Proceedings of the 15th International Conference on Manufacturing Systems – ICMaS
Published by Editura Academiei Române, ISSN 1842-3183
"Politehnica" University of Bucharest, Machine and Manufacturing Systems Department
Bucharest, Romania, 26–27 October, 2006

DESIGN AND DEVELOPMENT OF THE TECHNOLOGICAL PROCESSOR FOR PLANE SURFACE LAPPING

Andrea DEACONESCU

Abstract: *The finishing of workpieces is one of the defining elements of product quality. For this reason special attention should come to the study of surface smoothing operations, given their decisive role in obtaining high dimensional and geometric precision. One of these finishing processes is lapping. The paper presents a technological processor for plane surface lapping, a useful instrument for technology designing engineers. The technological processor allows the user to rapidly determine the duration of machining and the height of the layer of removed material.*

Key words: *lapping, technological processor, robust system, roughness, height of the removed layer.*

1. INTRODUCTION

Lapping is the smoothing process of surfaces by abrasive erosion in which, according to STAS 5456-80 the removal of the tooling allowance is obtained by grains located at the interface of the transfer object and the machined workpiece. Lapping falls into the category of cutting processes in which the cutting edges of the tools are not determined geometrically. It is a method of final processing in which the grains are freely distributed in a supporting fluid, cutting being typically achieved by means of a form transferring counter-part (transfer object).

This machining procedure – being part of the category of surface smoothing operations – has as its main objectives the increase of dimensional and geometric precision, flattening of surface micro-asperities, correcting of the relative position of machined objects and increasing of the contact area of parts operating in couples.

The areas of application of lapping are found in all branches of industry: hydraulics, pneumatics, electrical engineering, computers, fine mechanics and optics, chemistry, machines manufacturing, motor vehicles, aeronautics, spacecrafts, etc. Lapping is used to machine the most varied forms of parts like sealing systems for gas or liquid media, tools, measuring instruments, reference, base, guide surfaces, pistons, shafts and spindles, bores, etc. On special machines parts of dimensions up to 2 000 mm and masses up to 500 kg can be machined.

Lapping can be applied almost to all types of materials, like metal, ceramics, glass, natural rocks like granite, marble, basalt, precious stones, semi-conductors silicon, germanium, and also graphite and even diamond.

Surface smoothing by lapping can be achieved by three methods:

- by *mechanical cutting*, when the transfer object coincides with the working tool and is materialised by a an abrasive body (disk);
- by *mechanical-chemical cutting,* when the erosive action of the grains is accompanied by a chemical action of the abrasive paste. This softens the oxide layer at the workpiece surface, thus allowing the removal of the tooling allowance by means of less hard abrasives.
- by *hydro-dynamic cutting,* that is by inducing a turbulent flow of the abrasive suspension located between transfer object and workpiece.

Regardless of the selected method for surface lapping, the following requirements need to be taken into consideration for the machining process to be carried out under good conditions:

- correct selection of the abrasive materials, the form and materials of the transfer objects, and of the abrasive grain bearing liquid;
- correct selection of the working parameters (cutting speeds, contact pressure, eccentricity, etc);
- ensuring an adequate tooling allowance consequently to the machining operations previous to lapping.

The design of the technological process of surface lapping involves determining of the following elements:

- necessary time of machining;
- magnitude of the tooling allowance to be removed;
- cutting conditions (cutting speed, working pressure);
- characteristics of the abrasive paste (abrasive material, concentration, graining).

Determining of the optimised values of these elements is achieved by means of an original expert CAD-T system (Computer Aided Design – Technological), devised by the author based on theoretical studies and experimental research.

The components of this CAD-T system are:

- the human component;
- the material component (computers, working equipment, etc);
- the original software component, including:
  - the **LappMaster** application, consisting of two modules:
    - **NormMaster**, the module designed for computing:
      - the technical time norm for surface lapping;
      - the erosion parameters of the lapping disk and the of the workpiece;
    - **TagMaster**, the module designed for:
      - optimisation of the lapping process by means of the classical method of arrays of

experiments (classical design of experiment – DOE);
- optimisation of the lapping process by means of the Taguchi method of arrays of experiments (method of fractioned factorial orthogonal arrays of experiments).

