SSRG International Journal of Mechanical Engineering
ISSN: 2348 – 8360 /doi:10.14445/23488360/IJME-V5I1P106

Volume 5 Issue 1, 31-33, January 2018

Experimental Determination of Optimum Exchanged Diameter in Internal Grinding

Le Xuan Hung[#1], Vu Ngoc Pi[#2], Ho Ky Thanh[#3], Dang Thi Thanh Nga[*4,] and Banh Tien Long[**5]

#. Thai Nguyen University of Technology, Thai Nguyen 23000, Vietnam
**. Thai Nguyen College of Industry, Thai Nguyen 23000, Vietnam*
***. Ha Noi University of Technology, Ha Noi 100000, Vietnam*

Abstract — *This paper introduces an experimental study to determine optimum exchanged diameter in the internal grinding process. In the study, a cost structure for internal grinding was given. In the cost structure, the influences of grinding process parameters including the wheel life, the total dressing depth, the radial grinding wheel wear per dress, and the initial grinding wheel diameter on the exchanged grinding wheel diameter were taken into account. The influences of cost components, including the machine tool hourly rate and the grinding wheel cost, were investigated. Based on the cost structure, the setup, and the experiment's procedure to determine the optimum exchanged diameter were given. From the results of the experiment, the optimum exchanged grinding wheel diameter was found. Grinding with the optimum exchanged diameter, both the grinding cost and grinding time can be reduced considerably.*

Keywords — *Grinding process, internal grinding, grinding, cost optimization*

I. INTRODUCTION

The grinding process and the internal grinding process are the most commonly finishing machining, used for precision sharp, high-quality surface productions. Consequently, the optimization of the grinding process has been subjected to many studies. Until now, a lot of studies have been done for optimization in external cylindrical grinding [1, 2, 3, 4, and 5] or surface grinding [6, 7, and 8]. For the internal grinding process, studies on this topic have been done on off-line optimization for effective determination of the wheel life [9], on online-optimization for optimizing the process and dressing parameters to reduce the grinding time [10], on adaptive process control to increase the efficiency in internal grinding [11] or for determining the optimum exchanged grinding wheel diameter [12].

This paper introduces an experimental work to determine optimum exchanged grinding wheel diameter when the internal grinding tool steel 9CrSi. The optimum exchanged diameter of the grinding wheel for reducing both the grinding cost and grinding time was proposed from the work results.

II. THEORETICAL ANALYSIS

In internal grinding, the single manufacturing cost per piece C_{sin} can be calculated as follows:

$$C_{sin} = t_s \cdot C_{mt,h} + C_{gw,p} \tag{1}$$

Where,

$C_{mt,h}$ - Machine tool hourly rate (USD/h) including wages, overhead, and cost of maintenance, etc.;

$C_{gw,p}$ - Grinding wheel cost per workpiece (USD/workpiece); $C_{gw,p}$ can be calculated by:

$$C_{gw,p} = C_{gw} / n_{p,w} \tag{2}$$

in which, C_{gw} is the cost of an internal grinding wheel (USD/piece); $n_{p,w}$ is the total number of workpieces ground by a grinding wheel, and it can be determined by [13]:

$$n_{p,w} = \left(d_{s,0} - d_{s,e}\right) \cdot n_{p,d} / \left[2\left(\delta_{rs} + a_{ed,ges}\right)\right] \tag{3}$$

Where $d_{s,0}$ is the initial grinding wheel diameter (mm); $d_{s,e}$ is exchanged grinding wheel diameter (mm); δ_{rs} is the radial grinding wheel wear per dress (mm/dress); $a_{ed,ges}$ is total depth of dressing cut (mm); $n_{p,d}$ is a number of workpieces per dress and is given by:

$$n_{p,d} = t_w / t_c \tag{4}$$

In which, t_w is wheel life (h) and t_c is grinding time (h). In internal grinding, the grinding time can be expressed as:

$$t_c = l_w \cdot a_{e,tot} / \left(v_{fa} \cdot f_r\right) \tag{5}$$

Where $a_{e,tot}$ is the total depth of cut (mm), l_w is the length of a workpiece (mm), v_{fa} is axial feed speed (mm/min), and f_r is radial wheel feed (mm/double stroke).

