CA DESIGN, MANUFACTRUING AND INSPECTION OF FREE FORM SURFACES

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Abstract: *In this paper we present the relation between CA technologies and new phenomenon in engineering – free form surfaces. These both evolved jointly and their development is conjoint to day too. We will show how CA technologies are very close jointed, they synthetise the latest knowledge from many disciplines.*
Key words: *CA-technologies, CAD, CAM, CAQ, Free Form Surfaces*

1. INTRODUCTION

Very important area from viewing angle of computer aid of mechanical engineering is the Design, Manufacturing and Inspect of free form surfaces. The many software's firms produce night and day the new CA software for Design, Manufacturing and Inspect of free form surfaces. The designer can make new free form surface much better, quicker, comfortable. The machine operator can make the NC program for conventional machining without more knows of the cutting process. On the other hand the free form surfaces machining is not only the creation of NC programme but it is the creation of all philosophy and strategy of machining. The controller can inspect the machined free form surfaces very easy by the new CA inspection technologies and he can make the very exact resolutions. It claims to know the fundamentals of CA processes, new principles, constraints, recommendations by CA processes and actively using of CAD/CAM/CAQ tools for realisation of effective Design, Manufacturing and Inspection processes. It can keep design, cutting, inspection and computer engineer in one person – so we can say he is a CAD/CAM/CAQ technologist.

2. CAD SOFTWARE AND FREE FORM SURFACES

The main task of CAD software is quick and exactly to prepare the computer model of part. The newest versions of CAD/CAM systems provide the new resources of modelling of complex free form surfaces. This new styles of modelling has the mixed name – Free Form Modelling. The main philosophy of Free Form Modelling is: "make the complicated surfaces as a you sentient it". For this philosophy, the Free Form Modelling involve the special curvilinear and surface functions. They are dedicated for the dynamic manipulating with the surfaces in real time, with feedback on the quality of the realised curves and surfaces. By the Free Form Modelling are the surfaces created very fast and good very a savoir without the gaps between two surfaces, without sharp edges, corners and abrupt transition between surfaces, without ledges, mounts and lumps on surfaces. This is one of the most important conditions for HSC (High Speed Cutting) and HSM (High Speed Machining).

The free form software approach to modelling is like no other 3D modelling package you have ever used. It leverages your sense of touch to control basic tools that mimic sculpting and foam cutting. At the same time Free Form Modelling provides digital advantages and workflow capabilities that you expect from a computer application. The free form software adds sophisticated shape creation and deformation techniques which provide designers with the extra measure of control required to assure compliance with design criteria [1].

Fig. 1. Free Form Modelling system[1]

The Free Form Modelling is built on the 3D Touch technology. The 3D Touch allows users to directly interact with digital objects exactly as they do in the real world. Modelers sculpt as naturally in digital form as they do in clay and surgeons perfect their crafts with virtual patients instead of actual people [1].

Fig. 2. The example of 3D parts with free form surfaces [1]

3. CAM SOFTWARE AND FREE FORM SURFACES

In the CAM area of free form surfaces are two trends. The first trend is manufacturing of free form surfaces by HSM – High Speed Machining and second is manufacturing by Rapid Prototyping also called as Free Form Fabrication. Both trends (we can say technologies) are very intensive computer aided .

3.1 HSM

3.1.1 Philosophy of HSM

We use such cutting parameters as far as we can increase the productivity of cutting and regarding the quality of machine parts.

Machining speed

The productivity we can formulate by many parameters. One of many parameters is path of tools per time. It is in reality the machining speed (1) and it is the mathematically exact parameter and by this nearest for technologist [2].

$$v_f = f_z \, . \, z \, . \, n \, / \, 1000 \qquad [\mathrm{m.min^{-1}} \, ; \, \mathrm{mm}, \, \text{--}, \, \mathrm{min^{-1}}] \qquad (1)$$

where

v_f - machining speed [m.min^{-1}]

f_z – feed per cutting wedge [mm]

z - number of cutting wedges [--]

n - rotational frequency [min^{-1}].

From the equation (1) is clear that we have got only the one objective possibility to increase cutting productivity namely to increase rotational frequency n (by milling it is n for milling cutter and by turning it is n for workpiece.

Cutting speed

If we increase the speed so it is increased the very important parameter of cutting speed „v_C “ (2). The cutting speed is higher order value than by conventional cutting. In this continuity we know terms: HSM and HSC. The HSM is High Speed Machining, when we machine by high cutting speed and high speed of feed, and HSC is High Speed Cutting, when we machine by high cutting speed only.