○ the technological processor, the instrument made available to the technology designing engineer, devised for the automatic calculation of machining time and height of the removed layer of material.

The final aim of this entire set of components is to optimise the technological process of surface lapping, the main imposed condition being the achievement of a robust machining system.

2. THE TECHNOLOGICAL PROCESSOR

The technological processor is the component of the software application which is meant to provide the end-user with the necessary technical documentation. The technological processor includes specially developed working algorithms, a data base and the user interface.

The final aim of this processor is to provide the technology designer with information on the duration of machining and the height of the material layer removed by lapping.

The relations used for computing the duration of machining and the magnitude of the removed layer of material are based on the expression of surface roughness obtained by plane lapping: [1]

$$R_a = K_R \cdot e^{xR} \cdot C^{yR} \cdot vr^{zR} \cdot p^{uR} \cdot t^{vR}, \tag{1}$$

where:
- e is the eccentricity of the part-bearing plate;
- C is the concentration of the abrasive in the lapping paste;
- v_r is the machining (cutting) speed;
- p – working pressure;
- t is the duration of machining/cutting.

The coefficient K_R, as well as the exponents xR, yR, zR, uR and vR are specific for each type of machined material, their values for six tested materials being entered into a specially created database.

Following experimental research it could be established that for all analysed materials (OL37, OLC45, 40Cr10, 38MoCr09, 50WCr11, 18MoCr10) the dependence of the roughness of the machined surface depends on the time of machining has an evolution as shown in Fig. 1.

The graph shows that the decrease of roughness is more accelerated in the first part of the machining time, while towards its end the gradient of the curve being less steep.

Consequently from relation (1) the necessary time for machining (t) can be determined, depending on the known values of the initial roughness R_{ai} (obtained by the previous operation) and of the final roughness R_{af} (to be obtained by lapping). Corresponding to the known

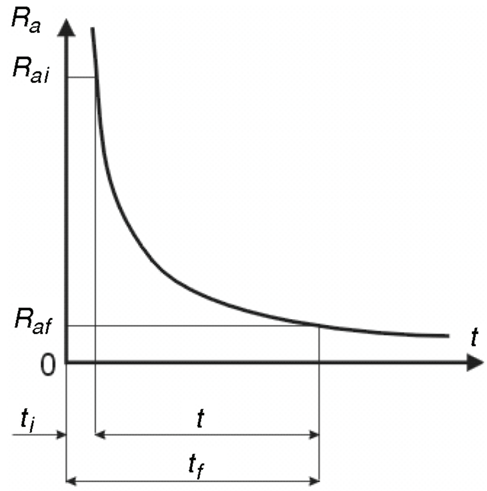

Fig. 1. Variation of roughness *vs.* machining time.

values of R_{ai} and R_{af} the times t_i and t_f are calculated, respectively, using the relations presented below:

$$t_i = \sqrt[vR]{\frac{R_{ai}}{K_R \cdot e^{xR} \cdot C^{yR} \cdot vr^{zR} \cdot p^{uR}}}, \tag{2}$$

$$t_f = \sqrt[vR]{\frac{R_{af}}{K_R \cdot e^{xR} \cdot C^{yR} \cdot vr^{zR} \cdot p^{uR}}}. \tag{3}$$

In accordance with the graph of Fig. 1 the necessary time for lapping (t) results, having taken into consideration R_{ai} and R_{af}:

$$t = t_f - t_i = \frac{\sqrt[vR]{R_{af}} - \sqrt[vR]{R_{ai}}}{\sqrt[vR]{K_R \cdot e^{xR} \cdot C^{yR} \cdot vr^{zR} \cdot p^{uR}}}. \tag{4}$$

The relation used to compute the height of the removed layer of material will have the form shown below [1]:

$$h = K_h \cdot e^{xh} \cdot C^{yh} \cdot vr^{zh} \cdot p^{uh} \cdot t^{vh}. \tag{5}$$

The time t intervening in this relation the one previously determined, by taking into consideration the roughness values R_{ai} and R_{af}. Consequently the relation for computing the height of the removed layer of material (h) considers (by the term t) the initial and final roughness values. Thus it can be said that the technological processor computes:

$$t = f(R_{ai}, R_{af}, e, C, vr, p) \tag{6}$$

and

$$h = f(t, e, C, v_r, p), \tag{7}$$

that is

$$h = f(R_{ai}, R_{af}, e, C, vr, p). \tag{8}$$

Also in the case of the relation for computing the height of the removed layer of material (h), the values of the coefficients and exponents K_h , xh, yh, zh, uh and vh are specific for each material in part and are entered into the processor database.

