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# Work Procedure Manual Incorporating Experienced Workers' Intuition and Knowhow

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***Abstract:*** *The stagnancy of Japanese machining skills in recent years is concerning. This is purportedly due to the implicit training style, which relies on the intuition and knowhow of experienced workers. This intuition and knowhow needs to be identified and imparted to inexperienced workers. We attempted a statistical and scientific approach to achieve this. We then created a work procedure manual incorporating experienced workers' intuition and knowhow to train inexperienced workers effectively and efficiently. We considered the working of a lathe and identified the difference in skills of experienced and inexperienced workers by analyzing (i) the workers' brainwaves, (ii) the vibration of the workpieces, and (iii) the odor emitted during the work. Our analysis demonstrated that experienced workers (i) relaxed and concentrated at appropriate times, (ii) adjusted the slide speed appropriately, and (iii) oiled the machine adequately, depending on the odor. Subsequently, we created a work procedure manual to teach when (i) the worker should relax or concentrate, (ii) the slide speed should be fast or low, and (iii) the worker should oil the machinery. We provide new insights for imparting experienced workers' intuition and knowhow to inexperienced workers.*
***Keywords:*** *intuition and knowhow, machining skills, work procedure manual*

## I. Introduction

The manufacturing industry has an important role in Japan's economy. One of Japanese manufacturing companies' strength is the high machining skills which form the basis of the manufacturing industry. However, the stagnancy of Japanese machining skills in recent years is concerning. This is purportedly due to the implicit training style the industry follows, which relies upon the intuition and knowhow of experienced workers. The companies need five to ten years for technicians to become fully independent, which implies that the development of technicians with skilled techniques requires an extended amount of time [1]. According to METI et al. (2015) [1], the main effort to develop human resources for manufacturing is experienced workers' giving instructions during daily work. On the other hand, several issues regarding education and training are "no time for development" and "there are not enough instructors". In order to train inexperienced workers effectively and efficiently under these circumstances, the implicit knowledge of experienced workers needs to be identified and imparted to them. Although a few studies have tried to identify this implicit knowledge in machining work [2–4], further research in this field is urgently needed. Based on Amasaka's application of statistics [5–7], we attempted to identify the intuition and knowhow of experienced workers through a statistical and scientific approach. We created a work procedure manual incorporating experienced workers' intuition and knowhow to train inexperienced workers effectively and efficiently.

Section II presents the analytical framework. Section III presents the results of our analysis. Section IV presents the work procedure manual based on the findings of our analysis. Lastly, Section V briefly summarizes our findings and provides suggestions for future research.

## II. Analytical Framework

### 2.1 Outline of Analysis

In this study, we considered the working of a lathe, using the lathe machine shown in **Fig.1**. We compared the skills of experienced and inexperienced machine workers when operating a lathe. Yanagisawa and Amasaka [2] analyzed the brainwaves of workers when working and identified the differences in mental states between experienced and inexperienced workers; their results provided important suggestions. In this study, we also focused on the brainwaves of workers at work.

In interviews conducted with some companies' experienced lathe workers, they indicated that their work depends on the vibration and odor emitted by the friction between the workpiece and the bite. Therefore, we also compared the vibration and odor of the lathe machining by experienced and inexperienced workers. In this study, we gave the same task to both the types of workers: to make the workpiece shown in **Fig.2**. A company worker, who was a medalist at WorldSkills, an international skills competition for youth, was selected as the experienced worker. A university student was selected as the inexperienced worker and he was given basic training for three months.

