Available online at www.sciencedirect.com

ScienceDirect

Procedia Technology 22 (2016) 48 – 54

Procedia Technology

9th International Conference Interdisciplinarity in Engineering, INTER-ENG 2015, 8-9 October 2015, Tirgu-Mures, Romania

Computer Aided System for Superfinishing Process Control

Tadeusz Mikolajczyk[a,]*, Tomasz Fas[b], Adam Kłodowski[c], Maciej Matuszewski[a], Adrian Olaru[d], Serban Olaru[e]

[a]University of Science and Technology, 7 Prof. Kaliskiego street, 85-789 Bydgoszcz, Poland
[b]Kazimierz Wielki University, 30 J. K. Chodkiewicza street, 85-064 Bydgoszcz, Poland
[c]Lappeenranta University of Technology, 34 Skinnarilankatu, 53850 Lappeenranta, Finland
[d]Politehnica University of Bucharest, 313 Splaiul Independentei street, 060042 Bucharest,Romania
[e]RomSYS Mechatronics System Society, 12 Menuetului street, 013713 Bucharest, Romania

Abstract

Superfinishing is one of the techniques ensuring a very low value of surface roughness of the most common external assets. The roughness of the obtained surfaces depends on the proper selection of the abrasive material and processing parameters. Yield in superfinish machining with oscillating tool depends largely on the kinematics of the oscillating movement trajectory. The paper presents the superfinishing control system based on frequency control strategy of the oscillating motion. System was developed to study the process of the controlled oscillation frequency of a grinding tool. Frequency control was enabled by the use of an inverter which provided input to the motor that drives the oscillating head. A system for automatic frequency control of the oscillating motion using computer was developed. The inverter was connected via an analog to digital interface to a PC. Dedicated control software in Visual Basic was made for this purpose. Therefore, a single system for controlling a two-stage superfinishing process has been created. This ensured quality implementation of the optimal well-known method for processing. The presented control system provides wide possibilities for control of the surface grinding, and creates opportunities for further research in determining optimal grinding conditions.

Peer-review under responsibility of the “Petru Maior” University of Tirgu Mures, Faculty of Engineering

Keywords: superfinishing; grinding process; automatic control.

* Corresponding author. Tel.: +48-52-340-8736; fax: +48-52-340-8245
E-mail address: tami@utp.edu.pl

Peer-review under responsibility of the “Petru Maior” University of Tirgu Mures, Faculty of Engineering
doi:10.1016/j.protcy.2016.01.008

1. Introduction

Superfinishing is a treatment of materials finishing allowing to achieve small surface roughness [1-5]. It is well known that this process allows only to improve the state of the surface [1].

Apart from the other parameters of the process [1], the important parameters of the superfinishing are: the angle of intersection of the oscillating movement trajectory traces, the angle between the path of grain and a plane perpendicular to the axis [1]. The literature [1,2] gives the optimal treatment conditions, providing high efficiency of the process and low roughness of the machined surface. Modern technology allows oscillating superfinishing treatment of interior and exterior surface of revolution using special machining stations [4,7] as well as traditional lathes with special oscillatory devices [1,2]. The importance of other grinding processes is increasing as well, for instance, grinding with abrasive belts has become popular [8]. Oscillatory superfinishing also applies to finishing of gear [7,9] or flat and curved surfaces [6]. Hybrid methods where the grinding process is supported by electrochemical process have also been introduced [10].

The development of computer technology in terms of both computational power and available interfaces creates opportunities for generation of original research in the field of automation of technological processes in machining [11]. In process optimization for instance neural networks have been used [12]. Modern technology enables monitoring of the superfinishing process, most frequently by forces analysis [13-16].

This article presents computer-controlled oscillating superfinishing station, which allows to control the frequency of the oscillatory movement based on the actual spindle speed. One application of the station is the automation of the two-stage oscillating superfinishing.

Nomenclature

d	diameter of a workpiece	[m]
n	rotational speed	[1/min]
V_w	tangential velocity	[m/min]
V_{osc}	oscillation velocity	[m/min]
f_s	oscillation frequency	[1/s]
$f_{s\,cor}$	corrected oscillation frequency	[1/s]
α	grinding directional angle	[degrees]
a	amplitude of tool oscillation	[mm]
M_e	corrected number of oscillations per rotation	
e	phase shift of the oscillating movement	

2. Methods and materials

2.1. The bases of the oscillating superfinishing

Oscillating superfinishing of the surface is based on the combined motion of the grind stone and workpiece rotation. It is possible to machine both the external and internal surfaces. Superfinishing process parameters are: frequency of the oscillation, amplitude of the oscillating motion of the grind stone, and the parameters associated with the movement of the workpiece - diameter and rotational speed. The other basic process parameter is the grinding directional angle.