t_s - Manufacturing time includes auxiliary time (h); in the internal grinding process, the manufacturing time can be express as:

$$t_s = t_c + t_{lu} + t_{sp} + t_{d,p} + t_{cw,p} \tag{6}$$

Where, t_{lu} -time for loading and unloading workpiece (h); t_{sp} - spark-out time (h); $t_{d,p}$ -dressing time per piece (h):

$$t_{d,p} = t_d / n_{p,d} \quad (7)$$

With t_d is dressing time (h); Substituting (4) into (7) we have:

$$t_{d,p} = t_d \cdot t_g / t_w \quad (8)$$

$t_{cw,p}$ is time for changing a grinding wheel per workpiece (h); $t_{cw,p}$ can be calculated as:

$$t_{cw,p} = t_{cw} / n_{p,w} \quad (9)$$

With t_{cw} is time for changing the grinding wheel (h). Substituting (3) into (9), we have

$$t_{cw,p} = 2t_{cw}\left(\delta_{rs} + a_{ed,ges}\right) / \left[n_{p,d}\left(d_{s,0} - d_{s,e}\right)\right] \quad (10)$$

t_c - grinding time (h); in internal cylindrical grinding, the grinding time can be calculated as [15]:

$$t_c = \frac{l_w \cdot a_{e,tot}}{v_{fa} \cdot v_{fr}} \quad (11)$$

III. EXPERIMENTAL SETUP AND PROCEDURE

A. *Experimental setup*

- Grinding machine MACHT-701 (Fig. 1);
- Grinding wheel 19A 120L 8 ASI T S 1A, Size 23x25x8 (Japan);
- Diamond dresser DKB3E002110;
- Workpiece material: 9CrSi (Fig. 2);
- Workpiece dimensions ϕ25 x ϕ36 x 22 (mm^3);
- Total depth of dressing cut: 0.15 (mm) including for medium finish 4 times 0.03 (mm); for fine finish 3 times 0.01 (mm) and 2 times with the depth of dressing cut equals zero;
- Grinding regimes (based on [12]): the grinding wheel speed n_w =12.000 (rpm.); the work feed v_f =150 (rpm.); the axial feed speed v_{fa} = 70 (mm/min.); the radial wheel feed f_r =0.0025 (mm/double stroke);

From the above analysis, to determine the cost of the internal grinding process, it is required to conduct experiments to determine the parameters mentioned, such as the grinding time, the wheel life, the number of workpieces per dress...

Fig. 1: Grinding machine

Fig. 2: Workpieces

B. *Experimental procedure*

The experiment was conducted as follows: Grinding at 5 values of grinding wheel diameters, including ϕ20, ϕ18, ϕ16, ϕ15, and ϕ13. Before grinding, dressing with the above regime was carried out. The grinding time, the dressing time, and the time for loading and unloading workpiece were determined in the experiment. To find the wheel life, with each grinding wheel diameter value, the grinding time was taken longer than the wheel life. Also, after grinding, the measurement of the surface roughness was performed. The wheel life is determined based on the surface roughness measurement results for comparing with the requirement.

IV. RESULTS AND DISCUSSIONS

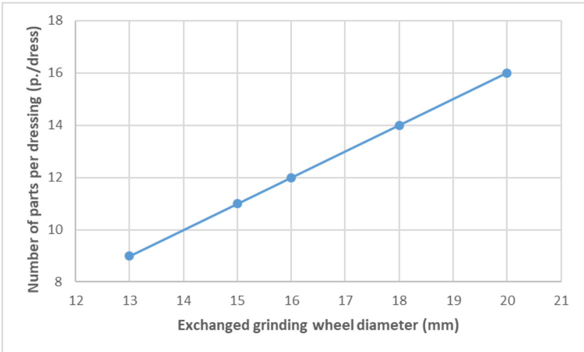

Fig. 3: *Number of parts per dressing*

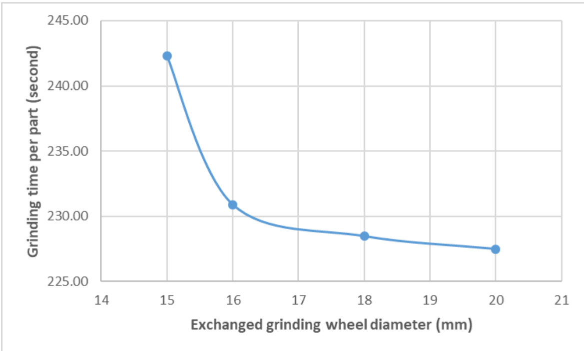

Fig. 4: *Grinding time versus exchanged grinding wheel diameter*

Fig. 3 shows the relation between the exchanged grinding wheel diameter and the average number of parts per dressing. From Fig. 3, it is clear that the number of parts per dressing depends significantly on the initial grinding wheel diameter. That means the wheel life depends on the exchanged grinding wheel diameter. Fig. 4 presents the relationship between the exchanged diameter and grinding time. It was found that when the exchanged grinding wheel diameter goes up, the grinding time goes down.