Replacing t in the relation for the computation of h, the height of the removed layer of material by its expression given by equation (4) we obtain:

$$h = K_h \cdot e^{xh} \cdot C^{yh} \cdot vr^{zh} \cdot p^{uh} \cdot \left(\frac{\sqrt[vR]{R_{af}} - \sqrt[vR]{R_{ai}}}{\sqrt[vR]{K_R \cdot e^{xR} \cdot C^{yR} \cdot vr^{zR} \cdot p^{uR}}} \right)^{vh} . \qquad (9)$$

Based on the above relations the final form of the technological processor for plane surface lapping could be obtained. The user-friendly interface is presented in Fig. 2.

The aim of the technological processor is to provide to the end-user (the technology designing engineer) information on the duration of machining, the magnitude of the removed layer of material, as well as the values of the optimum levels (values) of the input parameters of the system.

In a first step the user is required to select the material to be machined from an available database currently including information on six such materials (40Cr10, OL37, 38MoCr09, OLC45, 50WCr11, 18MoCr10). Access to information is achieved via an ADO type control (ActiveX Data Object), which connects to the *Access Materiale.mdb* data base type file. Once a material has been selected, the application displays the optimum levels of the input parameters of the machining system, values obtained by the LappMaster application, the TagMaster module. By implementing these optimum values, which are also stored in the data base, the system becomes robust, that is insensitive to external disturbing factors, known as noises.

The users may work with the values recommended by the application, which endow the machining system with robustness, or may use their own input parameter values (Fig. 3).

In the next step the user needs to enter the values of the initial roughness R_a from which the lapping process starts and the value of the final roughness R_f, the target value of the machining (Fig. 4).

The entering of both values is compulsory, a null value of any of these fields triggering warning messages (Fig. 5).

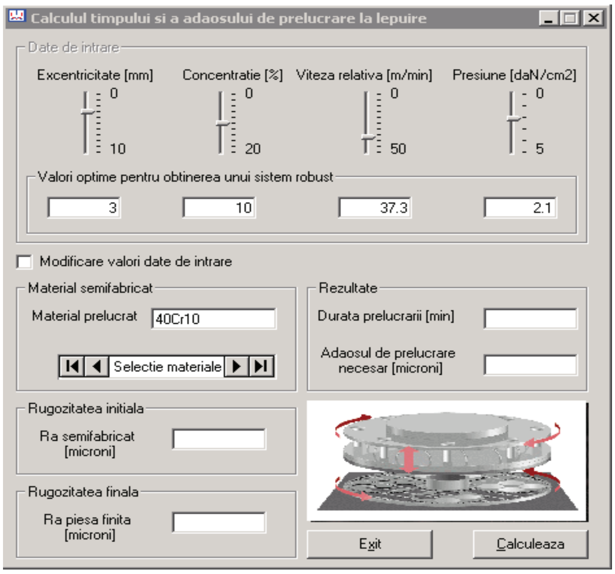

Fig. 2. User interface of the processor.

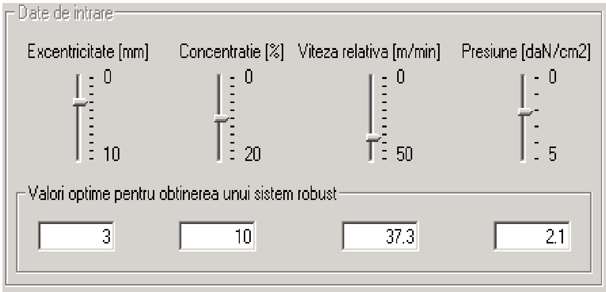

Fig. 3. Establishing the input parameter values.

