

RESEARCH ON THERMAL STRESS ON THE WORK SURFACE GRINDED BY SEGMENTED GRINDING WHEELS MADE IN VIETNAM

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GIÁN ĐOẠN ĐƯỢC SẢN XUẤT TẠI VIỆT NAM

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ABSTRACT

In recent years, because of the superiority in improving the surface quality of machining part, segmented grinding wheel is increasingly used in industry. There have been some researches on segmented grinding wheel but no research has examined residual thermal stress that the segmented grinding wheels create. This research will clearly show the advantages of segmented grinding wheels compared to traditional grinding wheels through temperature and residual thermal stress simulation by using method of finite elements combined with the empirical method on segmented grinding wheels. In detail, we will study the segmented grinding wheels with $Z = 20$, made of abrasive corundum 46; when grinding, the cut depths will be respectively 0.02mm, 0.05mm, 0.07mm. The surface roughness, temperature, surface heat stress will be significantly reduced, which results in a significantly improved surface quality. The material used in this study was material group with high hardness, steel SKD11 with high surface hardness. Research has demonstrated the superiority of segmented grinding wheel with $Z = 20$ compared to traditional grinding wheel through specific data comparisons.

Key words: Segmented grinding wheel, grinding thermal field, grinding thermal stress, SKD11 material through thermal treatment.

TÓM TẮT

Trong những năm gần đây, do tính ưu việt trong việc nâng cao chất lượng bề mặt chi tiết gia công nên đá mài gián đoạn ngày càng được sử dụng rộng rãi trong công nghiệp. Đã có một số nghiên cứu về đá mài gián đoạn nhưng chưa có nghiên cứu nào xem xét ứng suất nhiệt dư mà đá mài gián đoạn gây ra. Nghiên cứu này sẽ chỉ rõ ưu điểm của đá mài gián đoạn so với đá mài thường thông qua mô phỏng nhiệt độ và ứng suất nhiệt dư bằng phương pháp phần tử hữu hạn kết hợp với phương pháp thực nghiệm trên đá mài gián đoạn. Cụ thể, chúng ta sẽ nghiên cứu các đá mài gián đoạn có $Z = 20$, làm bằng corundum mài mòn 46; khi mài các chiều sâu cắt sẽ lần lượt là 0,02mm, 0,05mm, 0,07mm. Độ nhám bề mặt, nhiệt độ, ứng suất nhiệt dư bề mặt sẽ giảm đáng kể, dẫn đến chất lượng bề mặt được cải thiện đáng kể. Vật liệu được sử dụng trong nghiên cứu này là nhóm vật liệu có độ cứng cao - thép SKD11. Nghiên cứu đã chứng minh tính ưu việt của đá mài gián đoạn với $Z = 20$ so với đá mài thường thông qua so sánh dữ liệu cụ thể.

Từ khóa: Đá mài gián đoạn; Trường nhiệt mài; Ứng suất nhiệt mài; Vật liệu SKD11 qua nhiệt luyện.

1. INTRODUCTION

Most of the energy in the grinding process is converted to heat from which will be passed into the grinding wheel, the workpiece, the cutting compound and the surrounding air. Depending on the material of the grinding wheel, this amount of energy is converted to heat and transferred to the workpiece more or less. The surface quality of the highly machining parts is only obtained after the grinding process because the grinding stress in this process is rather low. In contrast, in grinding process for a large number of workpieces, there is still surface damage which is caused by heat. It could be seen that heat has negative impact on the uniformity of the surface. Some of the concerned reasons for this are: dispersion, precipitation and softening of the part under the impact of abrasive, phase change which lead to the hardening of the surface; chemical reactions which leads to the oxidization of the surface. In order to improve the quality of grinding parts, grinding heat is one of the most difficult issues to solve because the temperature causes mechanical changes in the workpiece material; leads to the residual thermal stress; increases the surface roughness, surface combustion and microcrack as well as other negative impacts.

This leads to researches on various types of grinding wheel which could reduce the grinding heat so then it could improve the quality of grinding details. Among various types of grinding wheels, segmented grinding wheel is an effective solution which has been widely applied. Recent researches on segmented grinding wheels have indicated the superiority of this type of grinding wheel over traditional grinding wheels. For example, segmented grinding wheels could reduce 26% temperature in grinding process according

to the study of Nguyen Thi Phuong et al. [6]. In this study, the micro model will be used to examine the residual mechanical stress of the grinding process and the macro model will be used to examine the temperature and residual thermal stress of the grinding process. From the above two results, conclusions on total residual stress, temperature, surface roughness will be made.