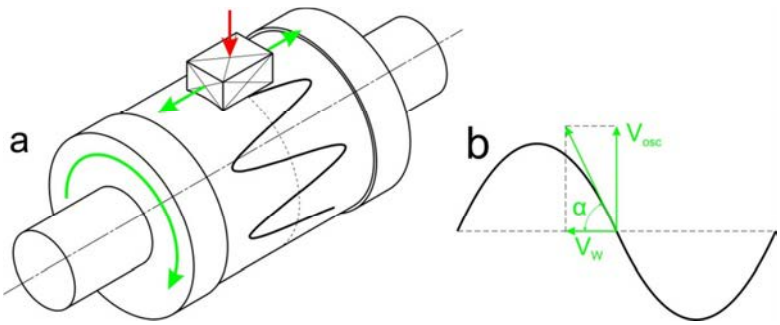

Fig. 1. Grind stone motion trajectory (a) superfinishing model; (b) grinding directional angle α.

To determine the process parameters, the recommended tangential velocity should be assumed. Superfinishing process characteristics determine the following relations:

$$V_w = \frac{3.14 \cdot d \cdot n}{1000} \tag{1}$$

On the basis of a predetermined value of grinding directional angle α, the oscillation velocity V_{osc} is determined:

$$V_{osc} = V_W \cdot \tan\left(\frac{3.14 \cdot \alpha}{180}\right) \tag{2}$$

After determining the oscillation velocity, oscillation frequency can be computed:

$$f_s = V_{osc} \cdot \frac{3.14}{60000} \cdot a \tag{3}$$

The calculated oscillation frequency needs to be corrected to ensure appropriate phase shift of the processing traces:

$$M_e = \int \frac{f_s}{n} + e \tag{4}$$

Here the corrected oscillation frequency is computed:

$$f_{s\,cor} = \frac{M_e \cdot n}{60} \tag{5}$$

Additionally frequency might be modified according to the results of research and analysis to further improve the output.

2.2. The test stand

Schematics of the developed test stand is shown in Fig. 2. The stand includes oscillating ODS 60 superfinisher mounted on the SBN 400 lathe (made in Romania). The motor of the oscillating device is connected to the inverter

FREQVAR 2000 (made in Poland). It is a 2 kW AC powered (230V) inverter that is capable of generating a three-phase current within frequency range of -120 Hz to +120 Hz.

The frequency setting is made by a potentiometer or external voltage signal, the second option was used in this study. The inverter is connected to the PC via the PCLD 8141 interface combined with PCL 816L analog output card. This allows to control the angular velocity in a wide range of values, including the possibility of increasing it above nominal value.

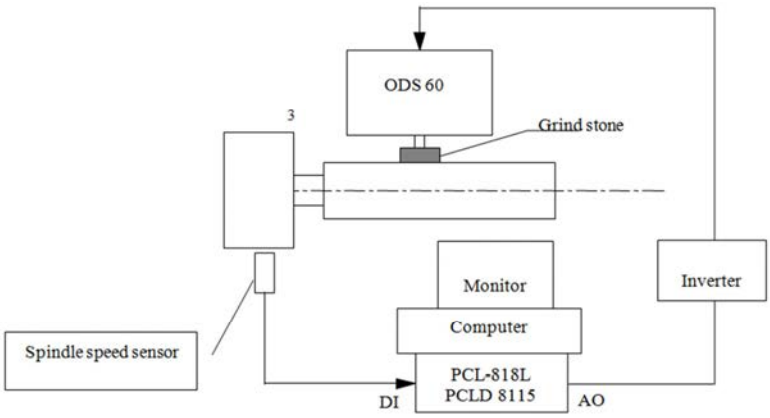

Fig. 2. The scheme of the setup

For controlling, characteristic of the oscillation frequency was done (Fig. 3). The characteristics was achieved by controlling the voltage level on the analog output card PCL 818L.

