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# DEVELOPMENT OF ULTRAPRECISIONAL TURNING IN CIM

**Summary.** Ultraprecisional machining becomes more and more frequent. On the other hand, its theory and practice gets adequate place and role both in graduate and postgraduate engineer education. An ultraprecisional CNC lathe laboratory has been installed in the Department of Production Engineering of the University of Miskolc (UM). This laboratory was estableshed following the winning of the competition of the National Technical Development Committee (OMFB, Budapest). We targeted some 3 μm ... 0.1 μm as final accuracy at the designing and its performance. Desired interval of average roughess: $R_a$ = 0.08...0.02 μm . Accuracy and roughness are the function of numerous factors. This work summerizes environmental conditions and those completion, shows the already performed laboratory and plans for its continued development. On the other hand, its theory and practice gets adequate place and role both in graduate and postgraduate engineer education.

## 1. INTRODUCTION

The sudden prevalence of microelectronics and mechatronics, as well as the development of the designing and production of mechanical devices has established the high accuracy production.
The interrelationship is unambiguous. On the one side, high accuracy production is a primary condition of microelectronics and mechatronics (extreme accuracy and surface roughness). On the other hand, application of microelectronics and mechatronics has made realization of ultra - accuracy or nano technologies possible. Certainly, research and development of mechanical devices has also kept pace with the needs.
The majority of the actuating and intervening mechanismis is still mechanical, but in the field of regulation or sensing, microelectronics and mechatronics became general.
Thus, tools of the high accuracy production have been established as a result of the complex interrelationship.
Ultraprecision turning is an example of the complex interrelationship, too [1, 2, 3, 4].

## 2. ULTRAPRECISIONAL MACHINING CONDITIONS

There are a number of conditions for ultraprecisional machining. These conditions are:
- machining installation of adequate accuracy;
- prefabricated material of desired quality (material, hardness, homogeneity, fine grained material structure, allowance, etc.);
- adjustable and deformation-free workpiece holder;
- diamond (for non-ferrous metal parts) and CBN (for hardened steel points) singlepoint tools of ultraprecion accuracy and geometry;
- optimum technological data ($v_c$, a, f);

- disturbance-free environmental conditions;
- roughness and length measurement of adequate accuracy (dimension, shape and position - accuracy control), etc.

All terms are supposed to be satisfied. Only those environmental conditions should be considered in detail that are considered at the designing and realization.

## 3. SYSTEM OF ENVIRONMENTAL CONDITIONS

Following important environmental disturbances (noises) shall be taken into account for ultraprecisional machining and measuring:

a/ Vibrations: Originating from the surrounding vibration sources, e.g. cutting machines. (Suppose that self-vibrations appearing on the ultraprecision lathe can be discarded).

b/ Air temperature changes

c/ Dust in the air, etc.

d/ Subjection disturbances (mistakes of the operating staff), etc.

In this case, however, we only deal with the listening of objective sources of error - a, - c, - and summarize those practicable limitation which is also a function of financial means at our disposal.

## 4. ENVIRONMENTAL CONDITIONS

Ultraprecisional machining and measuring are extremely sensitive to the environmental influences, especially to vibration, changing of temperature, the dust content of air and the air movements. Vibration comes from external sources and from the ultraprecisional lathe, itself. The machine tool in question (or machining unit) must be placed on a solid, non-vibrational base that is independent from building. The manufacturer of UP-1. lathe (*Csepel MachineTool Groups Ltd*) recommends a monolite, concrete mass with 1500x1500 mm of base area and 700 mm thickness. Increasing the dimensions of the mass will decrease the vibration. The independent base built at the University of Miskolc is 2000x2000x800 mm in size. It is a reinforced-concrete block with low steel-ratio of concrete.

The block is surrounded by hard rubber sheets which were embedded in stone packing. The stone packing (pebble bed) is a very good damper of vibration. The lathe can not be fixed to the base, it can only be installed either on a stand with efficient insulation and damping, or on air springs. By an appropriate change of the spring rating and damping factor of the vibration damping shoes of the bed, the vibrations can be limited to a minimum value.

In case of UP-1 lathe (made in Csepel Machine Tool Groups Ltd), according to the manufacturer, for precision-mechanical accuracy, the permissible amplitude of natural vibrations of the machine base (A) is less or equal to 0.25 μm, its natural frequency (F) is less or equal to 50 Hz and its acceleration (a) is less or equal to 7 $mm/s^2$. In addition to the submicron accuracy, the permissible values according to the previously mentioned order are as follows: $A \leq 0.1$ μm, $F \leq 5$ Hz, $a \leq 3$ $mm/s^2$. In case of the augmented optical accuracy which is between the accuracy of precisional machines and ultraprecisional equipment, the natural vibration characteristics of the base can be arranged between the aforementioned limit values. Transmission of vibration to the base of the machine (e.g. from a hydraulic supply unit) should be avoided. In the Ultraprecisional Turning Lab. of the University of Miskolc, an independent base and air springs were used together. Under the machine four air springs were built in.

