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POLISHING OF MOULD SURFACES

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Abstract

Finishing of mould surfaces is in most cases made by manual labour. It is an extremely laborious operation which demands a lot of time, so it is very expensive. The mechanisation or robot application seems to be a possible solution.

The term of mechanisation is to recognise the relationship between the waviness, striation and roughness of the surfaces before and after the machining. So, the type of the tool, the cutting speed, feed rate and the radial force between the surface of the workpiece and the tool can be determined.

To detect the connections and to determine the cutting parameters rubbing and polishing experiments are made on flat workpieces made of several structural materials prepared by different cutting methods.

The results and experiences can be used during the polishing by robots. It could be a faster and more economical solution of the finishing of mould surfaces than the actual employed method. Instead of applying human force to automate this process a robot with the polishing tool is introduced. The data needed for generating the polishing path are taken from both the postprocessor of a CAD system and a control program. To firm the optimal cutting conditions the pushing force between the tool and the workpiece surface needed to be controlled. An open structured robot control method is the solution of this task.

Keywords: polishing, mould surfaces, robot.

1. Fundamental Experiments

In the tool production most often used steel was chosen for the base experiments. From the steel group the marked C45, K100 and the M1 was selected. We have a plan to machine these materials in different heat treatment conditions. In the tool manufacturing not only steels, but aluminium, copper tool parts, sparking electrode (made from graphite or copper) are machined, so the observation of this materials polishability is very useful.

For the first time the test probes made of annealed C45 were produced. (*Fig. 1*). Both of the tested surfaces ('A') of the probes were prepared on the same way.

he milling operations are going to be realised on the POLYAX TC3 CNC machining centre and the sparking process is organised on an EDM machine type EROSIMAT D.

To polish we fixed a hand driven Proxxon Micromot 220/E type drilling-grinding tool head (revolution 20.000 1/min, and the max. power is 100W) to a

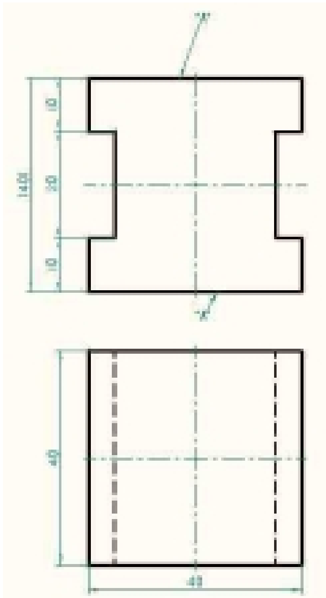

Fig. 1.

TOSH tool milling machine. A special fixture was produced to clamp the polishing spindle, which was fixed on the house of the TOSH main spindle. The polishing process needs tool spindle inclination along two axes. One of the leads is realised by the main spindle inclination facility and the designed fixture gives the other (*Fig. 2*).

Table 1.

C45	1. piece	2. piece	3. piece	4. piece	5. piece	6. piece	7. piece	8. piece
Machining	Milling (in one direction)	Milling (in one direction)	Milling (in one direction)	Milling (in one direction)	Milling (in two directions)	Milling (in two directions)	Sparking	Sparking
Type of the tool	Flat cutter	Side-tooth milling cutter	Ball cutter	Ball cutter	Ball cutter	Ball cutter	Roughing electrode	Finishing electrode
Dimension of the tool	∅20	∅40	∅10	∅6	∅10	∅6	45×45	45×45
Feed rate	0.05 mm/tooth	0.05 mm/ tooth	0.05 mm/ tooth	0.05 mm/ tooth	0.05 mm/ tooth	0.05 mm/ tooth		
Cutting speed	60 m/min	m/min	60 m/min	60 m/min	60 m/min	60 m/min	mm^3/min	mm^3/min
Surface roughness before polishing								

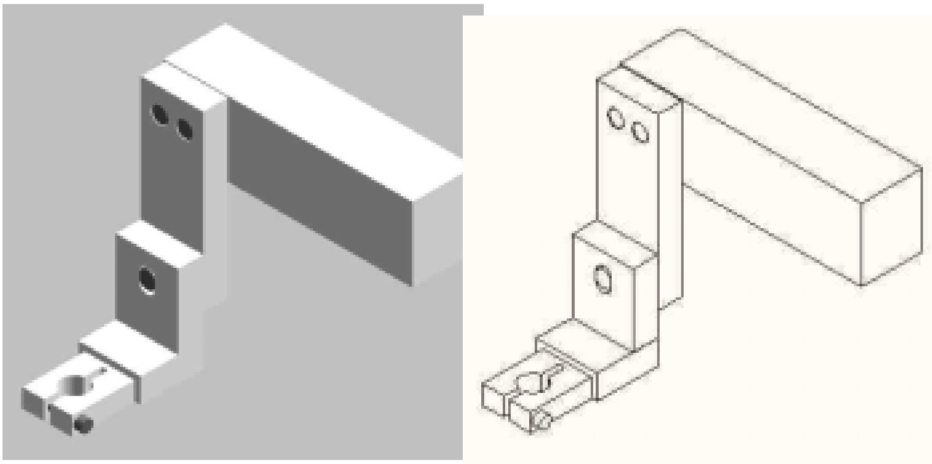

Fig. 2.

