Models in teaching – new possibilities

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Abstract - **Teaching is based on text and picture. Different forms of recording geometrical form are used such as Monge's projections, axonometry etc. Despite the fact that computer programs have been introduces, the picture on the screen still remains 2D. 3D physical model which can be touched is the most real since it does not require any additional skills to see it from any side. A model is a very precious tool which facilitates the transfer of information about solids. For people who start their learning it is the most effective method of information transfer. In the past it used to be a difficult process because it was necessary to create documentation and relocate it to a workshop where a model can be made. It was especially difficult to obtain irregular shapes. Currently due to the technological development it is much easier to create models e.g. Rapid Prototyping which means that a person without special preparation or practice (milling, rolling etc.) is able to prepare suitable models. CNC machines have been available for quite a while but they have been expensive and difficult to program. Nowadays it is possible to use digital model created in a given computer program e.g. Desktop prototype milling machine, 3D Printers, Stereolithography etc. These types of machines allow almost total freedom of creation of even the most complex models.**

Another aspect of using these machines in teaching is getting students to know the latest technological advances. It is especially important in such designing domains as architecture, mechanics etc. The models are important not only in designing but also in technological process designing. Apart from engineering models are more and more used in surgery, radiology and rehabilitation which form new domains of their application.

The paper presents the author's experience in creation and usage of the models.

Index Terms – CNC, model, teaching

INTRODUCTION

More and more common access to CNC machines offers new possibilities to use them in cognitive process not only at technical institutions of higher education.

Bigger and bigger potential provided by new technologies e.g. Rapid Prototyping, 3D Printers, Stereolithography etc. allow almost free shaping of a model. Lower costs of these types of machines as well as home made machine tools [4],[5] give possibilities of creating useful models for cognitive process.. Possibilities of modern machines are greater and objects which could be seen only on a computer screen, now can be made from different plastics and we can watch them in reality.

METAL CUTTING METHOD

The author's experience is based on machine tool Roland MDX-40R z Rotary Axis Unit, 3D Scanning Sensor Unit specification.:

- Acceptable materials: Acrylic, Polyacetal, ABS, Delrin, Nylon, Perspex, Wood, Wax, Epoxy and Modeling Boards
- X,V, and Z operational strokes: 305 (X) x 305(V) x 105 (Z) mm.
- Distance from spindle tip to table: maximum 125 mm
- Table size: 305 (W) x 305 (D) mm
- Loadable workpiece weight: 4 kg
- XYZ-axis motor: stepping motor
- Feed rate: 0.1 to 50 mm/sec. XY-axis
- Feed rate: 0.1 to 30 mm/sec. Z-axis
- Software resolution: 0.01 mm/step
- Mechanical resolution: 0.002 mm/step

DETERMINATION OF MACHINING PARAMETERS

Different materials can be machined on CNC milling machine or lathe. Since creation of a model (a real solid) is a single process and therefore machining material will be in a form of a cylinder or a plate. Due to the fact that a model will not carry loads there is no need to use highly durable materials. Therefore, for teaching and cognitive purposes soft materials can be used and they are easily machined. They can be plastics, wood etc. It is difficult to determine machining parameters for a given material since a given material has not always been designed for metal cutting method [2]. Therefore it may be necessary to determine the parameters for a given material. In case of wood additionally problems with anisotropic structure occur. There are clear rings which give locally harder material and it will cause machining problems. Consequently, the parameters must be chosen for those harder parts of material. In case of solid models, parameters selection should include two aspects: a given class of precision and forces which occur during the process.

It is not possible to see these processes as separate: machining parameters i.e. spindle speed and feed rate. These parameters are, due to their geometrical dependencies, related.

With too high rotation speeds of spindle, overheating of material can occur which would be seen as 'melting' or 'burning' of surface. Too low rotations can result in too greater forces, because with the same feed a significant slice of material will be taken. In case of harder material machining parameters influence the condition of a tool.

Rotation speed of a spindle together with feed decide how big slice of material will be removed. This value influences the forces which occur in the machining process. Too great forces can damage the machine and therefore care should be taken to choose optimal speed of a spindle. The size of a tool must be taken into account and naturally linear velocity of tool blade at the same speed depends on e.g. radius of milling.

Feed rate directly influences the exactness of obtained surface. The smaller feed, the more exact surface. But on the other hand the smaller feed, the longer the process. It can be important since a model constitutes only a fraction of the whole material being machined (e.g. maximal possible torus constitutes 54% of the used material).

PREPARATION OF SOLID MODEL

Due to technical aspects virtual model can be designed, based on different software. The used software of milling machine enables solid import in files of different formats. Thanks to that we can fully appreciate technical abilities of machine relaying on designs in CAD or visualization programs e.g. 3DstudioMax. However, powerful programs in surface/solid modeling are indispensable here, which have such format of output files that a machine will accept. While virtual designing of an object, technological possibilities of a given machine should be included, which results in necessity of good preparation of geometry tasks for machining. Some machining restrictions can be overcome e.g. by a change of material location by means of shift or rotation. Software usually enables creation of both virtual surface models as well as solid ones, accepted by a machine.