The ultraprecisional lathe should be operated in an air conditioned room. Entering is only possible through an air-release valve. The solution demonstrated in Fig. 1. also meets these requirements, but accuracy is limited by local circumstances and cost constraints. In the working range of high accuracy we targeted the maximum accuracy achievable in practice: the basic machine and its control equipment were only used there. All the heat and noise sources (e.g. hydraulic supply unit, oil cooler, 3 phase junction box, chip-exhaust unit, fog cooler) were placed outside the working range. They do not require expensive air conditioning. The permissible change of air temperature (Δt) is less than or equal to 1 °C per hour for precision mechanical accuracy. In case of submicron degree Δt 0.2 °C per hour is usual. The prescribed value for high optical accuracy may be between the two limits.

The limit for dust content of the working area is close to a surgery. Grains with 0.5 μm maximum size, 40,000 pieces per $m^3$ is permissible. For air speed, a limit of v ≤ 0.3 m/min must be observed. The laboratory installed at the University of Miskolc fulfills ultraprecision requirements [3].

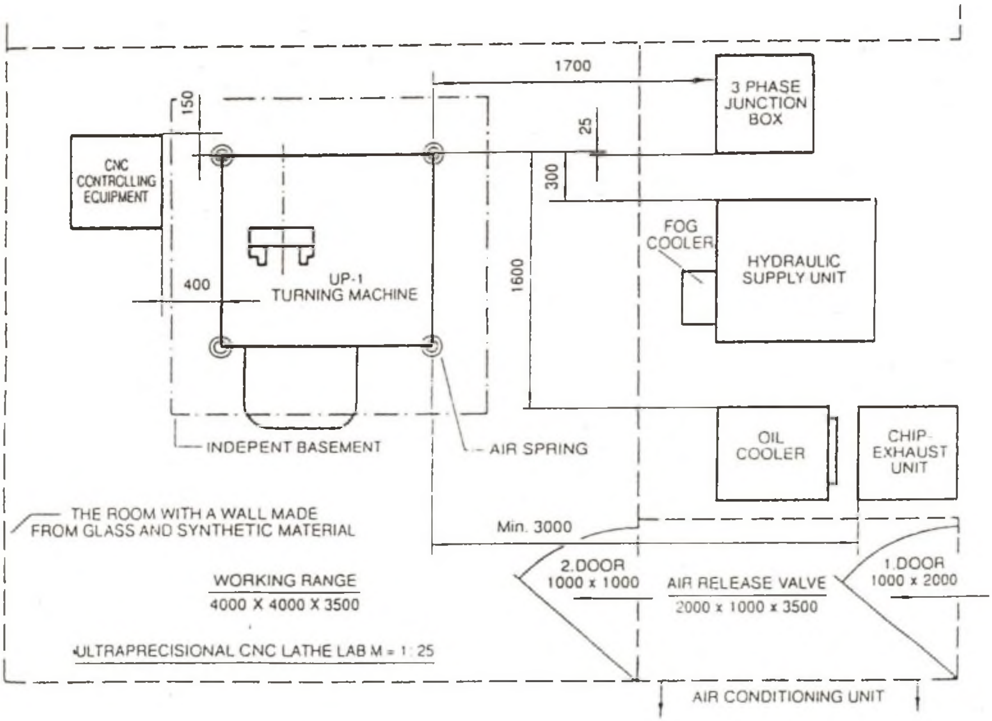


Fig. 1. Ground-plan of the ultraprecision lathe laboratory

## 5. MAIN STEPS OF THE DEVELOPING OF ULTRAPRECISION LATHE LABORATORY

In the preceding we discussed the present situation realized. Our main purpose was to ensure the most impotant basic functions for designing and performing the laboratory. Naturally, the lack of financial means had a very strong effect. Accuracy and surface quality can be improved further through the following measures and development.

First step. The following things can be achieved by minimum cost and business organization

- continuous ultra - filtration of air for air-conditioning (filter-changes);
- maximum two persons are allowed to stay in the operating area;
- strictest keeping of air-lock times and of temperature stabilization
- increase of cleanliness (change of clothes, slipper's, thread gloves, etc.);
- optimation of technological parameters and adapting to given jobs;
- making of NC computer program and computer simulation;
- design and production of high accuracy devices for the clamping of the workpieces (e.g. expansion mandrels);
- environmental conditions (e.g. temperature, measurement of the dust content of the air) , supervision and taking the necessary measures;
- second working of parts with one clamp
- turret system tool holder application and machining of less accurate surfaces with its tools;
- settling a design-aiding PC near the machine;

Second step:
- purchase and adapting of CAD/CAM softwares;
- using robots for the attendance of machines
- monitoring inspection of working process, etc.

At extreme accuracy the process of cutting can not be observed directly. The heat radiation of the human body is equal to a 300 W filament of a lamp, approximately.

The firm "*Toyoda*" recommends a TV chain for observing and controlling the cutting process.

Thus, there is no attendant in the operating area, its heat effect is eleminated, etc.

In the latter case, ultraprecision cell and robot would get a cell-controlling computer or would be supervised by that computer.