The feed rate can be set by separate values on the milling machine, and the revolution number may be controlled without discretisation on the high-speed spindle.

A fixture was designed and manufactured for clamping the workpiece by perfect positioning accuracy (*Fig. 3*).

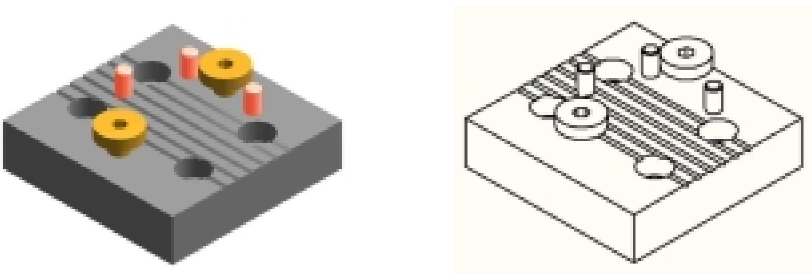

Fig. 3.

The workpiece-clamping device is located onto a force-measuring cell by which we are able to measure three force components. The measured forces are collected/signalled using a data acquisition card and stored on a computer during the complete polishing process.

We plan to analyse the force values, the contact surface, the cutting time and the surface roughness measured by several spindle speeds.

If we have enough experiments, probably, we can determine the connection among the material quality, the surface roughness before and after the machining, the used grain size, largeness of the contact surface, force components, polishing time, spindle speed and the feed rate.

The first three steps of the polishing, if the pre-product surface needed, we realise by a rubber bonded wheel, where the grain material is SiC and the grain sizes by FEPA are 100, 400, and 1200, separately. The next polishing phases are realised by diamond paste with 30, 15, 9, 6, 1, 0.3 (μm grain sizes. Each of the polishing phases has to be continued till the tracks of the previous process are not removed. We are measuring and storing on the computer the surface roughness and the workpiece shape errors between the polishing phases. Based on the measuring results we can prepare a parameter suggestion (grain size, number of phases, spindle speed and feed rate) for the used workpiece materials.

In the mould tool production it is a serious problem to avoid the overrounding of the outside edges during the polishing process. We hope to get a solution based on the force measuring. Probably the magnitudes of the force component load near the edges show us the tool path modification direction to avoid the overrounding. The force loading strongly depends on the spindle speed, and feed rate values, directions and edges position. Of course this solution is needed if there is no possible to protect the edges.

Interesting question is the 'inheritance' of the waviness and surface errors. If there is an error (scratch or wrinkle) on the surface, which has to be machined so large, that we cannot remove it with the used grains it remains on the surface after the polishing. It is changed a little of course.

We want to observe the changing rate of these errors, too.

After the fundamental experiences, based on the measured data processing we can prepare tool and process parameter suggestions depending on the workpiece material and machining requirements. There is a plan to continue the experiments on surfaces machined on the ultraprecision lathe tool owned by our department. During this measuring special press will be put onto the surface deflection caused by polishing.

Important tasks are to collect the polishing methods and tool head variations. After this, based on the position and the shape of the machined surface we can select the best method and polishing tool for the manufacturing.

2. Applying Robots

Nowadays, the polishing of mould surfaces is done in the factories by laborious and slow handwork. This process can be automated by applying robots. In the laboratory of the Department of Manufacture Engineering researches will be conducted to apply the experiences obtained in the field of conventional and ultraprecision grinding, rubbing and polishing to robotic machining. The robot moves a rotating, rubbing, polishing head. The data needed for driving the rubbing and polishing head would be taken from both the CAD model and the parametric model defined by the REPLICA measuring system of MTA-SZTAKI (Hungary), which is constructed using triangular method. The rubbing or polishing head, respectively the grain fineness will be chosen in the respect of the differences in shape determined by comparing the measuring results of the machined surface with the CAD model, the surface roughness, the shape and attitude of the surface by applying a software.

3. The Robot Control

3.1. The Generation of the Polishing Path

According to the basic conditions there are two different solutions to be separated.

The surface to be polished is based on the CAD model so it has been machined on a NC machine applied for the control program generated by a CAM system. In this case the shape and aberration of the result surface are approximately known. Thus, the polishing path can be generated on the CAD surface model as well.

