The Difference in Micro-deburring Finish Produced by Groove Cutting Method

Mitsunori Mori[1,2(✉)], Tatsuro Nagasuna[1], and Hiroyuki Hamada[2]

[1] Tango-Giken Co., Ltd., Kyoto, Japan
mitsunori-mori@tango-giken.co.jp
[2] Kyoto Institute of Technology, Kyoto, Japan

Abstract. It is ideal to remove micro-bur during the mechanical processing, however, burs in micro level must be removed manually. Moreover, in order to perform an even deburring process, precise angle control of deburring tool and repeatable motion control is necessary, which requires a skilled craftsmanship.

In this report, in order to establish a training method of high-level deburring craftsperson, we will study the difference between skilled and unskilled worker's working process. The research will involve monitoring several workers with different length of experience engaging in the same deburring process of micro-bur, and examine the difference in their working method through eye movement measurement and motion analysis. We will evaluate the data gained from this research and the difference in the time required for the deburring process between the workers of different experience. And with understanding these differences, we will define the process necessary for standardizing the deburring work.

Keywords: Deburring · Eye movement measurement · Motion analysis

1 Introduction

Although there are differences depending on the facility, shape and required precision, the common production process of metal parts involves these 5 steps below.

1. Machine Processing + Deburring
2. Heat Treatment
3. Finishing
4. Surface Treatment
5. Inspection

Among them, #1. is a process that mainly involves cutting and turning, which generate edges and burs that causes functional defects afterwards. It is ideal to remove burs during the machine processing. However, burs in micro level are difficult to remove during the machine processing, meaning it requires manual deburring. Moreover, in order to perform an even deburring, control of deburring tool and repeatable movement are required, which demand advanced craftsmanship.

V.G. Duffy (Ed.): DHM 2016, LNCS 9745, pp. 466–474, 2016.
DOI: 10.1007/978-3-319-40247-5_47

2 Method

2.1 Test Subjects

Test subjects are selected from the workers who have deburring experience. One expert female worker who have worked in the company for 23 years, one non-expert male worker who have worked in the company for 2 years, and one female beginner who even though has worked in the company for 7 years, but has no deburring experience. Table 1 shows each test subject's information.

Table 1. Detailed Information of test subjects

Test Subject	Age	Years of service	Gender	Dominant Hand
Expert	41	23	Female	Right
Non-expert	48	2	Male	Right
Beginner	42	7*	Female	Right

(* An inexperienced person)

2.2 Measuring Condition

Test subjects were instructed to debur a processing object in the same shape. They were given several common deburring tools such as files and grindstones without specifying which tools to use. Table 2 shows the list of deburring tools. The order of work process was not specified as well. Selection of the tools was left to the judgment of individual subject. As shown in the Fig. 1, the part to be deburred is a same-shaped part made of S45C Material. The Measuring location was where the test subjects normally conduct their deburring.

2.3 Measuring Method

Moving images recorded with a video camera was used for work process analysis and movement analysis. Eye movement measurement was conducted with "Mobile Type Eye Mark Recorder EMR-9 (nac Image Technology Inc.)". Figure 2 shows the view during the experiment. Analysis of the test subjects' eye movements/focus points during the deburring was conducted with CCD camera attached to the measurement goggles. The product evaluation after deburring was conducted with a digital microscope VHX-200 (KEYENCE Corporation) for appearance evaluation (in 20 magnification), and "Contour Measuring Instruments SURFCOM 1700DX2 (TOKYO SEIMITSU CO., LTD.) for quality/shape evaluation after deburring. The quality evaluation after deburring was conducted is a separate location that was not disclosed to the test subjects.

Table 2. List of deburring tools.

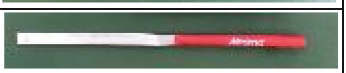
No	Name	Image
1	Half Round File	
2	Shaping Knife A	
3	Ceramic Grindstone	
4	Shaping Knife B	
5	Shaping File	
6	Flat File (Large)	
7	Ceramic Knife	
8	Flat File(Small)	

Fig. 1. Object for deburring

Fig. 2. View from eye movement measurement

3 Result and Examination

3.1 Movement Analysis Result

As shown in Fig. 3, a number was assigned to each section that requires deburring. This numbering was used to analyze the order/tools used for deburring. Figure 4 shows