**Fig 1.** Lathe machine.

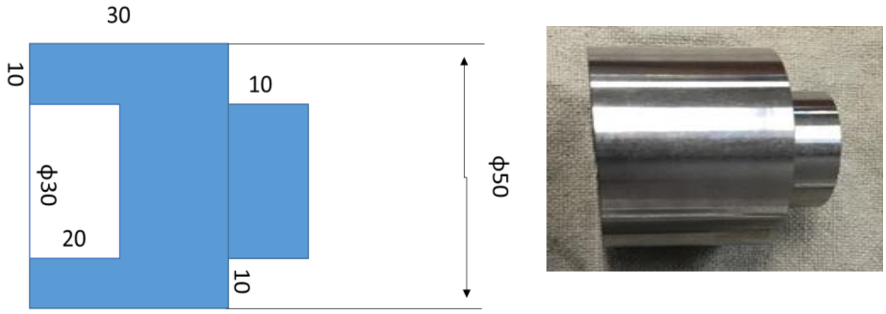



**Fig 2.** Task for experienced and inexperienced workers.

### 2.2 Measurements of Brainwaves, Vibration, and Odor

We focused on measuring brainwaves, especially the alpha and beta waves. Alpha waves pertain to mental relaxation, while beta waves are associated with concentration. Thus, we can tell if a worker is relaxed or concentrating by measuring his/her alpha and beta waves. The B3 Brain Band (B-Bridge International, Inc.) shown in **Fig. 3** was used to measure the alpha and beta waves of workers,who were asked to wear it when working. A general-purpose vibration meter, VM-82 (Rion Co., Ltd.), was used to measure the vibration of the workpiece. A portable odor level indicator, XP-329 III R (New Cosmos Electric Co., Ltd.), was used to measure the odor during the work. VM-82 and XP-329 III R were set on the tool holder, as shown in **Fig. 4**.

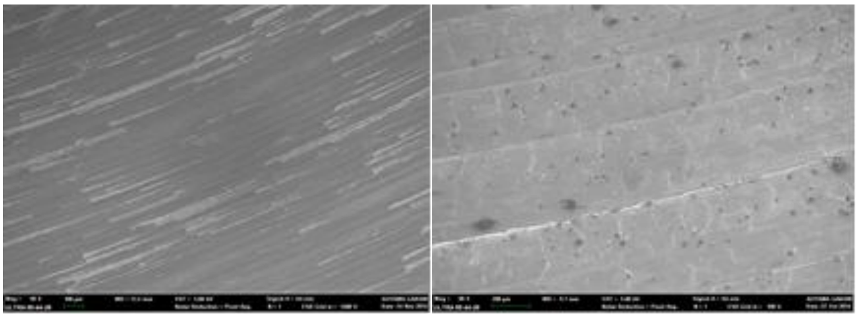
**Fig 3.** B3 brain band.


**Fig 4.** Placement of VM-82 and XP-329 III R.

## III. Results

### 3.1 Surfaces of the Products

The working times of the experienced and inexperienced workers were 41 min 36 s and 96 min 31 s, respectively. **Fig. 5** shows the surface of the finished products of each worker. The surface of the experienced worker'scompleted productis clearly smoother than that of the inexperienced worker.

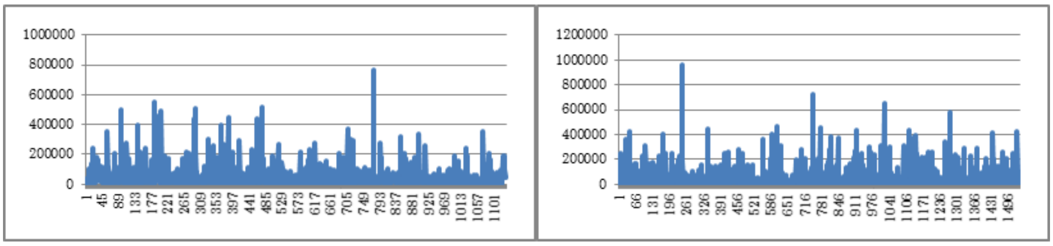


Experienced worker Inexperienced worker

**Fig 5.** Surfaces of completed products.

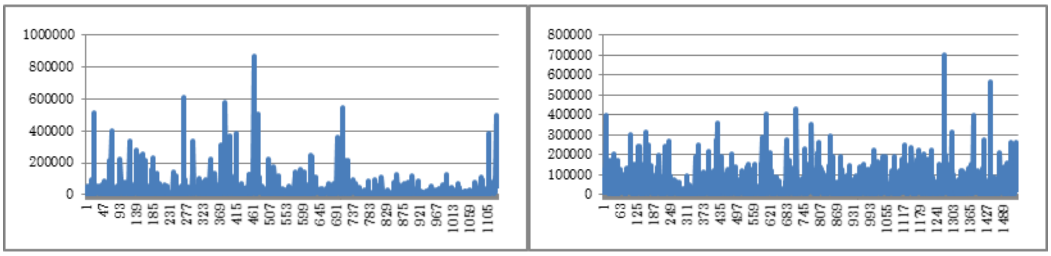
### 3.2 Brainwaves

**Fig. 6 and 7** demonstrate the changes in the alpha and beta waves, respectively, of the experienced and inexperienced workers when working.




