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# Impact of Work-Rest Period on Mental Fatigue in Inspection Task with Microscope: Case Study of Hard Disk Drive Component Manufacturing Company

Rungchat Chompu-inwai and Kanitha Yajom

*Abstract*— **In recent years, inspection has declined in importance as statistical process control has assumed a more prominent role in the quality function. However, product quality inspection is still an important task in the production of hard disk drive component manufacturing. In the case study company, which produces hard disk drive component, inspection occurs at many points in a process. Inspectors perform 100% inspection using microscope for many hours without adequate break. After continually monitoring the performance of inspectors, it was found that certain nonconformities were more difficult to find, the number of nonconformities reported was unusual, and inspectors varied in their abilities. Turnover rate of the quality inspection division in this company is high. Therefore, this research aims at determining the impact of working duration and resting time on reducing the mental fatigue in inspection task with microscope in the hard disk drive component manufacturing. Five types of working duration and resting time were studied and compared using Randomized Complete Block Design of Experiment with two replicates. A variety of data collection tools were used to assist in the data collection. The data collection tools used included bipolar questionnaire, reaction time, and critical flicker frequency (CFF). The analysis of variance (ANOVA) was conducted. The result showed that, the work-rest period type significantly affects the mental fatigue reduction as measured by questionnaire scores and reaction time. However, the work-rest period type significantly does not affect the mental fatigue reduction as measured by CFF.**

*Index Terms*— **Ergonomics, Mental Fatigue, Inspection, Reaction Time, Critical Flicker Frequency, Hand Disk Drive Manufacturing, Design of Experiment**

## I. Introduction

Hard disk drive manufacturing industry generates a large amount of exporting income to Thailand. However, Thai hard disk drive manufacturing is now facing problems in the global competition. Investment is shifting to lower-wage countries such as China and Philippines. Furthermore, industrialized countries such as Singapore and Malaysia possess higher technologies. To survive in the highly competitive environment, Thailand has to find its own strength. "Workers" can be a key to the success. By increasing the number of well-trained, healthy and motivated workers, in the meantime, maximizing the efficiency of the existing workforce, Thailand may be able to compete.

The hard disk drive component manufacturing company studied in this research produces electronic components such as membrane switch, magnetic coil assembly, and optical fiber components. It is located in the Northern Industrial Estate Zone, Lamphun province, Thailand. It has the production of small parts in large quantities; requiring a number of complex processes linked together. Product quality inspection is an important task in the production. Inspection occurs at many points in a process. Inspectors perform 100% inspection using microscope with magnification ratio 10x and 40x for many hours without adequate resting time. Quality inspection in the production forces worker to become high concentrated by made them have an eye on the small product, in the meantime make decision about product nonconformities. This accelerates fatigue on workers which effect working efficiency and increases accident. After continually monitoring the performance of inspectors, it was found that certain nonconformities were more difficult to find, the number of nonconformities reported was unusual, and inspectors varied in their abilities. Furthermore, turnover rate of the quality inspection division in this company is high.

Quality inspection task is considered as repeated and boring. It causes pain and fatigue [1]. Fatigue can be classified into 2 categories; physical fatigue and mental fatigue. Physical fatigue causes painful stiffness on abdominal muscles. Mental fatigue causes dimness, tiredness, and laziness. This research aims at determining the impact of working duration and resting time on reducing mental fatigue in inspection task with microscope in the hard disk drive component manufacturing.

A review of the literature revealed only limited previous research focused on determining impact of working duration and resting time on reducing mental fatigue in quality inspection task with microscope in the hard disk drive component manufacturing. The published research has focused on other tasks or inspection task in other industries.