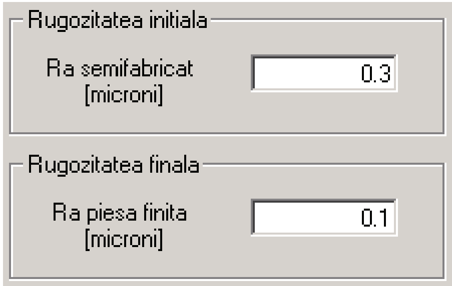

Fig. 4. Setting the values of surface roughness.

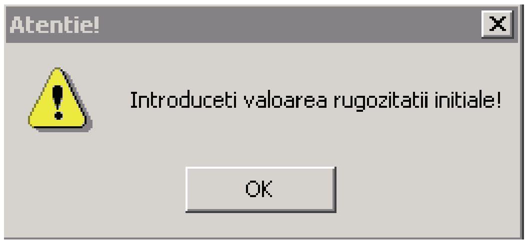

Fig. 5. Display of error message.

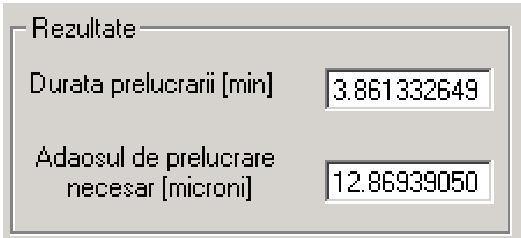

Fig. 6. Display of results.

Finally, by clicking the "Calculate" button the values computed by the application will be displayed for the duration of cutting [min], and for the removed layer of material [μm]. Thus for instance for an initial roughness of 0.3 μm and a final one of 0.1 μm, the obtained results will be like in Fig. 6.

The Table 1 features a centralised presentation of the formulae used by the application [1].

The values of all coefficients and exponents included by the relations are entered for each material into a specific database of the technological processor.

Figs. 7 and 8 show two forms corresponding to the *Materiale.mdb* file, in which the values of the optimum levels of the input quantities are stored, as well as those of the coefficients and exponents of the computational relationships. These values are illustrated for two materials:

Table 1

Computational relations used by the technological processor

Material	Relation for R_a	Relation for h
40Cr10	$R_a = 0.029 \cdot e^{0.294} \cdot C^{-0.49} \cdot vr^{0.619} \cdot p^{-2.012} \cdot t^{-0.624}$	$h = 0.332 \cdot e^{0.088} \cdot C^{0.305} \cdot vr^{0.809} \cdot p^{1.228} \cdot t^{0.314}$
OL37	$R_a = 0.0051 \cdot e^{0.267} \cdot C^{-0.64} \cdot vr^{0.528} \cdot p^{-0.686} \cdot t^{-0.067}$	$h = 0.791 \cdot e^{0.083} \cdot C^{0.189} \cdot vr^{0.635} \cdot p^{0.847} \cdot t^{0.289}$
38MoCr09	$R_a = 0.158 \cdot e^{0.051} \cdot C^{-0.817} \cdot vr^{0.387} \cdot p^{-2.439} \cdot t^{-1.799}$	$h = 0.258 \cdot e^{0.1} \cdot C^{0.251} \cdot vr^{0.848} \cdot p^{1.09} \cdot t^{0.258}$
OLC45	$R_a = 0.222 \cdot e^{0.023} \cdot C^{-0.465} \cdot vr^{0.218} \cdot p^{-1.581} \cdot t^{-1.144}$	$h = 0.181 \cdot e^{0.188} \cdot C^{0.195} \cdot vr^{0.804} \cdot p^{0.988} \cdot t^{0.376}$
50WCr11	$R_a = 0.05 \cdot e^{0.075} \cdot C^{-0.905} \cdot vr^{0.805} \cdot p^{-2.291} \cdot t^{-2.201}$	$h = 0.062 \cdot e^{0.176} \cdot C^{0.199} \cdot vr^{1.013} \cdot p^{1.19} \cdot t^{0.433}$
18MoCr10	$R_a = 0.009 \cdot e^{0.208} \cdot C^{-0.865} \cdot vr^{0.533} \cdot p^{-0.343} \cdot t^{-0.943}$	$h = 0.234 \cdot e^{0.141} \cdot C^{0.166} \cdot vr^{0.818} \cdot p^{0.945} \cdot t^{0.356}$