The models used to study the thermal distribution in workpiece during the grinding process are based on the principles of moving heat sources of Carlaw and Jaeger [1], [2], [3], [4].

Segmented grinding wheel are created on the basis of traditional grinding stones with segments that can work on discontinuous surface. Grinding wheels with different number of segments and with different tilt angles can create various types of grinding wheels which will be suitable to be used in different cutting modes. This article focuses on straight segmented grinding wheels made in Vietnam with $Z = 20$ referring to the conclusions of many articles [7] on the superior ability of straight segmented grinding wheels with $Z = 20$.

2. THEORETICAL BACKGROUND IN RESEARCHING RESIDUAL THERMAL STRESS BY METHOD OF FINITE ELEMENTS

There are many researchers in the world who have introduced models of moving heat, such as Outwater and Shaw [4], who offer a model of moving heat in sliding form on slip surfaces. In fact, the energy in sliding surfaces can not be calculated. Hahn [4] proposed a general model of moving heat on specific 

surface grinded by abrasive. In this model, the researcher calculates the energy at the contact position and ignores the energy on the slip surface. As a result after studying some thermal models, the moving heat source of Jaegers is used with the heat source arrangement as shown below:

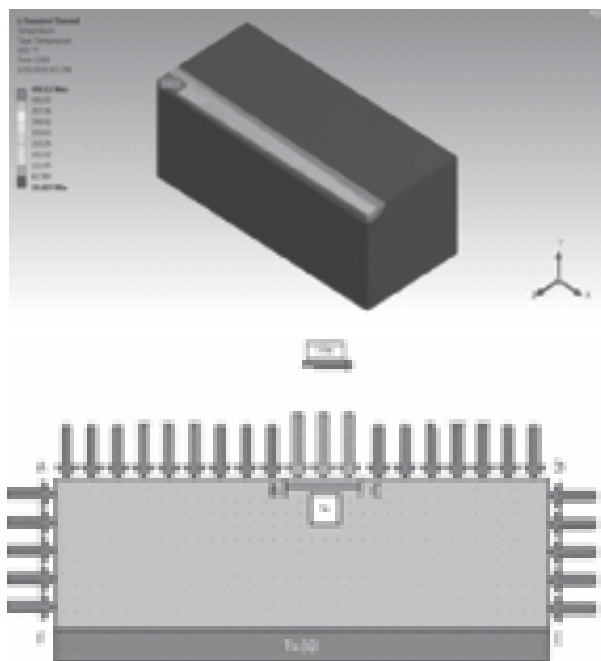


Figure 1. Jaeger's model of moving heat sources

In which the thermal flux is calculated by $\sqrt{d \cdot t}$ the formula:

$$\dot{q}_w = K_v \cdot K_w \cdot \frac{v_c \cdot F_t}{l_g \cdot b_w} \quad (1)$$

In formula (1) the coefficient K_v represents for the percentage of energy transferred during the grinding process to the heat form. In the grinding process, almost all of the generated energy is transferred into heat [2], so the coefficient $K_v = 1$. The coefficient K_w represents for the amount of heat passed to the workpiece. In the case of machining by abrasive Corundum and ceramic binder, the

coefficient $K_w = 0.85$ [5].

is the length of tangent area between the grinding wheel and the workpiece and is determined:

Within:

t: cutting depth (mm)

d: grinding wheel diameter (mm)

Heat transfer theory in method of finite elements:

In the method of finite elements, to solve the problem of temperature and heat moving in solids, we must solve the following matrix:

$$(K + K_h + K_r) T = RQ + Rq + Rh + Rr \quad (2)$$

3. THERMAL SIMULATION RESULTS BY METHOD OF FINITE ELEMENTS

3.1. The temperature of grinding workpiece when using traditional/ normal grinding wheel and segmented grinding wheel

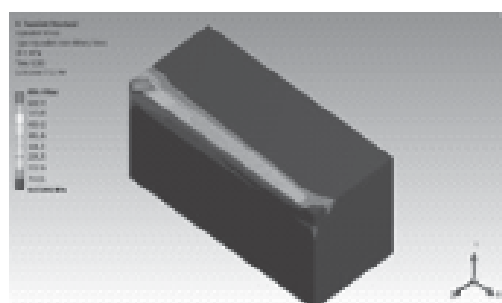


Figure 2. Temperature of grinded part with traditional grinding wheel ($z=0$) and the cutting depth $t=0.05$ mm