Experienced worker Inexperienced worker

**Fig 6.** Alpha waves of experienced and inexperienced workers.




Experienced worker Inexperienced worker

**Fig 7.** Beta waves of experienced and inexperienced workers.

We calculated the number of times the experienced and inexperienced workers' alpha and beta waves exceeded the upper thresholds. The upper threshold was calculated in a similar way to identify the upper control limit of an X-R control chart.

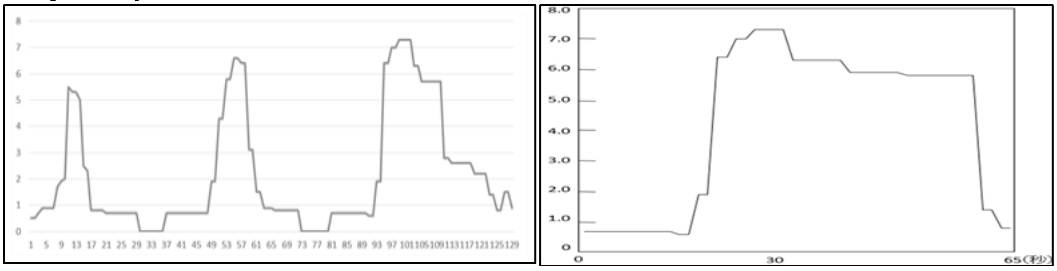
**Table 1** summarizes the number of times the upper threshold was exceeded divided by the working times. The alpha waves of the experienced worker exceeded the upper threshold more frequently than those of the inexperienced worker. This result shows that the experienced worker was more relaxed than the inexperienced one. The beta waves of the experienced worker exceeded the upper threshold fewer times than those of the inexperienced worker. This suggests that the inexperienced worker concentrated at all times when working. Thus, such workers need to learn when it would be appropriate to relax.

**Table 1** Number of Times Alpha and Beta Waves Exceeded their Upper Thresholds

| | Alpha waves | Beta waves |
|---|---|---|
| Experienced worker | 2.57 times/min | 2.37 times/min |
| Inexperienced worker | 2.33 times/min | 2.69 times /min |

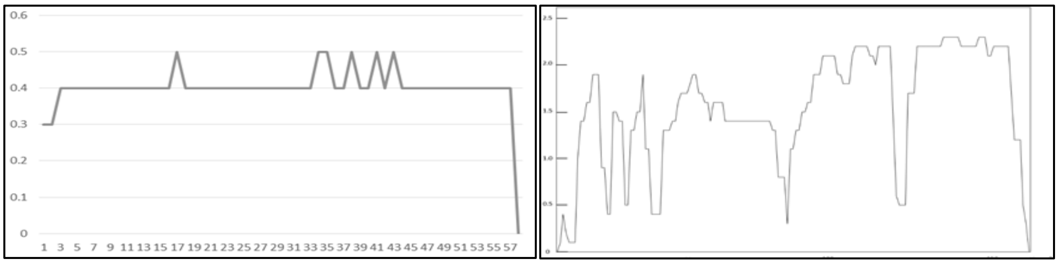
### 3.3 Comparative Analysis of Vibration

**Fig. 8 and 9** compare the changes in the vibrations during the rough-cutting process and finishing process, respectively.



