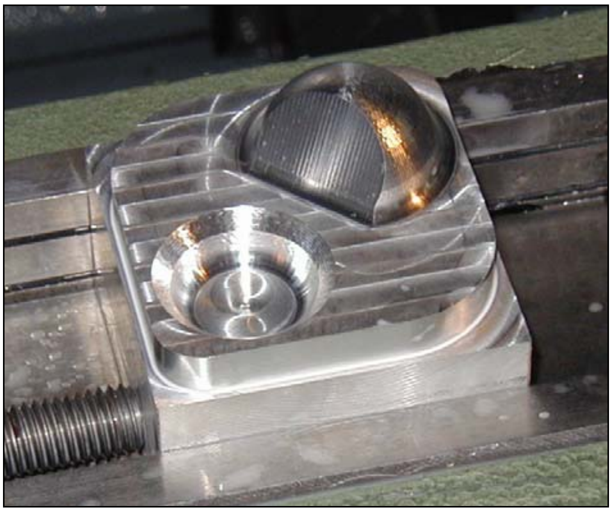
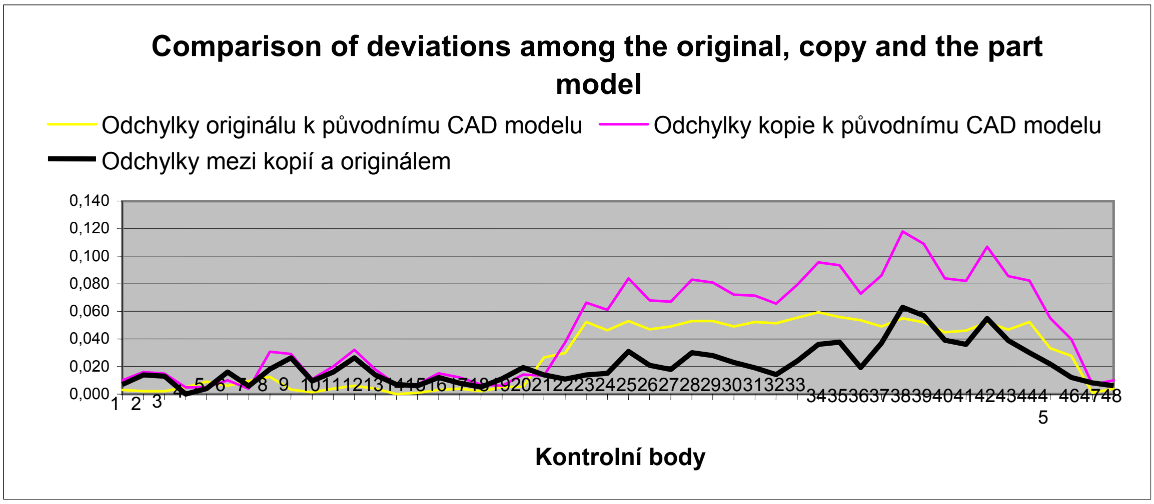