For calculation of cutting speed we know the equation (2). From this equation is clear that the increasing of rotation frequency directly increase the cutting speed. The diameter of tool or workpiece in this equation is the constructional parameter that is not possible to change in the large range. It comes to this, that the parameter – rotational frequency is again the determining factor of high speed machining technology. Either this parameter directly and eminently influences the quality of machined surfaces.

$$v_C = \pi \,.\, d \,.\, n / 1000 \qquad [m.min^{-1} ;\ mm, --, min^{-1}] \tag{2}$$

where

v_C - cutting speed [m.min^{-1}]

d - diameter [mm]

n - rotational frequency [min^{-1}].

3.1.2 HSM and CAtechnologies

The main requirements of the machining strategies are to keep the load on the cutter as consistent as possible and to minimise any sudden changes in the cutting direction.

One of the basic changes in strategy needed to achieve these conditions is the use of offset machining for roughing rather than the traditional raster approach. Whenever possible, machining should be completed from the centre of the job outwards to minimise any need for full-width cuts. The initial advice for high-speed machining was to keep both the step-over and step-down small compared to conventional machining. Recent developments in cutting tool technology mean that the latter restriction no longer applies. Roughing with deeper cuts is now possible by using a ball-nose cutter with four or six flutes that can cut with the side of the tool. The step-over, however, must still be comparatively small. Cutting with the side of the tool can also be used to optimise finishing routines by working from the bottom upwards when finish machining steep walls.

By [3] climb machining is recommended for all roughing operations, as this will reduce tool wear. Although this approach does involve extra air moves, this time can be made up by maximising the speed of the cutting moves. A combination of conventional and climb machining can be used safely in finishing operations where less than 0,3 mm of material is being removed.

With both rough and finish machining arcing moves should be used when approaching and leaving the job. Plunging onto the surface of the part should be avoided as this slows down the cutter and leaves a dwell mark on the surface. When cutting corners, the radius of the cutter needs to be considerably less than the radius of the corner, so that the maximum contact distance can be kept to less than 30% of the circumference of the cutter. This allows sufficient cooling to take place and also avoids a sharp increase in the load on the tool as it enters the corner. Very important cutting strategy for HSM is NURBS machining. It gives higher surface quality.

The CAM software for HSM should include a considerable increase in the 5-axis machining capabilities within the program. Very important are the routines for the calculation of gouge-free leads and links as the machine tool moves between the various surfaces within a part. These will enable the generation of safe toolpaths for 5-axis machining through a point or to a point, and for automatic adjustment of tilt angles for both lead and lag. Until now, 5-axis machining has been used mainly in the aerospace industry and has had limited application in toolmaking. The newest routines in many CAMs will encourage the use of 5-axis machining in mould and die manufacture by allowing the complex shapes in a single set-up, so saving time, and by enabling shorter cutters to be used in deep cavities, so giving increased machining speed and accuracy [3].

3.2 Rapid Prototyping

The technology of Rapid Prototyping is dedicated for the quickly production of models with free form surfaces. Philosophy of Rapid Prototyping: to make the 3D complicated model by the addition (add dropwise, add stepwise) of material.

To day we know these 5 Rapid Prototyping methods:

1. LOM – Laminated Object Manufacturing,
2. SLA – Stereolitography,
3. SLS – Selective Laser Sintering,
4. FDM – Fused Deposition Manufacturing,
5. BPM – Ballistic Particle Manufacturing.

a) SLS Machine

b) metal part

Fig. 3. Rapid Prototyping [4]

In general the CA software for Rapid Prototyping enable very easy support removal, surface finish, fast support editing and post-processing. With a click in a dialog box, 3D Rapid Prototyping software Z-smoothing option minimizes slice contour irregularities on shallow-sloped or curved surfaces, for better surface finish directly from the vat [4].

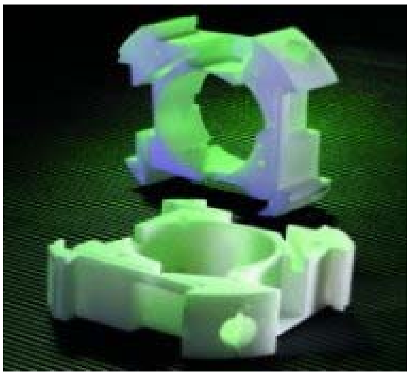

Fig. 4. Examples: some parts of Rapid Prototyping [4]

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