The study was based on empirically developed relationship:

$$f_{steer} = f_s \cdot I \tag{6}$$

where:

I – proportional empirical coefficient of the oscillation frequency; I = 0.192

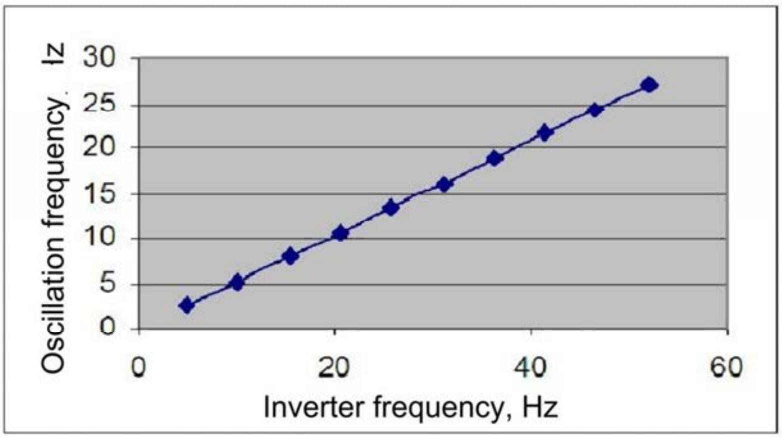

Fig. 3. The relation between the current frequency and oscillating motion

Frequency of the driver was set, using the PCL818L card using empirical relationship for the voltage, U:

$$U = 0.06 + 0.172 \cdot f_{steer} \tag{7}$$

Determination of the trajectory of the oscillating movement required data on the diameter of the workpiece, to determine its rotational speed. Developed system, due to the absence of a second inverter is currently not capable of controlling this value – so the system read the actual rotational speed with an inductive sensor. Pulse counting system is connected via the PCLD 8141 interface using its digital input (See Fig. 2).

The developed stand, despite the only oscillating movement control, has great potential in control applications of the superfinishing oscillation. It enables continuous control of the machining process without interrupts. However, in addition to hardware, also software development was required to achieve this goal. The paper presents a two-stage machining process control software.

3. Computer software for control of the two-stage superfinishing process

Developed control system is operated by custom made software that relates inverter input signal with spindle speed sensor values. The algorithm of the control system of the two-stage superfinishing is shown in Figure 4.

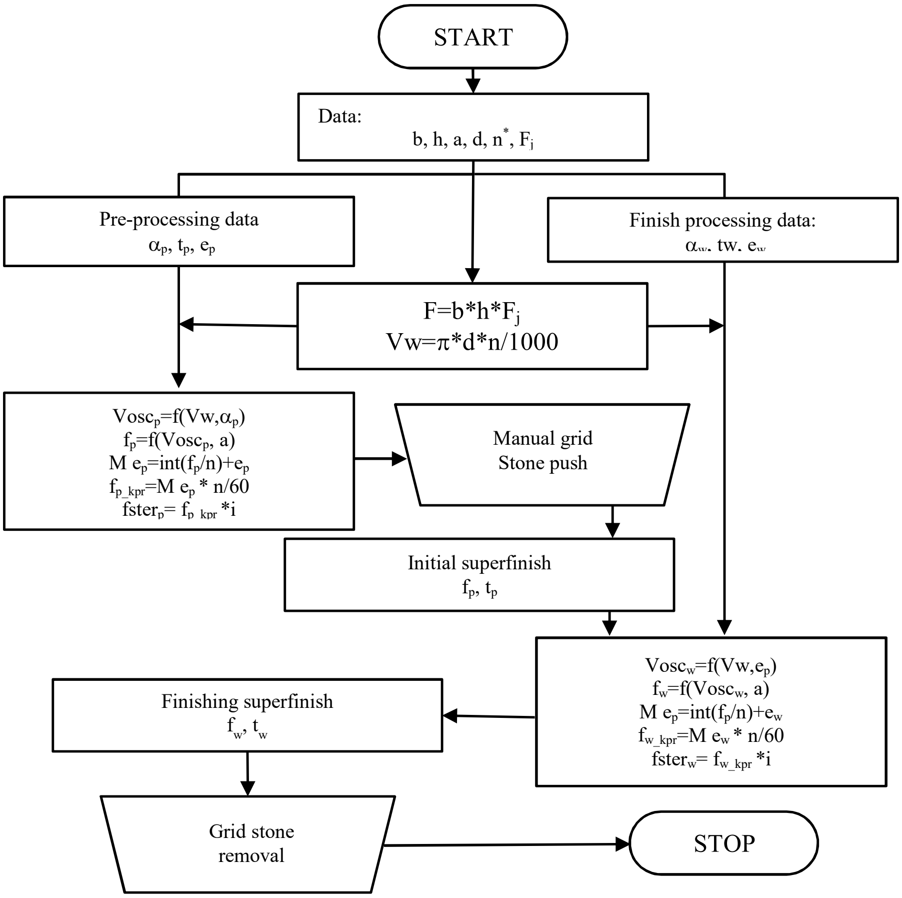

Fig. 4. The control of the stand algorithm: *b, h* -dimensions of the grid stone, *a* - amplitude of grind stone motion, *Fj* - unit pressure of grind stone, *F*-down force of the grind stone, *t* – time of the processing