Figure 8. Specimen original



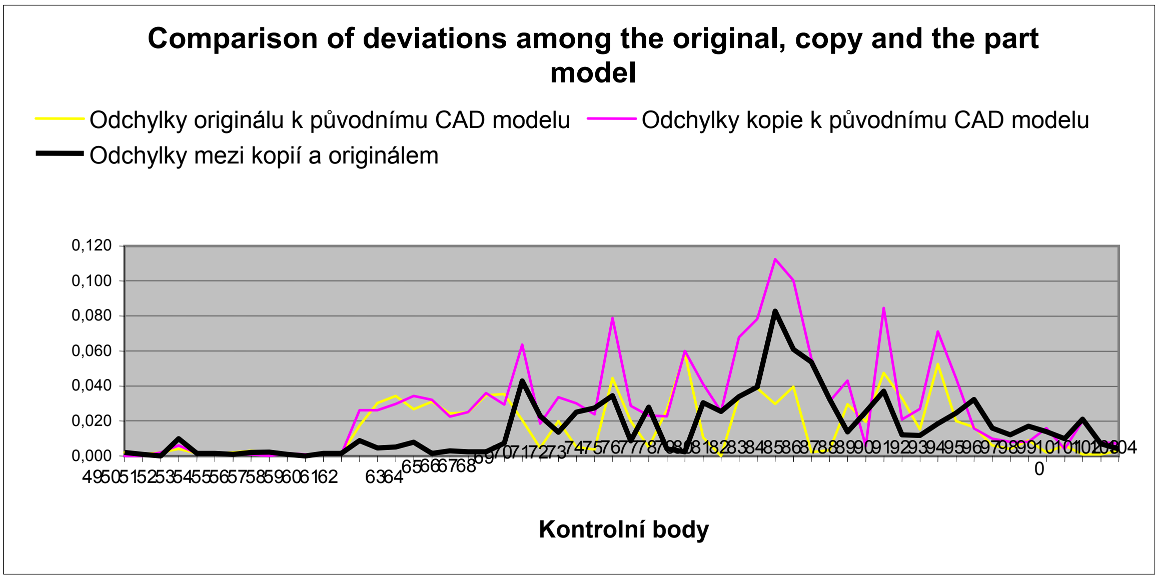


Figure 10. Deviations found on other surfaces

In the next step, the errors were looked for in the process chain – CAD/CAM part processing – its digitalization – CAD/CAM model from the digitalized data – NC programme- specimen copy making – measuring – comparison with the original part. For this purpose a part with complicated surface was used processed according to the scheme shown on Fig.7.
As the results show the deviations (original part vs. its copy) depend on a shape of the surface processed. The more complicated (sculptured) surface is the higher are the deviations. They also depend, to some extend, on the surface quality of the original part. Another reason of deviations found may by the fact, that the milling centre control system Heindenhain TNC 426 does not control the tool track in spline but in linear interpolation. Despite this relatively good results were achieved as the maximum deviation in the checked points didn't exceed 0,06 mm and cca 0,4 mm of deviation average (Fig.9, Fig 10).
One possibility of problems and of errors origin was the unbalanced rotating tool itself, causing not only dimension deviations but also lowering surface quality and the tool life.

Figure 11. Balancing system Balance IN

For research purposes in this case, the balancing system Balance IN by ISCAR Co developed mainly for high speed cutting applications was used. It enables perfect balancing of the tool clamped in the chuck collets with the balancing rings.
The balancing was carried out on a balancing machine PTB – 7.1 at Žďas Co. in Žďár nad Sázavou, by the assistance of ISCAR Co. technicians. From the report information can be obtained about the magnitude of unbalanced mass as well as of limits which should not exceed those for high speed cutting applications.
The balancing machine PTB – 7.1 (Fig.11) is suitable for tool and tool holder static balancing held in the chuck adapter and HSK (hollow cone holder) or in another corresponding centralizing tool holder of the machine.

Fig. 12 Balancing machine PTB – 7.1

The balancing of the whole system was achieved by setting 19 gmm on the balancing nut as reported. Unbalancing of the system was carried out by adding step by step 9 gmm up to 36 gmm to a balancing nut settings, having on its scale gradually 28,37,46,55 gmm. Effect of it was continuously evaluated by taking a width of a milled slot as a measure of unbalancing. The width was checked by a contact measuring probe (Fig.13). It was found out that at 4 500 rpm the maximum width deviation was 0,013 mm well corresponding to the mathematical model. To prove the model in detail, further research work is prepared. Using of the accelerating head FAEMAT in revolutions range between 2 000-2 500 rpm is suggested for this purpose.

Figure 13. Slot width measuring by a contact probe

In the effort to follow introduction of new cutting materials into the practice, new long-term works on programming of progressive cutting tools working cycles were prepared. The great attention was devoted to the programming system KOVOPROG for which a number of unique technologies using some of the new cutting tools was developed. The main advantage of the system is its overstructure enabling making its own general programmes so called macres, which can be added to the system. These may contain our knowledge about the optimal tool usage obtained either from the producer or from our own experience.
As an example of a working cycle, a cycle of milling a hole into a plain material using a helix interpolation can be presented (Fig.14).

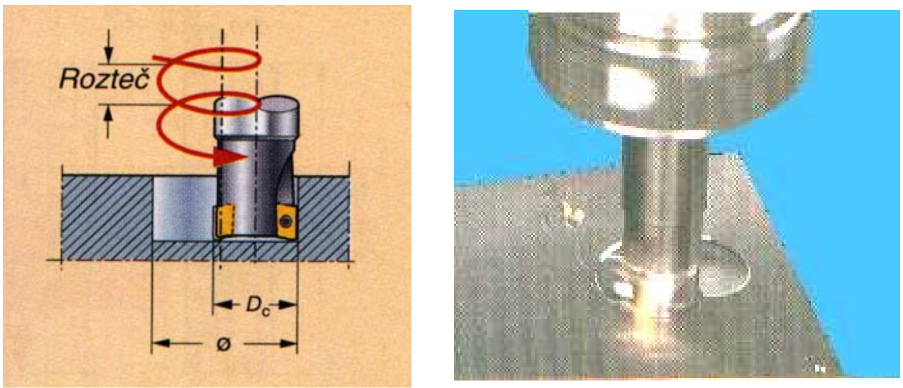


Figure 14. Milling of a hole using a helix interpolation

Its principle as shown is a end mill helix motion. If there is a blind hole the mill makes a circular motion to make the hole bottom flat. The mill starts milling from the part surface in the utmost position of the hole diameter. Its exit at the bottom is in a circle interpolation towards the hole axis. It's important to choose proper mill dimension. Using of a producer's catalogue is advisable.