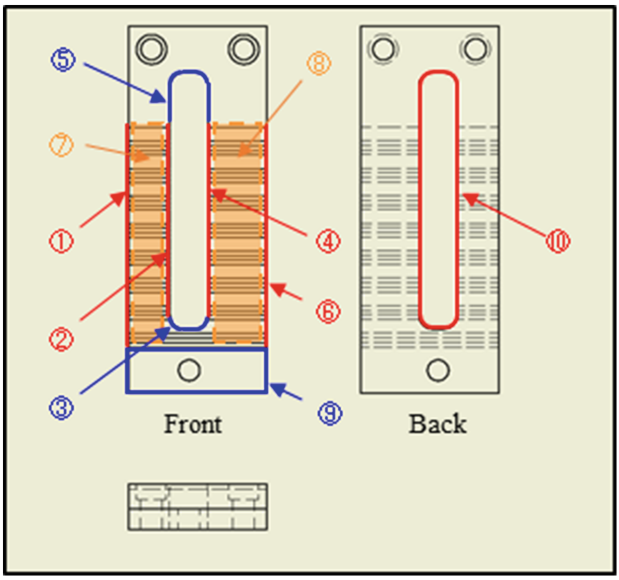


Fig. 3. Section numbers for deburring

the movement analysis of work done by the expert, the non-expert and the beginner. The expert deburred the same section 2.3 times on average, which tends to be lower as compared to the average of the non-expert, which was 4 times. Furthermore, both the expert and non-expert sometime used the same tool that they once finished using, but the average number of times they used the same tool on the same section was 2.1 times for the non-expert as opposed to the 0.5 time of the expert which results in lower tendency. As shown in Fig. 5, the number of palpation done by the expert was 65.3 % less than that of the non-expert.

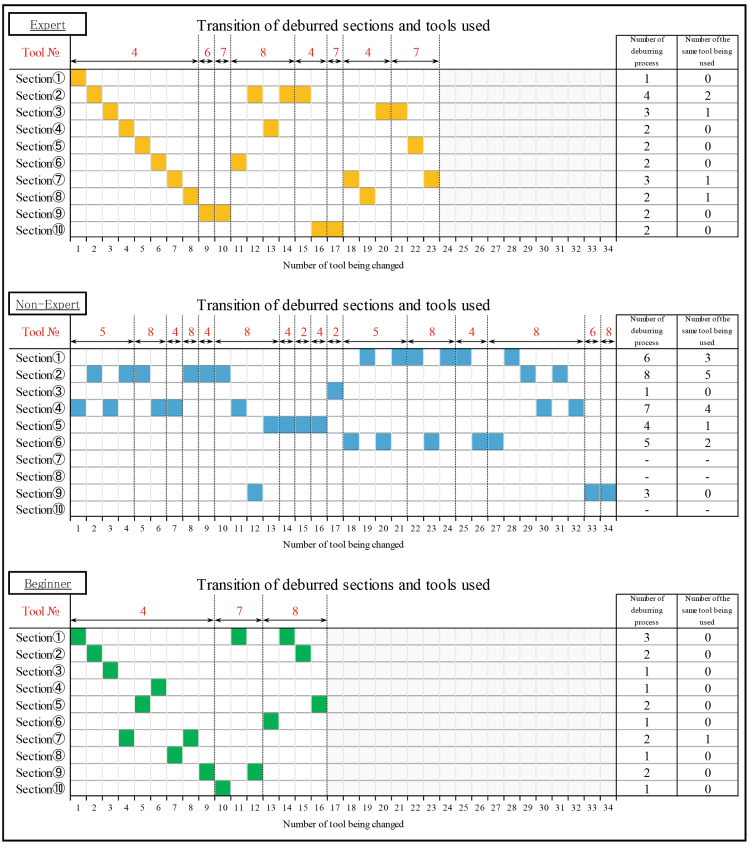


Fig. 4. Movement analysis results

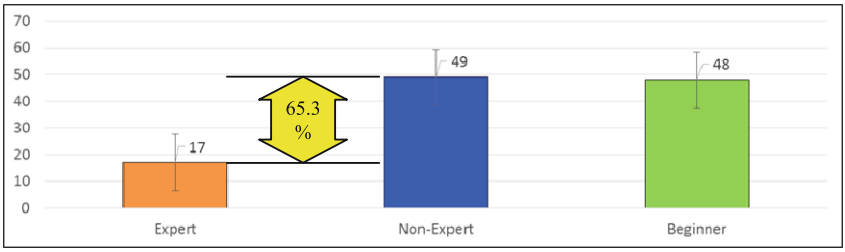


Fig. 5. Number of palpation during deburring process

3.2 Eye Movement Measurement Result

Figure 6 shows the results of eye movement analysis of the expert, the non-expert and the beginner. Even though duration of focus was longest for the expert, she completed the work in more than 45.94 % shorter time as compared to the non/expert and the beginner. Moreover, she had over 10 points less in the result check ratio as compared to the other subjects. Additionally, the expert repeated the 2 steps, namely "checking the shape before deburring" and "focusing on the section to be deburred".