On the basis of the input data, the algorithm based on the given diameter of the work surface, the amplitude of the oscillating movement, the set speed (subject to the control), and according to the given grinding directional angles, selects oscillation frequency to provide adequate conditions for grinding directional angles [6] by setting value of the *e* parameter. Dimensions of the grind stone are used to calculate pressure unit used to determine the required clamping force. At the same time algorithm oversees the pre superfinishing times and automatically goes into finishing, and signals the end of treatment.

The increase in the tangential speed recommended in the finishing phase [6] requires the interruption of the machining process to adjust the rotational speed of the spindle. As soon as the spindle speed control is implemented and a corresponding feed to the actuator control will be created, the system will allow for fully automatic machining process control taking into account also the down force adjustment.

The algorithm (Fig. 4) uses relationships (1)-(7), which are implemented in the control software developed in VB6 (Fig. 5). Program window consists of three panels. On the “Data” panel input fields are provided for the input settings. The second panel, "Manual" allows to define: the peripheral speed, the speed of oscillation, the frequency of the oscillating movement.

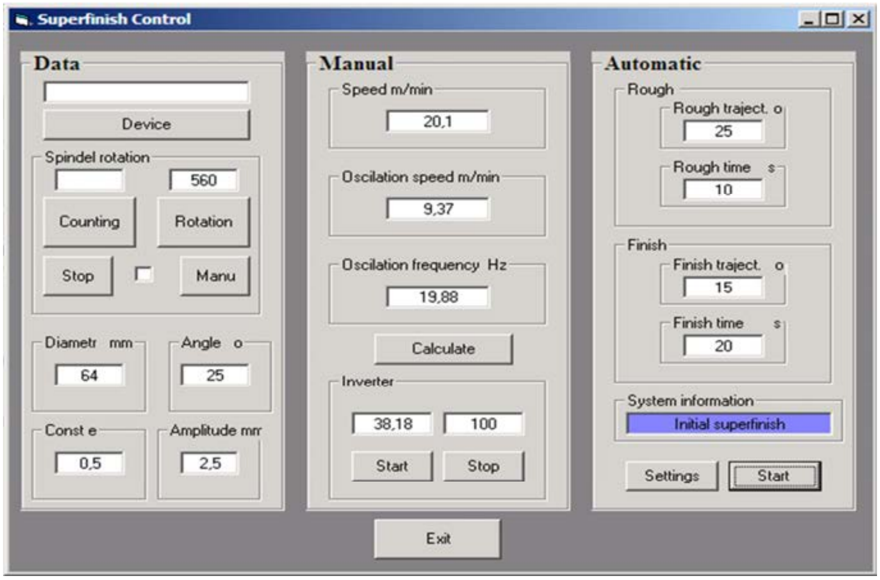

Fig. 5. Control panel of software

Start button on the “Manual” panel enables manual control of an oscillation frequency using the inverter.

On the "Automatic" panel two-stage processing data can be provided:

• grinding directional angle,
• time period,
• the *e* parameter.

The program suggest defaults values for all the parameters. At the same time the software uses built in tables allowing selection of parameters based on the literature [1].

After clicking the *Start* button, system starts the process of manual processing while adjusting to the desired grind stone down force. The program oversees the process in accordance to the predetermined algorithm giving appropriate system messages and signaling as the processing advances.

Experiments have shown the correctness of the control superfinishing process. Oscillation frequency has been observed during several program runs. The frequency perfectly followed the machining sequence input by the user in all the test cases. The status of the machining was presented by color signals and text messages in the *System* *information* window. The developed system allows optimum oscillating motion parameters selection for the actual rotational speed of the object.

4. Summary

The computerized superfinishing system enables the optimization of the oscillating frequency due to the established value of the grinding directional angle and can even recommend an offset sine wave *e*, taking into account the actual speed of the object. The main limitation of the presented configuration is that it uses manual spindle speed control, which required interruption in the process for manual speed adjustment. Therefore, common spindle speed value has to be chosen for the first and second stage of machining process, while automatically adjusting oscillations according to the two-step grinding process sequence. Main improvement to the laboratory setup will be the use of continuous variable spindle speed control and the use of controlled infeed speed. This will allow for further optimization of the processing parameters, including speed profiling for each phase of the process and automated whetstone motion to enable adaptive pressure control depending on the processing step.