Plane model

Such a model is relatively simple to generate. Very popular DXF files format enables creation of a model even outside graphic program. A given program can be written in one of the programming languages e.g. C, Pascal, Basic. Model is then created from planar quadrangles and it is then necessary to calculate location of vertexes of a quadrangle or triangle so that the creating element is planar, that is in one plane.

Solid model

Possibilities of virtual modeling outside the specialist programs are much more limited here. However, one of the advantages of such models is e.g. possibility to use logical operations of B-spline, including NURBS surface. Virtual solid model is easier to prepare and thus designing time is shorter and it allows creation of models of limited shapes.

Necessary material allowance

In every creation process based on metal cutting methods some kind of material allowance should be foreseen. This allowance results from the necessity of fixing the element and also due to e.g. later unification.

PREPARATION OF PROPER MATERIAL FIXING FOR SOLID CREATION

Application of various materials and then creating different, quite often complex elements out of them, implies the usage of various and ingenious solutions. For that purpose in production sites there are special divisions designing and next elaborating additional equipment[3]. This equipment is relatively expensive and designed for one type of element. For academic purposes we cannot afford such extravagancy and so we had to elaborate very 'flexible' system of fixing machined material. This is fixing for experimental stage where we test different materials and it has two clamps of changing length. (Photo 1).

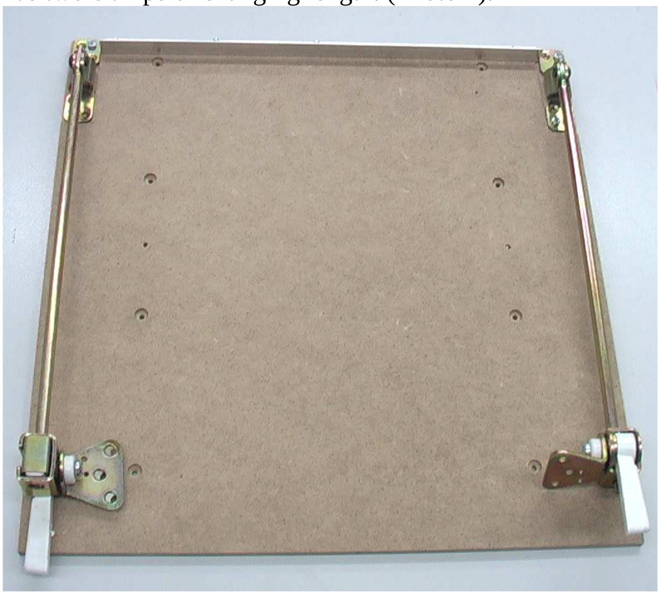

PHOTO 1 FIXING FOR EXPERIMENTAL STAGE

In this way it is possible to use even small pieces of material for determination of optimal conditions for machining. For teaching purposes, due to the time of machining, it is the best solution to use soft materials. However, soft materials do not last long and clamping fixing is impractical since machining element could be easily destroyed. Logically, one can imagine that the clamping would be strictly controlled but it would need expensive monitoring device. What is more, for each operation it would be necessary to determine the value of permissible force of clamp, since joint: clamp and material can refer to various surfaces and it means a change in clamping force.

For a given plastic, clamping is determined which causes distortion by 10% e.g. XPS equals 0.2-0.7 [MPa].That is why the choice of surface clamping seems to be a better solution. We suggest that material for the model should be glued to thin plate made from Polymethyl methacrylate (PMMA) glue, water soluble one. This plate is waterproof and even with thickness of 2-3 mm it is rigid enough. When machining is finished an element can be glued out.

Machining with single fixing

Due to surface fixing it is optimal to plan machining in a way that in one fixing final model is made. From a type of machining and kind of fixing it results that one surface will not be machined. With rotary axis it is possible to get desirable shapes in one fixing, which needs machine tool with four degrees of freedom. However, we should not forget that machine tool has some restrictions resulting from its construction and that is why it is impossible to make for example a whole of conic shape (Fig. 1).