The second case is when there is not any CAD model of the workpiece or the manufacturing was not based on the CAD model. Then the surface to be polished has to be digitised by applying the REPLICA measuring system of MTA SZTAKI (Hungary) and the CAD model of the surface has to be built. The machining method can be chosen and the tool path can be generated in the respect of the differences in shape determined by comparing this CAD model with the designed model of the workpiece.

3.2. The Generation of the Robot Control Program

During the machining of sculptured surfaces collision problems can occur. Basically, there are two different cases in respect of the shape and the attitude of the surfaces.

1. There isn't any undercut from the direction of the tool. In this case the machining can be managed by applying a simple straight-type rotary tool (*Fig. 4*). In these circumstances only 5 axis control is needed, because the position and attitude of the robot arm are defined by 5 parameters (x, y, z, α, β) (*Fig. 5*). 5 axis robot control program can be generated by applying a CAM system if it has an acceptable postprocessor, however, a collision avoidance algorithm has to be applied.

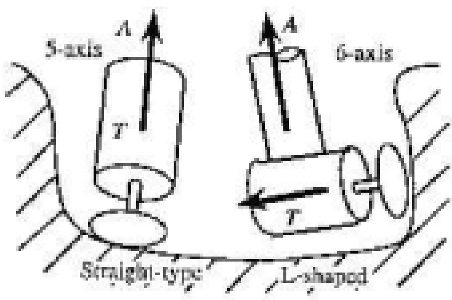

Fig. 4. Necessity of 6-axis control [1]

2. If there is an undercut surface on the workpiece an L-shaped rotational tool needed to machine the side wall of the concave workpiece, otherwise the collision between the tool and the workpiece is avoidless. This tool is composed of an arm axis mounted on the robot arm and a tool axis perpendicular to the arm axis with a bevel gear. A rubber pad with sandpaper or felt is mounted on the spindle of the tool axis. *Fig. 2* presents the relationship between the tool configuration and 6 control parameters of the robot in using the L-shaped rotational tool. The position and attitude of the robot arm can be designed by giving the parameters of (x, y, z) and (α, β, γ). As seen from the structure of the L-shaped rotational tool, it is identified by a tool axis vector T and an arm axis vector A. As the arm axis vector A, which is defined by 5 parameters (x, y, z, α, β), can rotate around its axis, it has to be aligned to the direction of the tool axis vector T by assigning the parameter γ. Thus, 6 degrees of freedom allow the robot to control the L-shape rotational tool. The method of the collision analysis and determination of the position and attitude of the robot arms is made clear in [1].

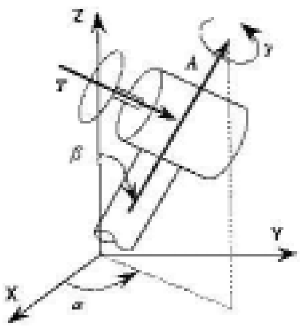

Fig. 5. Tool attitude in the robot coordinate system [1]

The generated polishing path data consisting of polishing points, tool axis vectors, arm axis vectors and robot control codes are described in the work coordinate system. To actually polish with a robot it is necessary to transform the polishing data in the work coordinate system into the robot coordinate system, taking into account the position and attitude of the workpiece. In addition, the data are transformed to robot control commands consisting of position (x, y, z) and attitude (α, β, γ) of the top of the robot arm, and motion instructions [1].

3.3. *The Control of the Pushing Force between the Tool and the Workpiece*

On the account of the improvement of surface fineness the pushing force between the tool and the workpiece has to be approximately permanent respectively the volume of the force has to be in accordance with the type of the surface. Therefore, the pushing force has to be controlled. There are some possibilities to solve this problem:

1. The solution explained in [1] is a linear guide with an air cylinder, which moves an air turbine on the arm axis. This is used to apply the tool onto the workpiece surface and control pushing force of the tool by regulating the air pressure.
2. The polishing tool has to be fixed on the robot arm in a holder, which contains elastic elements in the direction of the three coordinate axes. Thus, the pushing force can oscillate, but the peaks caused by the inaccuracy of the robot can be reduced.
3. The polishing head is fixed in a similar holder to the 2., but instead of the elastic elements there are three air cylinders applied. In this way the pushing force can be controlled along the three coordinate axes by regulating the air pressure.
4. There is a load cell in the holder of the polishing tool, to measure the pushing force along the three coordinate axes. During the machining the polishing path continuously can be corrected in the respect of force volume needed. An opened structured robot control method is needed to that. A control method like that has been previously developed at the Department of Manufacture Engineering, Technical University of Budapest in a Ph.D. study. This method was planned to be used to solve this problem as well.

References

[1] DONG-FANG GE, – YOSHIMI TAKEUCHI – NAOKI ASAKAWA (1995): Dexterous Polishing of Overhanging Sculptured Surfaces with a 6-axis Control Robot, in *Proc. IEEE International Conference on Robotics and Automation 0-7803-1965-6/95*, pp. 2090–2095.