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For instance, [2] reported on the assessment of mental fatigue in inspection task in electronic component assembly factory. The researcher found that resting time and shift work affected mental fatigue of workers. In addition, [3] conducted a study in a relay manufacturing factory. It was found that workers had pains and fatigue, which ultimately affected their safety and work performance. Symptoms of fatigue included weakness, lack of energy, tiredness, exhaustion, palpitations (feeling the heart beating), dizziness, shortness of breath, etc [4]. It was found that the type of task, shift work, and the amount of products, were factors that highly affected the worker fatigue. Reference [5] applied Fuzzy set theory to study the impact of task and shift work on mental fatigue of workers in coating department, stove department, and quality control department in sanitary ware factory. It was found that the type of work (department), as well as shift work highly affected the worker mental fatigue. Similarly, [6] applied Fuzzy set theory to study mental fatigue occurred in cutting-pipe and shaping-pipe workers by measuring fatigue with critical flicker frequency (CFF), reaction time, and hand grip strength. Mental fatigue was also measured using bipolar questionnaire. The research showed that CFF data was related to the result obtained from bipolar questionnaire. Furthermore, [7] reported on the study of eyestrain in inspection and clerical workers. In the study, eye fatigue has been measured among inspectors in manufacturing factory with high usage of machines, comparing to general tasks of clerk position. The eye fatigue was measured using CFF machine. The result showed that CFF value and working quality decreased gradually after the work began in both clerk and inspector position.

## II. Research Methodology

This research study utilized both subjective and objective research methodologies.

### A. Research Question and Research Hypotheses

The research question is:

*"Does the working duration and resting time affect mental fatigue reduction?*

Research Hypotheses are:

$H_0$: $\mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5$

$H_1$: $\mu_i \neq \mu_j$ *at least 1 pair*

where

$\mu_i$ = mean of the differences of the response before and after the resting period of the work - rest period type i

i, j = 1, 2, 3, 4, 5

### B. Participants

The participants in this study included all six final quality inspection workers working with product A. Each inspector works with a 10x magnification ratio microscope (Fig.1)

One product is inspected by 3 workers. Each worker inspects different product areas. The inspection rate is approximately 100 pieces per hour.

Fig. 1 Inspection task with microscope [8]

The current working duration time are explained as follows. There are two shift work; day shift and night shift. Day shift starts in the morning from 8.00 a.m. until 00.15 p.m., then 45 minute lunch break. In the afternoon, a worker works from 1.00 p.m. to 3.00 p.m., then 20 minutes break, and works again from 3.20 p.m. – 5.00 p.m. For overtime working case, a worker works until 5.30 p.m., then 30 minutes break, and then continues to work until 8.00 p.m.

Night shift starts from 8.00 p.m. to 11.30 p.m., then 45 minutes break. Then, a worker works again from 00.15 a.m. to 03.00 a.m., 20 minutes break. Then, a worker works again from 03.20 a.m. to 05.00 a.m. For overtime working case, worker takes a 30 minute break, and then continues to work until 8.00 a.m.

### C. Design of the Experiment

#### 1) Independent variable

Five types of working duration and resting time were studied and compared as follows:

Type 1: 4 hour-working, no resting period
Type 2: 1 hour-working, 5 minute-resting period
Type 3: 2 hour-working, 5 minute-resting period
Type 4: 2 hour-working, 10 minute-resting period
Type 5: 2 hour-working, 15 minute-resting period

There were many cycles of work-rest period in each day.

#### 2) Response variable

Mental fatigue was investigated by both subjective and objective research methodologies. A variety of data collection tools were used to assist in the data collection. The data collection tools used included bipolar questionnaire, reaction time, and CFF.

##### a) Bipolar questionnaire

The bipolar questionnaire used in this study was modified from a previously-developed questionnaire [6]. Workers were asked to indicate their feelings on each questionnaire item (for example on a scale 0 to 10, where 0 represents the most negative feeling and 10 represents the most positive feeling). The lower the scores, the higher the mental fatigue the worker has. There were 7 questionnaire items as follows:

| | | |
|---|---|---|
| Bored | -------------- | Interested in |
| Do not like | -------------- | Enjoy |
| Tired | -------------- | Fresh (mental) |
| Weak | -------------- | Strong (physical) |
| Exhausted | -------------- | Energetic |
| Sleepy | -------------- | Alert |
| Stress | -------------- | Relaxed |

Each worker was asked to answer the questionnaire twice: before and after the break or resting period. 120 pairs of data

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in total were collected. Differences between before and after the resting time data were calculated (i.e. after data minus before data.) Then, data of the same work duration and resting period were averaged.

*b) Reaction time*

Reaction time means the interval of time between application of a stimulus and detection of a response. The higher the reaction time, the higher the mental fatigue the worker has. Reaction time measuring equipment was used.

Each value was measured twice: before and after the break or resting period to identify if mental fatigue decreased or not. 120 pairs of data in total were collected. Differences between before and after the break were calculated (i.e. before data minus after data.) Then, data of the same work duration and resting period were averaged.