To compare the results with the ones reported in literature, surface roughness needs to be measured in an automated way for instance using reflectometrics method [17]. Further work on the control of the oscillatory tools trajectory shall bring more insight into the automated machining process.

References

[1] Weiss E, Kształtowanie jakości wyrobów i wydajności obróbki w procesie dogładzania (Development of product quality and processing efficiency in the superfinishing). Politechnika Poznańskia, Seria: rozprawy nr 346, Poznań, 1999
[2] Dąbrowski L, Obróbka ścierna w technikach wytwarzania (Abrasives and manufacturing techniques). Oficyna wydawnicza Politechniki Warszawskiej, Warszawa, 2005
[3] Kacalak W, Lewkowicz R, Ściegenka R, Podstawy efektywnego doboru parametrów i warunków mikrowygładzania foliowymi taśmami sciernymi (Basics efficient selection of parameters and conditions micro-abrasive foil tapes). XXV Naukowa Szkoła Obróbki Ściernej, Wrocław - Duszniki Zdrój, 2002
[4] superfinish machinen www.supfina.de
[5] http://darmann.com/other/The_Art_of_Superfinishing.pdf
[6] Nowicki B, Dynarowski R, Teoretyczne i eksperymentalne badania niekonwencjonalnego gładzenia powierzchni krzywoliniowych (Theoretical and experimental research of unconventional honing curved surfaces). Międ. Konf. Naukowa Obróbka Materiałów, 2000.
[7] Oczoś K, Habrat W, Innowacje w obróbce ściernej. Cz. II Szlifierki narzędziowe i wykończeniowe urządzenia ścierne. (Innovations in grinding machining. Vol. II Tool Grinding and Abrasive Finishing equipment Mechanik, nr 12 2008
[8] Kacalak W, Tandecka K, Effect of superfinishing methods kinematic features on the machined surface, Journal of Machine Engineering, Vol. 12, No. 4, 2012
[9] Masseth J, Kolivand M, Lapping and superfinishing effects on hypoid gears surface finish and transmission errors Proceedings of the ASME 2007 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDETC/CIE 2007 September 4-7, 2007, Las Vegas, Nevada, USA
[10] Mikołajczyk T, ATR Bydgoszcz Urząd Patent. PRL nr 186061, data zgł. 31.12.1980, data opubl. 31.01.1984 Narzędzie do elektrochemiczno-ściernej obróbki powierzchni zwłaszcza dogładzaniem oscylacyjnym (Tool for electrochemical and abrasive surface machining especially by superfinishing)
[11] Mikolajczyk T, Olaru A, Krainski P, Adaptive control system for drill machine, Applied Mechanics and Materials 436, 2013, 445-450
[12] Lepadesdatescu B, Yordanova S, Neuro-fuzzy logic based modelling for optimisation in superfinishing process, Faculty of Technological Engineering and Industrial Management Advances in Automatic Control, Modelling & Simulation (http://www.wseas.us/e-library/conferences/2013/Brasov/ACMOS/ACMOS-06.pdf)
[13] Higashi K, Isa H, Kitagawa T, Onishi T, Ohashii K, Real-time monitoring of the superfinishing process, NTN No 82, 2014 (http://www.ntn.co.jp/english/products/review/pdf/NTN_TR82_en_061_067p.pdf)
[14] Iguchi T, Onishi T, Ohashi K, Higashi K, Tsukamoto S, Development of monitoring technology for superfinishing process, The Japan Society for Abrasive Technology, Proceedings of Abrasive Technology Conference, 2011, 297
[15] Yamashita S, Onishi T, Ohashi K, Higashi K, Iguchi S, Yamamoto R, Tsukamoto S: In-process monitoring of machining state in superfinishing – determination of machining state by machining force ratio, The Japan Society for Abrasive Technology, Proceedings of Abrasive Technology Conference, 2012, 45
[16] Onishi T, Ohashi K, Higashi K, Yamashita S, Iguchi S and Tsukamoto S, In-process monitoring of machining state in superfinishing, Proceeding of the 7th International Conference on Leading Edge Manufacturing in 21st Century (LEM21), 2013, 89-92.
[17] Mikolajczyk T, System to surface control in robot machining. Advanced Materials Research, vol. 463-464, 2012, 708-711