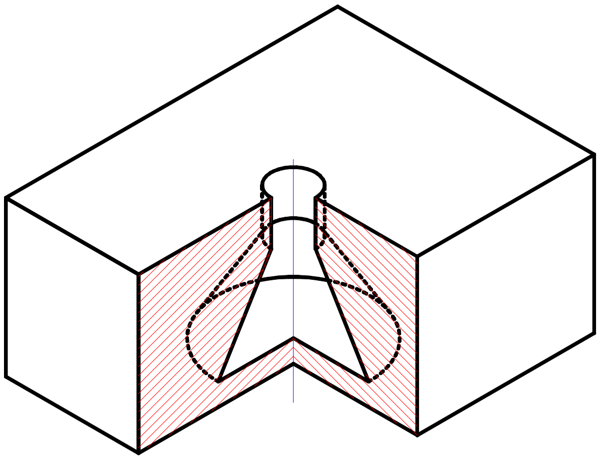

FIGURE 1 IMPOSSIBLE TO MAKE - WHOLE OF CONIC SHAPE

Machining with changing fixing

With the possibility of changing object location e.g. machining after the change of fixing, the range of machining possibilities increases. In this way it is possible to obtain a model which is machined from every side. With great machining exactness 0.1-0.05 mm it is possible to make divided models. Nevertheless, making a model in parts should be predicted at the level of virtual model so that later the parts can be precisely joined. Suitably prepared junctions which would position elements one in relation to another can be given as example.

CHOICE OF SUITABLE STRATEGY OF MODEL CREATION

There are different ways of model creation to choose as– surfacing, roughting, finishing, drilling and also we can select type of tool path to create – scan lines, unidirectional x or y, contour lines, spiral. The choice of proper method can significantly shorten machining time. It is important to choose such way of machining which includes topology of created object. Some programs after generating tool path, determine its length and it shortens machining time. For the less experienced it is a way to select suitable working path.

FINISHING PROCESS

Finishing process is an important element of the process. Thanks to the application of small feed we get surfaces of high smoothness. Similarly to parameters of basic/prime machining it is necessary to determine parameters of finishing process. On the one hand small feed gives very smooth surface, but on the other hand it extends the time of machining. Therefore, we must choose between these two contradictions.

TECHNOLOGICAL RESTRICTIONS

An idea of a model which is to be used in didactics must be compared with the possibilities of a machine In each creative process there are some drawbacks and a designer should be aware of them. Technical possibilities are discovered in particular designing and realization circumstances. First restriction is maximal size of machining element, other can be machining of sides, which are perpendicular to the table and thus parallel to spindle axis. It must be remembered, when making a model of e.g. a surface, that spindle does not have dimensions of a tool. It can lead to a collision of spindle and material.

POSSIBLE WAYS OF AVOIDING TECHNOLOGICAL RESTRICTIONS

In order to overcome restrictions which result from machine tool construction as well as from necessity of making a given model, various solutions can be suggested:

- Division of model into elements which can be made
- Change in the location of element without changing the fixing
- Change in the location of element with changing the fixing
- Application of specially prepared tools e.g. profile cutters
- Application of special layers for finishing process

Depending on the situation other solutions can be used resulting from model shape.

MODEL IN DIDACTIC PROCESS

It is the real model which appeals to students the most. It can be confirmed by models which for many years have been used in didactic process. However, for technical reasons they have been simple models e.g. a rotation cone, rotational cylinder, torus etc. Department of Mathematics TU Dresden, offers a great collection of models where models have been made and collected for almost 100 years.[7]

New laboratories have been created, equipped with recent technological advances for modeling, not only for virtual modeling, in places where they have had the experience of using models in didactic process. [8]

Thanks to great possibilities the following models are planned to be made or have been made: parabolic cylinder, hyperbolic cylinder, elliptic paraboloid, hyperbolic paraboloid, ellipsoid, one-sheeted hyperboloid, two-sheeted hyperboloid, elliptic cylinder, Platonic solids (octahedron, dodecahedron, icosahedron).

PHOTO 2
HYPERBOLIC PARABOLOID – MODEL (25%)

CONCLUSIONS

Up till now in order to prepare a drawing of the presented issues in a form of a model it was necessary to have a workshop with experienced workers and a big number of different machines. Introduction of CNC machines of small size and user friendly software allows people with much less experience and knowledge to make models. The degree of model difficulty made on CNC machines has increased significantly. Although as it can be understood from the paper the process of making a model on CNC machine is a time consuming, its possibilities based on computer model make up for this drawback.

A model made in a traditional way has some drawbacks:

- It is necessary that a person is experienced
- Usage of suitable machines
- Necessity of preparation of technical documentation
- Costs
- For some models lack of possibility of repetition

There are some advantages as well:

- Possibility of using very durable materials e.g. steel

A model made on CNC machine has some disadvantages:

- Low durability of material
- Problems with fixing

As well as advantages:

- Easy service (CAD model)
- One machine substitutes few traditional ones
- Small size and weight
- Possibility of creating one's own CNC machines

For example 3D printer lacks these drawbacks.

To sum up a teacher, not necessarily university teacher has been given subsequent aid in geometry teaching. This aid does not refer only to technical courses, since models can also upgrade the quality of education of doctors, artists etc

FUTURE WORK

In the future we should deal with application of CNC machines in learning. The presented material refers to model preparation by a teacher. Providing students with an opportunity to design and make an element gives them a possibility to work out certain features necessary for a future engineer. As a result of such teaching one should expect better understanding of the issues concerning both geometry and technology.

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