*c) CFF*

The eye fatigue was measured using CFF machine (Fig. 2.) The lower the CFF, the higher the mental fatigue the worker has.

Fig. 2 CFF equipment [9]

Each value was measured twice: before and after the break or resting period to identify whether or not the mental fatigue decreased. 120 pairs of data in total were collected. Differences between before and after the break were calculated (i.e. after data minus before data.) Then, data of the same work duration and resting period were averaged.

*3) Experimental Design, Data Collection and Analysis*

This study applied the design of experiment (DOE) using Randomized Complete Block Design (RCBD) with two replicates to investigate the research question. Operator factor was treated as a nuisance or blocking factor (i.e. factor that has large effects, but the researchers may not be interested in now.)

Fundamental DOE assumptions were checked. These assumptions are that the errors are normally and independently distributed with mean zero and constant but unknown variance. The residual analysis was opted for model adequacy checking.

The analysis of variance (ANOVA) was conducted on the mean of the difference between before and after the resting time data at the confidence level of 95%. Post-ANOVA comparison was also analyzed.

## III. Analysis and Results

### *A. Residual Analysis*

Through analysis of residuals, many types of model inadequacies and violations of the underlying assumptions can be discovered [10]. Fig. 4, 5, and 6 present residual plots of the mean of the differences before and after resting period data of the questionnaire scores, reaction time, and CFF respectively. The normal probability plots of residuals for each response appeared satisfactory. Plots of residuals in time sequence for each response showed that the assumption of independence or constant variance was satisfied. Plots of residuals versus fitted values did not reveal any obvious pattern. The histograms of the residuals of all responses looked like a sample from a normal distribution centered at zero. Therefore, all assumptions were satisfied.

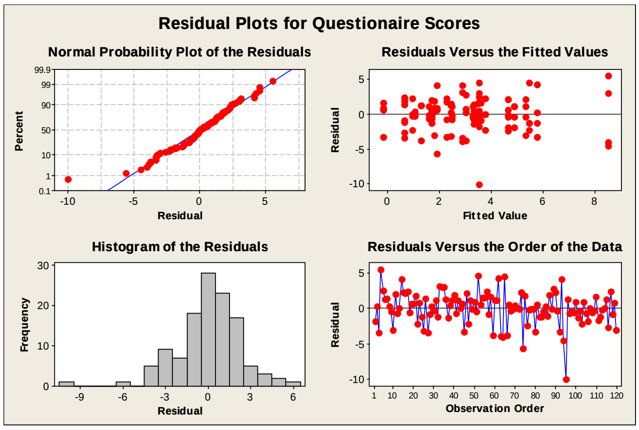


Fig.3 Questionnaire score residual plots

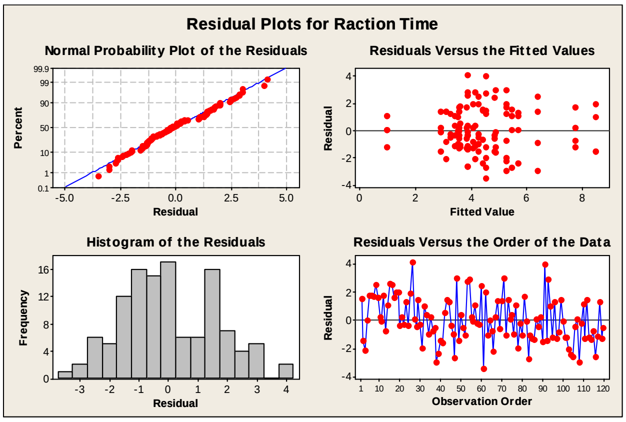


Fig. 4 Reaction time residual plots

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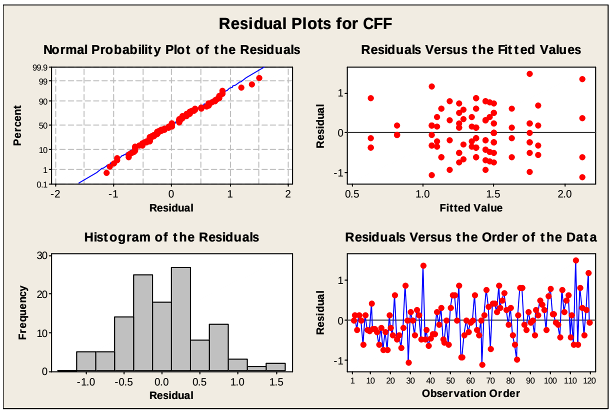


Fig. 5 CFF residual plots

*B. Analysis of Variance (ANOVA)*

This research aims at determine whether or not five different types of work-rest period reduce worker mental fatigue differently using a RCBD considering operators as blocks. Each operator worked with all the work-rest period types and the order in which the work-rest period types were tested was randomly determined. The example of RCBD is shown in Table 1. The response variables were the mean of the differences before and after resting period data of the questionnaire scores, reaction time, and CFF.