Experienced worker　　Inexperienced worker

**Fig 8.** Vibration during the rough cutting process.



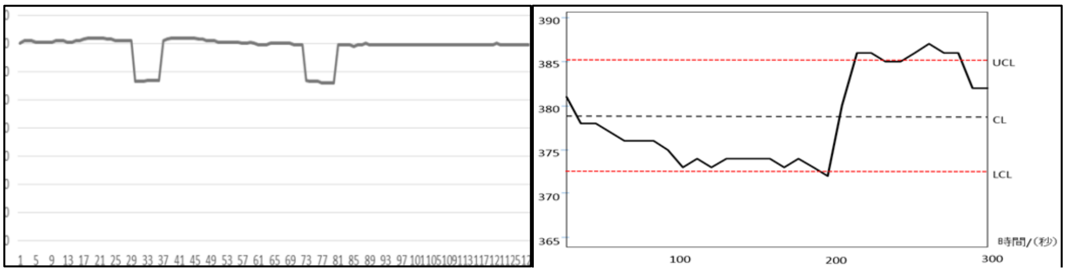
Experienced worker　　Inexperienced worker

**Fig 9.** Vibration during the finishing process.

The vibrations of the experienced worker's rough cutting process changed regularly compared to those of the inexperienced worker. This suggests that the experienced worker adjusted the slide speed appropriately. The vibration during the experienced worker's finishing process was low and constant, while that during the inexperienced worker's varied greatly. This is purportedly because the experienced worker adjusted the slide speed to be low and constant during the finishing process.

### 3.4 Comparative Analysis of Odor

**Fig. 10** compares the changes in odor during the rough cutting process. The experienced worker's graph was constant, while the inexperienced worker's value varied. The results suggest that the experienced worker adjusted the amount of oil depending on the odor.




Experienced worker　　Inexperienced worker

**Fig 10.** Odor during the finishing process.

## IV. Work Procedure Manual

In order to propose an effective training method, we developed awork procedure manual incorporating the experienced worker's intuition and knowhow.The comparative analysis of the beta waves suggests that it is important to relax and concentrate at appropriate times. Thus, we analyzed the beta waves of the experienced worker and identified when he was relaxed or concentrating. We added the marks on the work procedure manual to inform workers of the times at which to concentrate or be relaxed. **Fig. 11** shows awork procedure manual on the rough cutting process where we added the marks "relax" or "concentrate" based on the results of our brainwave analysis.

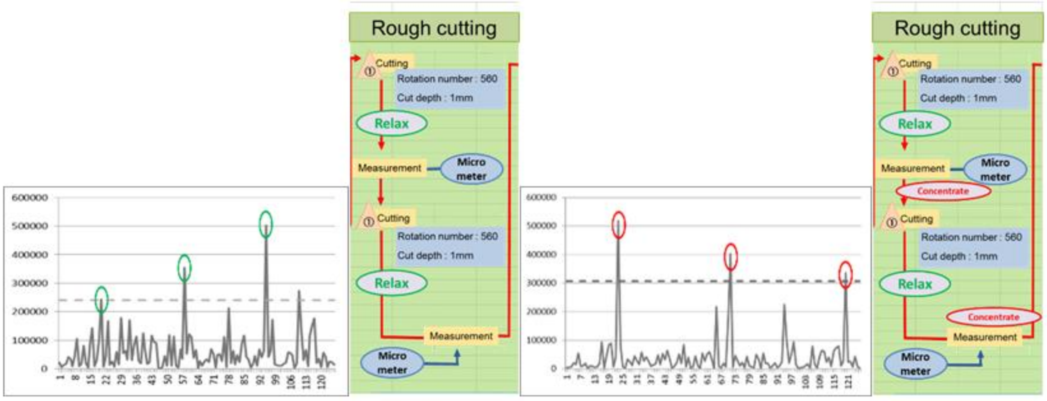



**Fig. 11.** Work procedure manual incorporating the results of brainwaves analysis.

The comparative analysis of the vibration showed that the slide speed is important. Thus, we analyzed the slide speed of the experienced worker based on the vibration and video records of him working. We added marks on the map to inform workers when the slide speed should be fast or slow as shown in **Fig. 12**.