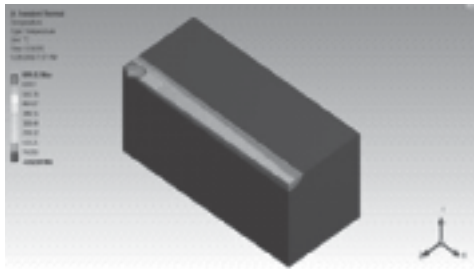


Figure 3. The results of temperature simulation when using segmented grinding wheels with $Z=20$, $t=0.05$ mm

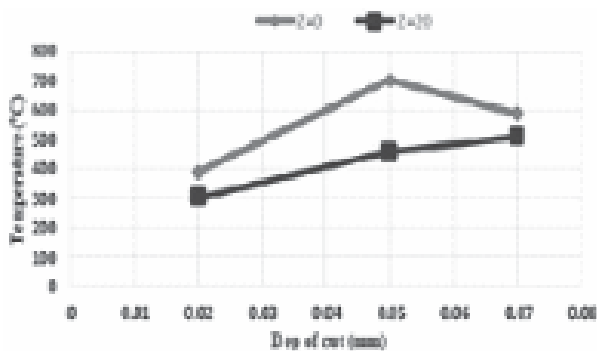


Figure 4. The maximum temperature during the grinding process with two types of grinding wheels

After obtaining the temperature field, we use that simulation result as the input for the thermal stress problem [6]. The simulation time of the mechanical problem is similar to the simulation time of the thermal problem. We obtain the following stress results:

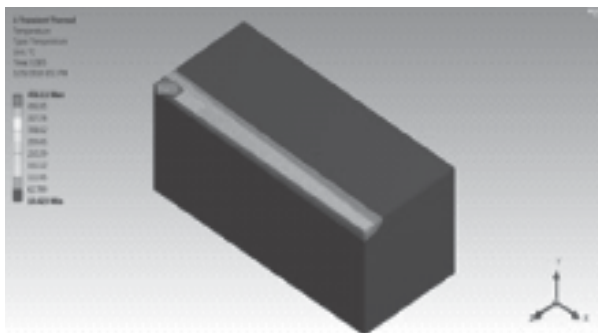


Figure 5. Thermal stress and cutting depth during grinding process with traditional/ normal grinding wheel ($Z = 0$)

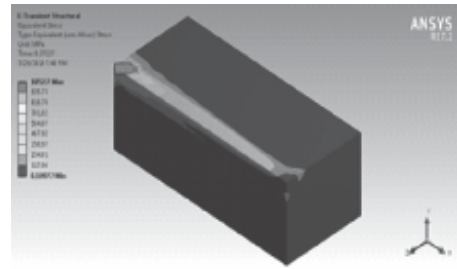


Figure 6. Thermal stress of the workpiece when using segmented grinding wheel

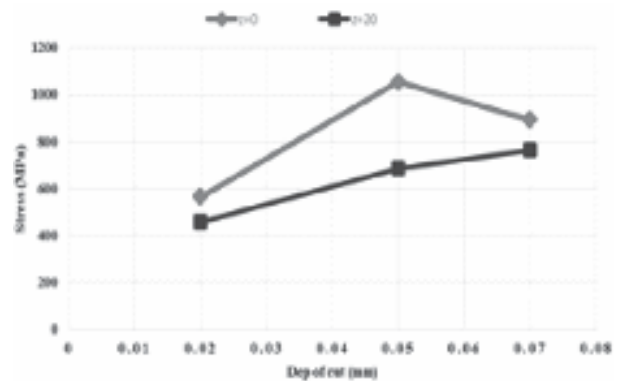


Figure 7. The relationship between the thermal stress and the cutting depth during grinding process

4. EMPIRICAL METHOD BY USING SEGMENTED GRINDING WHEEL MADE IN VIETNAM

In the test of surface grinding the material with high value of surface hardness SDK 11, segmented grinding wheel Cn46 is used with $Z = 20$. The following figures show the shape and size of grinding wheel Cn46.

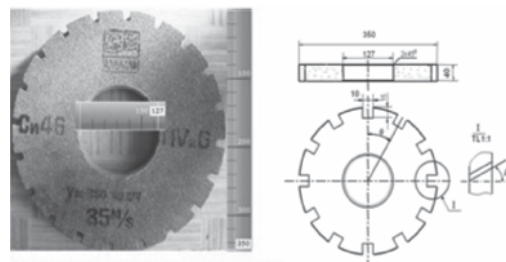


Figure 8. Segmented grinding wheel used in this experiment.