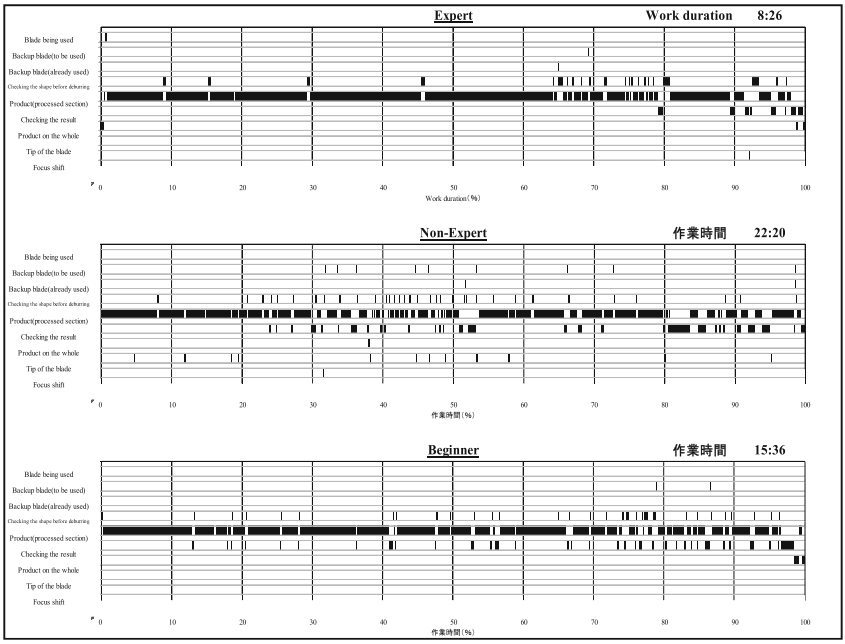


Fig. 6. Eye movement measurement results

In contrast, the non-expert and the beginner showed the tendency to add one more step, namely "checking the result", to these 2 steps. Figure 8 shows this result. The expert conducted the aforementioned 3 steps only after 80 % of the work is completed in 5 out of 6 times. This shows that she emphasizes the certainty of the deburring and evaluates the product quality requirement from the condition of the product at near-completion of deburring, instead of evaluating the effectiveness of deburring through checking the result immediately after deburring (Fig. 7).