More considerable expenditures are needed, and costs are investmentlike.

Third step: In addition to this, the system can be supplemented with measuring and quality control. Contact-free roughness measuring and laser interference length measurement will be needed for accomplishing this duty. These units would also be connected to the cell-controlling computer and would assure quality regulation of work pieces. In the highest level, tool adjusting appliances and tool monitoring makes the system complete. Realization of certain developing steps is a function of economic conditions, and it will be seen in the future. Successful competition work or research order, however, may have a positive influence.

At the device or tool market, there is not significant supply for the latter, mainly in the 0.1 μm range of accuracy.

We have dealt on the merits with all of the jobs encountered in the first development step, or we have already realized these with the exception of their PC computer installation, although, connecting place of the computer network has already been introduced.

The steps that only need organizational jobs can be implemented at any time, but attention must be paid to the university education (regular and post-graduate training), too.

The machine has been supplied with 8 tool space turret, which can be operated or programmed from the control unit (NUM 760 T) [4].

Considered application of the turret -system tool holder has several advantages.

One: high accuracy and expensive tools (on the plane-table: 1...3 prices) can be preserved, are only used when necessary.

On the other hand, high accuracy tools are adjusted once and they need no change or repair, which decreases accuracy or can lead to tool damages. From another point of veiw, turret system tool holder saves a considerable auxiliary time.

Certainly, we must consider the positioning error, consequently, ultra accuracy surfaces are not machined from the turret.

NC programming, simulation and dimensioning of the expansion mandrels clamping the workpiece are aided by softwares made by ourselves [5, 6].
Realization of the development steps is a function of the economic conditions and industrial orders, which will be seen in the future. Our narrow means do not allow improvement of the ultraprecision machine presently. Such job could be e.g. design and implementation of a hydrostatic tailstock. Industrial orders could also speed up the development process.

## 6. APPLICATIONS

In view of the accuracy and roughness required at the beginning of the article, 40-70 per cent calculated from above of the given interval can be reached presently, too. Further research and application experiences improve this value.
As a matter of course, it still is the high tech.
Foreign applications of ultraprecision turning are known [1, 2], now these will not be listed.
We shall discuss two parts of our work, their high accuracy machining can be related to industrial jobs.
One of these: automobile carburetter part made of aluminium alloy (AlMgSi1), of very complicated shape; the tool must also work in bores, and the lowest surface roughness must be reached because of the lessening of flow loss (Fig. 2.).
Material of the other part (Fig. 3) is hardened steel (GO3, HRC 60 ± 2).
We were able to assure the needed accuracy and roughness for both jobs.
Further jobs will be discussed for the production of high accuracy tools, appliances and special bearings.
Research work is being done with the aid of OTKA 2361/91.

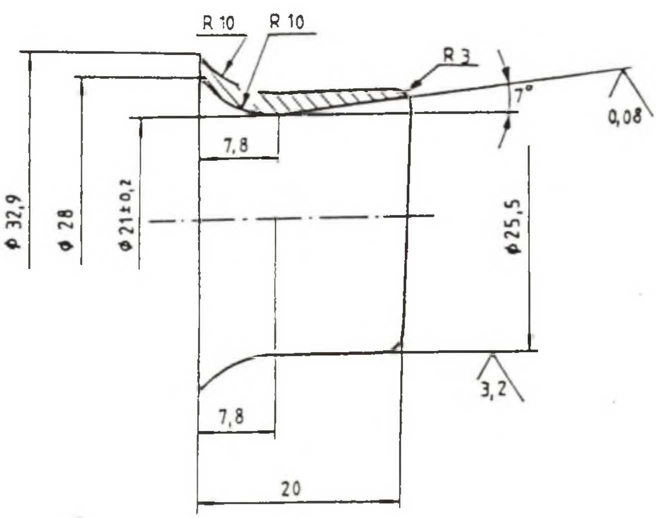


Fig. 2. Carburetter part

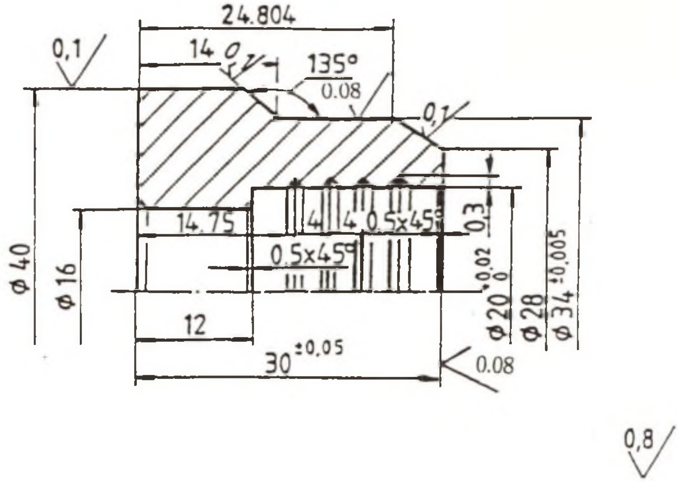


Fig.3. Part made of hardened steel

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