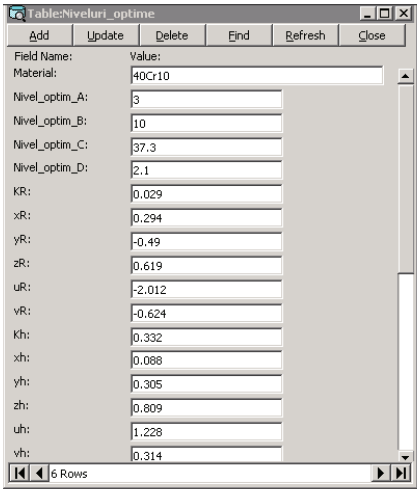

Fig. 7. Form including material information (here 40Cr10).

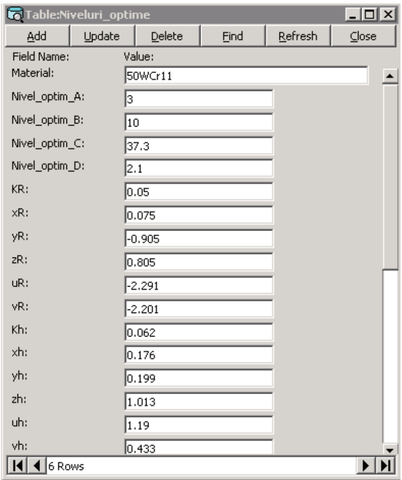

Fig. 8. Form including material information (here WCr11).

3. CONCLUSIONS

The technological processor designed for plane surface lapping presented in this paper is meant to be used by technology designing engineers for establishing the duration of machining and the magnitude of the removed layer of material.

The processor significantly simplifies the computational effort related to these two quantities.

The data base attached to this processor while currently including data of only six materials, can easily be expanded as further experimenting is completed.

REFERENCES

[1] Deaconescu, A. (2005). *Optimizări privind prelucrarea suprafeţelor prin lepuire*, Ph.D. Thesis, "Transilvania" University of Braşov.

[2] Deaconescu, A. (2003). *Development and utilisation of a data base with experiment matrices for the optimisation of lapping as a technological process*, International Conference on Economic Engineering and Manufacturing Systems, ICEEMS 2003, Braşov.

[3] Deaconescu, A. (2004). *Robust design of the technological lapping process*, CoSME 2004, Computing and Solutions in Manufacturing Engineering, Edit. "Transilvania" University of Braşov, pp. 319–324.

[4] Deaconescu, T. (2005). *Sisteme şi tehnologii speciale.* Edit. Cartea Universitară, Bucharest, ISBN973-731-221-X.

[5] Fowlkes, W., Creveling, C. (1995). *Engineering Methods for Robust Product Design*, Wesley Longman, Reading, Massachusetts, ISBN 0-201-63367-1.

[6] Ivan N. V. (2001). *Sisteme CAD/CAM. Algoritmi şi programe CAD-T*, Edit. Didactică şi Pedagogică, Bucharest, ISBN 973-30-2760-X.

[7] König, W., Klocke, F. (1996). *Fertigungsverfahren. Band 2*, VDI Verlag GmbH Düsseldorf, ISBN 3-18-401560-2.

[8] McGeough, J. A. (1988). *Advanced Methods of Machining*, Chapman and Hall, London.

[9] Shaw, M. (1996). *Principles of Abrasive Processing*, Oxford University Press, ISBN 0-19-859021-0.

[10] *** (2002). *Microsoft Visual Basic 6.0. Ghidul programatorului*, Edit. Teora, Bucharest, ISBN 973-601-459-2.

Author:

Dr. Eng. Andrea DEACONESCU, M.A., Lecturer, "Transilvania" University of Braşov, Economic Engineering and Production Systems Department, E-mail: deacon@unitbv.ro