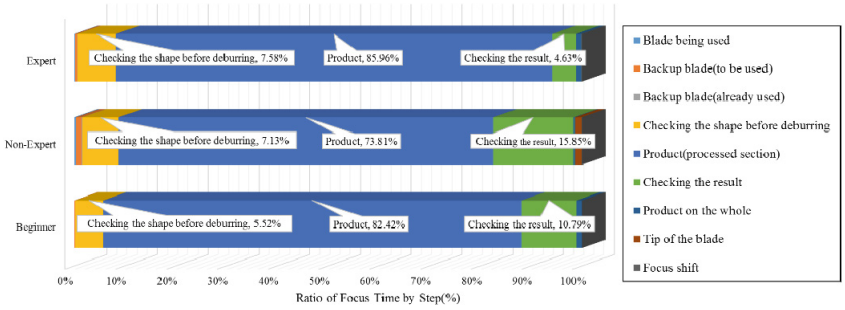


Fig. 7. Ratio of focus time by step

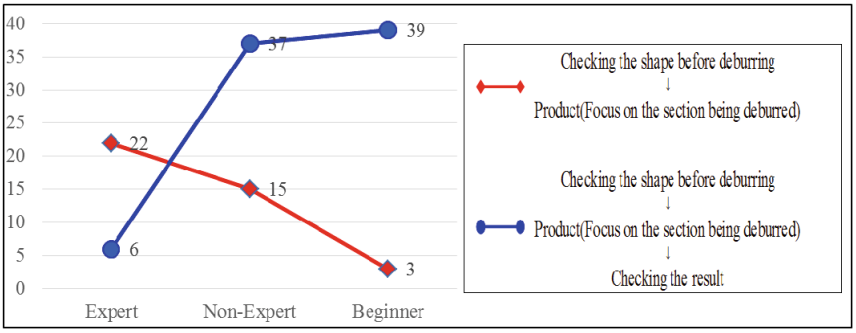


Fig. 8. Numbers of movement repetition according to experience

3.3 Shape Evaluation

Figure 9 shows the results of shape measurement before and after the deburring, as well as magnified pictures. Regarding the burs in the sizes between 0.04–0.06 mm before deburring, the surface after deburring done by the expert and the non-expert were in the state as specified by light chamfering. In contrast, the surface after deburring by the beginner still had burs about 0.04 mm without being removed. On the magnified pictures showing the surface after deburring by the expert and the non-expert display successful deburring. In contrast, the magnified pictures showing the surface after deburring by the beginner show that burs were left partially or continuously.

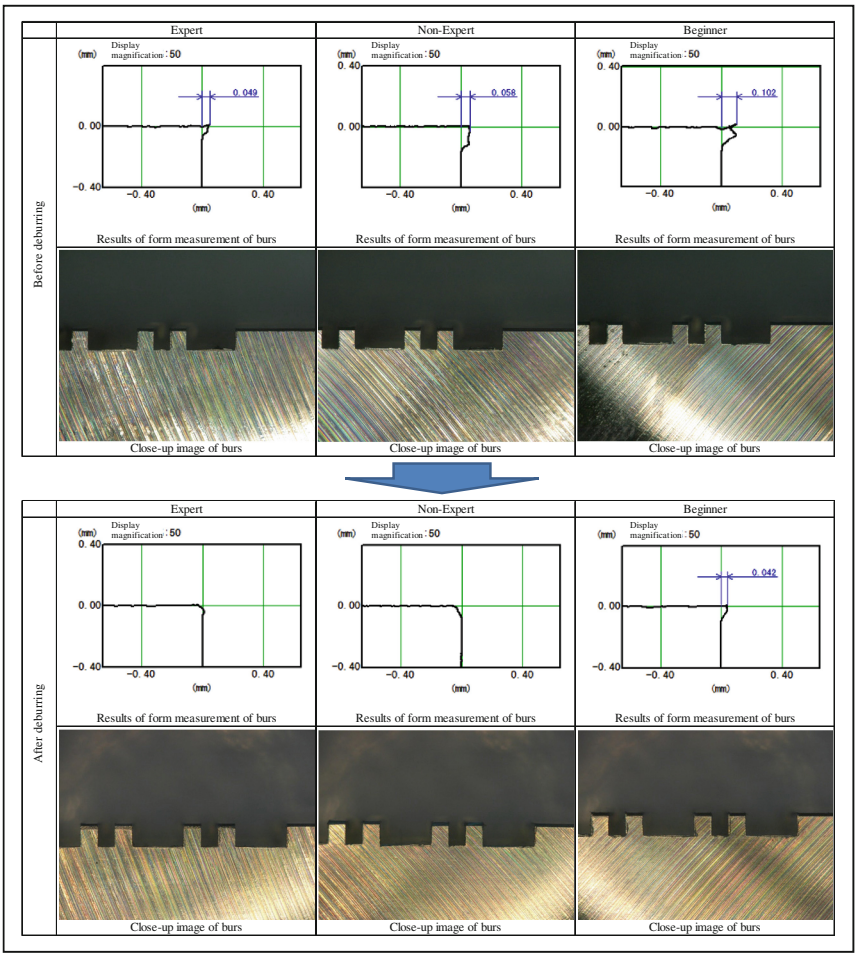


Fig. 9. Quality evaluation result

4 Conclusion

In this research, we conducted the movement analysis, eye movement analysis and quality control during the deburring works done by an expert, a non-expert and a beginner. The result showed that the expert and non-expert have already acquired the ability to produce/assess products that satisfy the required quality standard, despite the differences in their work duration/work process. The expert demonstrated that by acquiring a skill to optimize the deburring process, she could shorten the time spent on "checking the result". Moreover, she is deemed to consider/select the most suitable tools while "checking the shape before deburring" in order to conduct her work with least possible tools and deburring number. In contrast, both the non-expert and the beginner demonstrated that their duration/number of deburring is more than that of

expert because they assess the effectiveness of their deburring by “checking the result”. It was also concluded that even though the movement analysis of the beginner showed that she displayed smaller number of tools used, deburring number and repetition of deburring the same section, she did not perform deburring that satisfy the quality standard and therefore she was not conduct an effective deburring process.