The relation between the exchanged diameter and the grinding cost per part was shown in Fig. 5. It was noticed that the grinding cost depends on the exchanged grinding wheel diameter. In addition, there is an optimum value of the exchanged diameter at which the grinding cost gets minimum (Fig. 5). Interestingly, the optimum diameter was much larger than the traditionally exchanged diameter. In this work, the optimum diameter was about 15.3 mm (Fig. 5), while the traditionally exchanged diameter was 13 mm. In addition, with the optimum diameter, the grinding cost per piece was 0.3215 (USD/p.) when it was 0.355 (USD/p.) with the traditionally exchanged diameter (13 mm). Consequently, in this case, grinding with an optimum diameter can reduce the grinding cost for:

$$\frac{(0.355 - 0.3215) \cdot 100}{0.355} = 9.44\% .$$

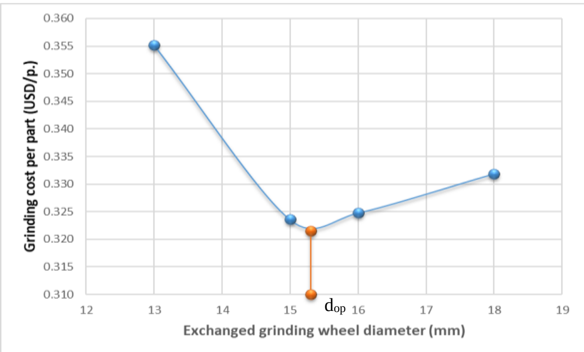

Fig. 5: *Grinding cost versus exchanged grinding wheel diameter*

V. CONCLUSIONS

An experimental study on the optimization of internal grinding was performed. In the study, the cost structures for the internal grinding process were analyzed. An experiment was set up to determine the optimum exchanged diameter to get the minimum grinding cost. The effects of exchanged diameter on the grinding process results, such as the wheel life, the grinding time, and the grinding cost, were calculated from the experiment results. Also, the value of the optimum exchanged diameter was found. Grinding with this optimum diameter can save a lot of grinding costs.

ACKNOWLEDGMENT

The Thai Nguyen University of Technology supported the work described in this paper for a scientific project.

REFERENCES

[1] J. Peters, R**. Aerens**, *Optimization Procedure of Three Phase Grinding Cycles of a Series without Intermediate Dressing*, CIRP Annals - Manufacturing Technology, Volume 29, Issue 1, 1980, Pages 195-200

[2] **G**. F. Li, L. S. Wang, L. B. Yang**,** *Multi-parameter optimization and control of the cylindrical grinding process,* Journal of Materials Processing Technology, Volume 129, Issues 1-3, 11 October 2002, Pages 232-236.

[3] R. Gupta, K. S. Shishodia, G. S. Sekhon, *Optimization of grinding process parameters using enumeration method,* Journal of Materials Processing Technology, Volume 112, Issue 1, 3 May 2001, P. 63-67.

[4] Y. C. Fu, H. J. Xu, J. H. Xu**,** *Optimization design of grinding wheel topography for high efficiency grinding*, Journal of Materials Processing Technology, Volume 129, Issues 1-3, 11 October 2002, Pages 118-122.

[5] Vu Ngoc Pi, Phan Quang The, Vu Hong Khiem, Nguyen Ngoc Huong**,** *Cost optimization of external cylindrical grinding,* Applied Mechanics and Materials, Vols. 312 (2013), pp. 982-989.

[6] X.M. Wen, A.A.O. Tay, A.Y.C. Nee**,** *Micro-computer-based optimization of the surface grinding process*, Journal of Materials Processing Technology, Volume 29, Issues 1-3, January 1992, P. 75-90.

[7] Aliuru Gopala Krishna, K. Mallikarjuna Rao, *Multi-objective optimization of surface grinding operations using scatter search approach,* International Journal of Advanced Manufacturing Technology (2006) Vol. 29, pp. 475-480.

[8] Vu Ngoc Pi, Le Xuan Hung, Luu Anh Tung, Banh Tien Long, *Cost optimization of Surface Grinding process*, Journal of Environmental Science and Engineering A 5 (2016) 606-611.

[9] I. Inasaki, Monitoring, and Optimization of Internal Grinding Process, CIRP Annals - Manufacturing Technology, Volume 40, Issue 1, 1991, Pages 359-362.

[10] G. Xiao, S. Malkin, *On-Line Optimization for Internal Plunge Grinding*, CIRP Annals – Manufacturing Technology, Volume 45, Issue 1, 1996, Pages 287-292.

[11] H.K. Tönshoff, A. Walter, *Self-tuning fuzzy-controller for process control in internal grinding,* Fuzzy Sets and Systems, Volume 63, Issue 3, 10 May 1994, Pages 359-373.

[12] Vu Ngoc Pi, Le Xuan Hung, Luu Anh Tung, Banh Tien Long, *Cost optimization of Internal Grinding,* Journal of Materials Science and Engineering B 6 (11-12) (2016) 291-296.

[13] W. Brian Rowe, *Principle of Modern Grinding Technology,* William Andrew, 2009.