Helix interpolation can also be used for another working cycle, i.e. milling of external and internal threads with a single point disposable cutting insert. It differs from the previous one at the hole bottom by not having a circular interpolation. The helix pitch is equal to the thread pitch. Important is a proper diameter setting of the tool as the tool must be set on the pitch diameter of the thread cut.

Similar to thread milling with a single point insert is that with a multi point insert (Fig.15). The tool in this technology makes a trace equal only to 1-11/4 helix lead. The tool is set on a full length of the thread, makes a radial motion to the full depth of cut and finally moves axially 1-11/4 helix lead.

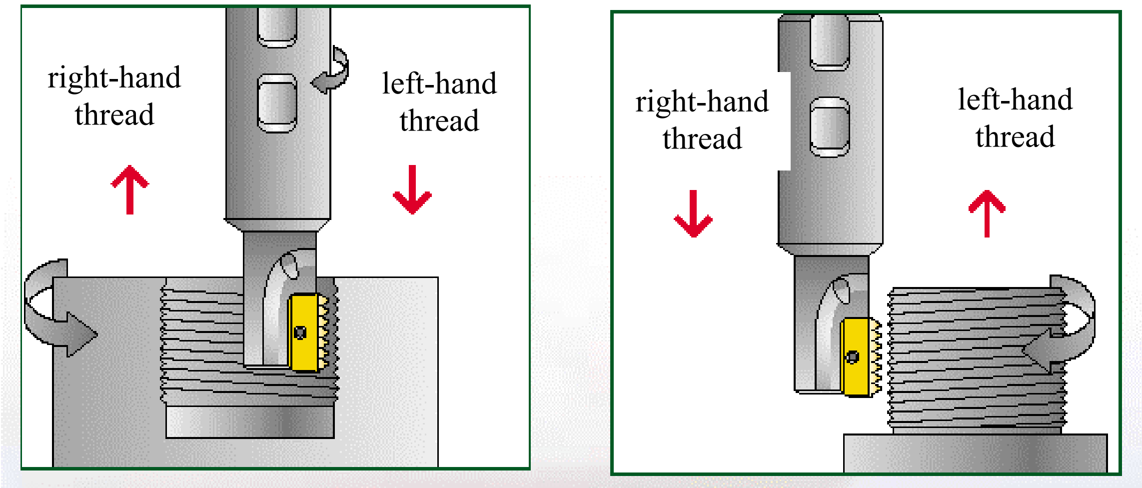


Fig. 15 Milling of internal and external threads

Another working cycle is so called groowing milling or cavity roughing (Fig.16).This cycle is used for milling of deep cavities with extended tools usually of smaller diameters, where if classical milling is used with a side feed, vibrations or larger tool deflections may arise.

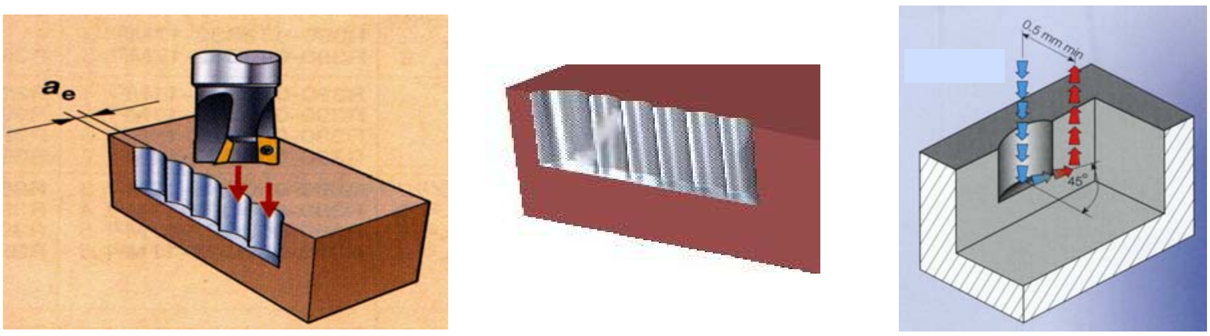


Fig. 16 Groowing milling

As the last example of working cycles is so called ramping shown on Fig.17. In this way e.g. a slot for a key by means of an end mill can be made, without using a special slot milling cutter. The tool motion can be arranged by programming (lightened) in its utmost positions as shown on Fig. 17, when the milling cutter E 90 A -D25 by ISCAR Co. was used.

Within the framework of our research, we have processed 12 of such working cycles for the progressive cutting tools available on the market.

All members of the teaching staff concerned would like to appreciate cooperation with our students both in undergraduate and graduate doctoral study programmes.