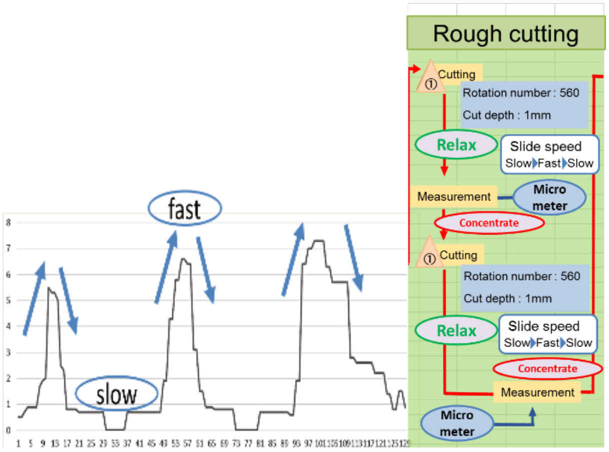



**Fig 12.** Work procedure manual incorporating the results of vibration analysis.

The comparative analysis of the odor highlighted the importance of the timing of machinery oiling. Thus, we analyzed when the experienced worker oiled the machinery based on changes in the odor and video records of him working. We added the marks on the map to inform workers when to oil the machinery as shown in **Fig. 13**.Fig. 13 is the completed work procedure manual incorporating experienced workers' intuition and knowhow in rough cutting process.

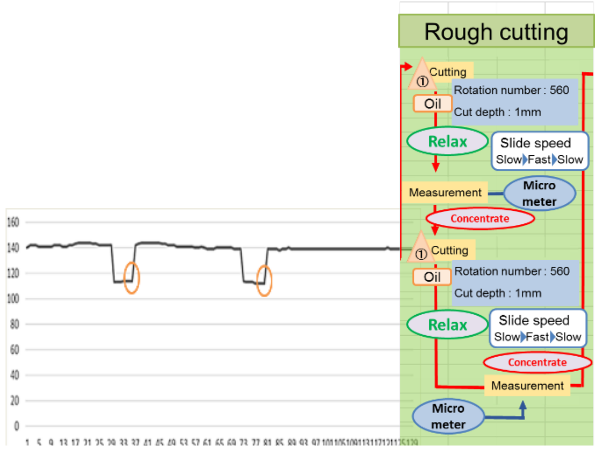
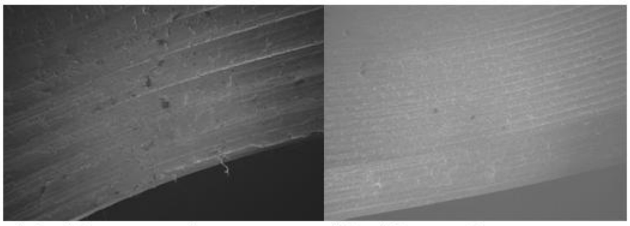



**Fig 13.** Work procedure manual incorporating.

To verify the effectiveness of our proposed work procedure manual, the same inexperienced made the same workpiece again while looking at the manual. **Fig. 14** compares the surface of the finished products (1) when he made it without the manual and (2) when he made it with manual. The surface of the completed product which he made with manual has less burr and is clearly smoother. Thus, it was demonstrated that our proposed work procedure manual is effective in imparting experienced workers' intuition and knowhow to inexperienced workers. Furthermore, we interviewed expert lathe trainers that train inexperienced workers. They evaluated our work procedure manual to be useful for both trainers and trainees.



(1) Without manual (2) With manual

**Fig. 14.** Surfaces of completed products of inexperienced worker.

## V. Conclusion

In this study, we investigated how intuition and knowhow make a difference between the skills of experienced and inexperienced workers by analyzing (i) the workers' brainwaves, (ii) the vibration of the workpieces, and (iii) the odor emitted during the machining. Our analysis demonstrated that the experienced worker (i) relaxes or concentrates at appropriate times, (ii) adjusts the slide speed appropriately, and (iii) oils the machinery adequately depending on the odor. We created a work procedure manual incorporating experienced workers' intuition and knowhow to teach workers when (i) to relax or concentrate, (ii) the slide speed should be fast or low, and (iii) to oil machinery.Our results provide new insights for imparting experienced workers' intuition and knowhow to inexperienced workers. Future research in this domain should consider applying our methods to other kinds of work.

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