14th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2010, Mediterranean Cruise, 11-18 September 2010

METHODOLOGY AND ADJUSTMENT OF THE TEST FOR DETERMINING THE POLISHING DIFFICULTY DEGREE OF HARDENED STEEL SURFACES, PREVIOUSLY OBTAINED BY HIGH-SPEED MILLING PROCESSES

I. Buj-Corral; J. Vivancos-Calvet; R. Casado-López
Technical University of Catalonia (UPC). Departament of Mechanical Engineering.
School of Industrial Engineering of Barcelona (ETSEIB), Avda. Diagonal 647, 08028-Barcelona, Spain

ABSTRACT
In the moulds and dies manufacturing it is important to reduce the manual polishing time after end milling processes. The polishing difficulty is related to surface topography shape and roughness values obtained in the previous end milling processes. It is interesting to develop a methodology and a test to evaluate the polishing difficulty.
The aim of the present work is to establish a methodology and a test for quantifying the difficulty degree for polishing hardened steel that is used for moulds and dies, manufactured by high-speed milling.
An automatic polishing machine was used. First, the test parameters to be used were defined: rotation speed of the pad, force between the workpiece and the polishing disk, type of abrasive material, grain size of abrasive and elemental polishing time corresponding to an elemental polishing operation. Second, a parameter that will allow the quantification of the difficulty degree for polishing was determined: either the total necessary polishing time or the number of elemental polishing operations that are necessary to obtain the final roughness defined. Third, a roughness pattern was manufactured of each one of the materials to be studied, in order to materialize the final roughness to be obtained after polishing.
Keywords: polishing test, roughness, high-speed milling

1. INTRODUCTION
In the manufacturing process of moulds and dies an important part of the cycle time is due to the manual polishing operation after milling. Manual polishing is necessary in those processes because machine polishing is possible only on flat, cylindrical or spherical surfaces [1]. However, several authors studied the polishing operation by means of a polishing machine with the aim of using a standard process where the different parameters can be varied: rotation speed of the pad, force of the part on the surface of the pad, type of abrasive material, grain size of the abrasive, etc. [1-4]. In this work, the test parameters of a polishing test were defined. Afterwards, the parameter that is necessary for defining the difficulty degree for polishing a sample was determined. Finally, preliminary tests were performed on previously ground hardened steel samples. The surface finish of the samples was observed by means of a microscope. In addition, both arithmetical average roughness R_a and peak-to-valley roughness R_t were measured. In future work, a study and analysis of the sensitiveness of the roughness parameters regarding the polishing operation after contour milling will be carried out.

2. MATERIALS AND METHODS

2.1. Materials

Different materials were tested: hardened steel W Nr 12344 used for moulds, hardened steel W Nr 12379 used for dies and hardened stainless steel W Nr 12083 used for moulds.

2.2. Methods

Prior to the polishing operations, the parts were ground. An INGAR RT-618-2A grinding machine was used. The characteristics of the grinding wheel are were 38A60K5V. The feed speed was 200 mm min^{-1} and the cutting depth was 0.02 mm.

For the polishing test, an automatic polishing machine Mecapol P230 was employed. Corundum polishing pads were used with grain size 400, which is the usual grain size for the first manual polishing operation in the manufacturing process of moulds and dies.

The polished surfaces were observed by means of a binocular microscope Leica S8AP0 connected to the image treatment software Motic Images Plus 2.0.

For measuring roughness, a Taylor Hobson Taylsurf Series 2 roughness stylus profilometer was employed with Taylor Hobson µltra software (v. 4.6.8).

3. POLISHING METHODOLOGY

The polishing methodology consisted of defining three different aspects:

1. Test parameters.
    a. Type and grain size of abrasive material. Corundum 400, according to the mould manufacturers' recommendations.
    b. Rotation speed of the pad. Initial value: 20 min^{-1}, (lowest possible speed in the polishing machine).
    c. Force of the part on the surface of the pad. Initial value: 0.5 daN, (lowest possible force in the polishing machine).
2. Duration of each elemental polishing operation. Successive polishing operations will be carried out with a minimum duration that allows significant changes in surface roughness. An initial elemental polishing time of 30 s was chosen.
3. Definition and manufacturing of roughness patterns of each material studied that materialize the final roughness to be obtained.

The methodology that is used for defining the difficulty for polishing consisted on performing successive elemental polishing operations (polishing test during an elemental polishing time) until the final roughness is reached. After each elemental polishing operation, the roughness of the sample is compared visually to the roughness of the corresponding pattern by means of the microscope. Once the roughness of the polished workpiece (observed with the microscope) is similar to the roughness of the pattern, the test is finished and the final roughness is measured by means of the profilometer. The difficulty degree for polishing is defined either by the total polishing time or by the number of elemental polishing operations that are necessary for reaching the final roughness. Roughness is measured both in the longitudinal and transversal direction, at different points. An average value of R_a and R_t is obtained for each test.