The experiment is carried out as follows:

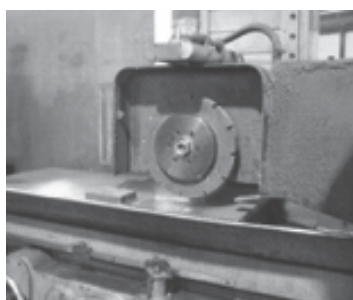


Figure 9. Frame structure for segmented grinding wheel on the machine

Cutting mode used in experiment has the parameters as following: $S_d = 12\text{m / ph}$; $t = 0.05\text{ mm}$; $S_{ng} = 4\text{mm / HTK}$; $V = 26\text{ m/ s}$. The rock code is: Cn46 MV2 350x40x127-35m / s. The steel workpiece used for this testing process is SKD11 steel which has been through steel heat treatment to reach the hardness level of 58-60 HRC, produced by the Corporation of industrial machines and tools, with $a \times b \times c = 70 \times 30 \times 25\text{mm}$. Figure 11 shows a sample of the workpiece used in the experiment.

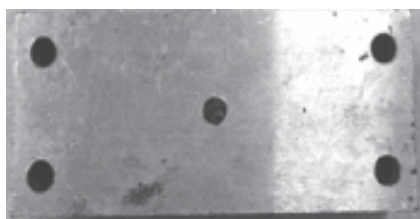


Figure 10: The experimental sample

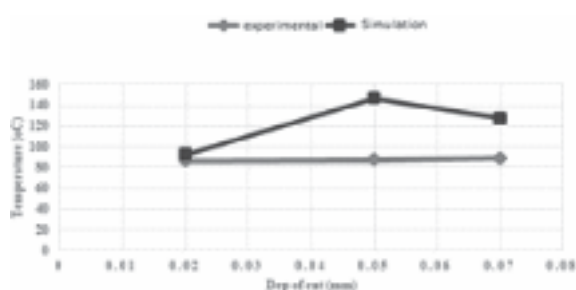


Figure 11: Temperature graph between experimental and simulation results when using traditional/ normal grinding wheel

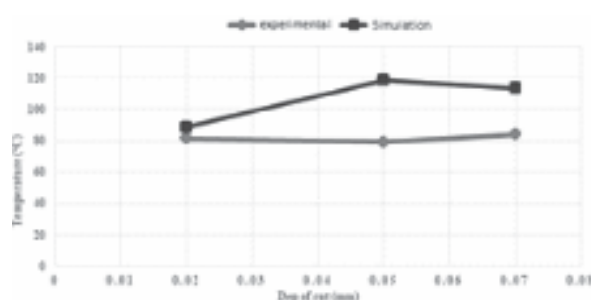


Figure 12: Temperature graph between experimental and simulation results when using segmented grinding wheel

- When comparing traditional/ normal grinding wheel and segmented grinding wheel, the temperature of the position which is roughly 2 mm far from the machining surface, when using the segmented grinding wheel, reduced significantly in both simulation and experiment, in simulation was 12.38% and in Experiment was 7.1%.

5. DISCUSSION

Average temperature of 3 cases of cutting depth of normal grinding wheel and segmented grinding wheel decreases by 30%. We achieved this very optimistic result due to the special property that only segmented grinding wheel has, the discontinuity of the grinding surface makes the tangential cutting of the grinding stone significantly reduced, and so the heat flux caused by friction and collision of the abrasive grains with the workpiece also decreases, which makes the surface temperature on the surface significantly lower.

Thermal stress in the grinding process is proportional to the temperature field, so when using the interrupted grinding stone, this value is also significantly reduced, namely the average of 3 depths cutting heat stress when using grinding wheel section reduced 34% compared to conventional grinding.

6. CONCLUSION

From the results of the simulation of the temperature field and the experiment that used segmented grinding wheel to machine SDK11 heat-treated material, it can be concluded as follows:

1. The construction of a macroscopic model based on tangential cutting forces to find a temperature field helps to reduce difficult experiments to measure the surface temperature of grinding wheels. finite element method helps to save costs for identifying, predicting mechanical properties of grinding details, effectively serving for production research.

2. Straight-edge grinding wheels manufactured in Vietnam have the ability to reduce cutting force (up to 17.6%) and cut heat (up to 24.23%) than conventional abrasives. Thermal stress was also reduced by 23.99%, with an average of 3 cutting depths of 0.02 mm, 0.05 mm and 0.07 mm, and a roughness of 25.17%.

3. When flat grinding, the $z = 20$ grindstone has a high efficiency in surface finish quality compared to conventional grinding $Z = 0$. ❖

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