4. TESTS PERFORMED

The following tests, from 1 to 5, were successively performed to the each one of the three samples corresponding to the three different materials (Table 1).

Table 1. Characteristics of the polishing tests performed

Test	Force (daN)	Speed (min^{-1})	Elemental test time (s)	Total time (s)
1	0.5	20	30	30
2	0.5	20	30	60
3	1.5	50	30	90
4	1.5	50	30	120
5	1.5	50	30	150

For tests 1, 2, 3 and 4, the same polishing pad was used, while for test 5 a new polishing pad was employed.

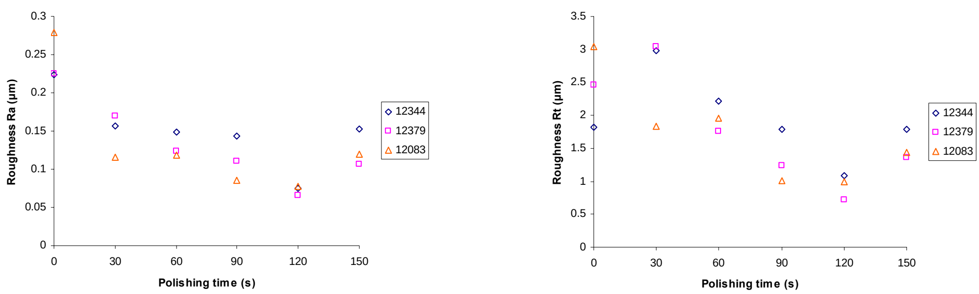
5. RESULTS
6.
5.1. Microscope
In Figure 1 the photographs obtained with the microscope (magnification of 40) are shown, as an example, for material W Nr 12344.

(a) (b) (c)

Figure 1. Photographs of pattern 12344 (magnification of 40) with different polishing times: (a) 0 s, (b) 30 s, (c) 60 s

Figure 1a shows only grinding marks. In Figure 1b polishing marks are predominant although still some grinding marks are seen. In Figure 1c there are mostly polishing marks.

5.2. Roughness
Roughness results for R_a (arithmetic average roughness) and R_t (peak-to-valley roughness) are presented in Figure 2.



(a) (b)

Figure 1. Roughness of patterns 12344, 12379 and 12083: (a) R_a, (b) R_t

R_a values after grinding range between 0.22 and 0.28 µm. After a polishing operation of 120 s, R_a roughness values are lower than 0.1 µm in all cases. At the final polishing operation of 150 s, roughness increased, because with the new polishing pad there are more protruding grains than with the used polishing pad. The roughness parameter R_t showed a similar behaviour.

6. MODIFICATION OF THE METHODOLOGY

The main modifications of the polishing methodology are as follows:

1. Definition of the test parameters.
A force of 1.5 daN will be used so to assure the correct fixing of the parts. A turning speed of 50 min^{-1}, will be employed so to avoid an extreme low speed value of the polishing machine.

2. Definition of the elemental polishing time of an elemental polishing operation.
This time will be reduced to 20 s, in order to have a greater resolution for assessing the difficulty for polishing, provided that there will be a significant change in roughness between successive polishing operations of 20 s.

3. Other considerations.
As the use of a new polishing pad implies higher roughness on the surface of the polished parts, an initial "running-in" operation will be carried out prior to the use of each polishing pad, so to assure a correct roughness value. In addition, the life of the polishing pad will be limited to a total time of 180 s, before roughness will decrease because of excessive wear of the pad, according to experimental tests.

7. CONCLUSIONS

A polishing methodology was defined that will assure that the part surface will be completely polished with the minimum polishing time, using successive elemental polishing operations of 20 s.
Parts will be polished until their surface roughness is similar to that of previously polished patterns of the same material.
The difficulty degree for polishing is quantified either by the necessary number of elemental polishing operations or by the total necessary polishing time to obtain the final roughness.
About the polishing pad, it is necessary a previous running-in and also to change it periodically for preventing its excessive wear out.

ACKNOWLEDGEMENTS

The authors would like to thank the Spanish Ministry of Science and Education for the financial support of Project DPI2007-66546.

8. REFERENCES

[1] Brinksmeier E., Riemer O., Gessenharter A.: Finishing of structured surfaces by abrasive polishing, Precis. Eng. 30, 325-336, 2006.
[2] Huang M.F., Lin T.R., Chiu H.C.: Effect of machining characteristics on polishing ceramic blocks, Int J Adv Manuf Technol. 26, 999-1005, 2005.
[3] Xie Y., Bhushan B. Effects of particle size, polishing pad and contact pressure in free abrasive polishing, Wear. 200, 281-295, 1996.
[4] Sato M., Kameyama T., Nonami T. Copper polishing with a polishing pad incorporating abrasive grains and a chelating resin, Precis Eng. 33, 167-174, 2009.