Table 1 RCBD for the mental fatigue experiment

| | Operator (Block) | | | | | |
|---|---|---|---|---|---|---|
| Work-rest period | 1 | 2 | 3 | 4 | 5 | 6 |
| Type 1 | | | | | | |
| Type 2 | | | | | | |
| Type 3 | | | | | | |
| Type 4 | | | | | | |
| Type 5 | | | | | | |

The ANOVA of the questionnaire scores, reaction time, and CFF is shown in Table 2, 3, 4 respectively.

Table 2 ANOVA for questionnaire scores

| Source of Variation | Sum of Squares | d.f. | Mean Square | $F_0$ | P-Value |
|---|---|---|---|---|---|
| Type of work-rest period | 58.34 | 4 | 14.59 | 2.59 | 0.048 |
| Blocks | 47.53 | 5 | 9.51 | | |
| Error | 281.20 | 50 | 5.62 | | |
| Total | 387.07 | 59 | | | |

From table 2, because the P-value is less than 0.05, the null hypothesis was rejected. It can be concluded that the work-rest period type significantly affects the mental fatigue reduction (as measured by questionnaire scores.)

From table 3, because the P-value is less than 0.05, the null hypothesis was rejected. It can be concluded that the work-rest period type significantly affects the mental fatigue reduction (as measured by reaction time.)

Table 3 ANOVA for reaction time

| Source of Variation | Sum of Squares | d.f. | Mean Square | $F_0$ | P-Value |
|---|---|---|---|---|---|
| Type of work-rest period | 41.98 | 4 | 10.49 | 2.59 | 0.048 |
| Blocks | 50.61 | 5 | 10.12 | | |
| Error | 202.65 | 50 | 4.05 | | |
| Total | 295.23 | 59 | | | |

Table 4 ANOVA for CFF

| Source of Variation | Sum of Squares | d.f. | Mean Square | $F_0$ | P-Value |
|---|---|---|---|---|---|
| Type of work-rest period | 1.54 | 4 | 0.38 | 1.45 | 0.233 |
| Blocks | 1.13 | 5 | 0.23 | | |
| Error | 13.27 | 50 | 0.27 | | |
| Total | 15.94 | 59 | | | |

From table 4, because the P-value is more than 0.05, the null hypothesis was not rejected. It can be concluded that the work-rest period type significantly does not affect the mental fatigue reduction (as measured by CFF.)

```
Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Type
Individual confidence level = 99.34%

Type = 1 subtracted from:
Type Lower Center Upper    +---------+---------+---------+
2   -4.608 -1.792  1.024          (--------*--------)
3   -4.524 -1.708  1.108          (--------*---------)
4   -4.503 -1.687  1.128          (--------*---------)
5   -5.920 -3.104 -0.288    (---------*--------)
                           +---------+---------+---------+
                          -6.0      -3.0      0.0       3.0

Type = 2 subtracted from:
Type Lower Center Upper    +---------+---------+---------+
3   -2.733  0.083  2.899               (--------*---------)
4   -2.712  0.104  2.920               (--------*---------)
5   -4.128 -1.313  1.503          (---------*--------)
                           +---------+---------+---------+
                          -6.0      -3.0      0.0       3.0

Type = 3 subtracted from:
Type Lower Center Upper    +---------+---------+---------+
4   -2.795  0.021  2.837               (--------*--------)
5   -4.212 -1.396  1.420          (--------*---------)
                           +---------+---------+---------+
                          -6.0      -3.0      0.0       3.0

Type = 4 subtracted from:
Type Lower  Center  Upper  +---------+---------+---------+
5   -4.233 -1.417  1.399          (--------*---------)
                           +---------+---------+---------+
                          -6.0      -3.0      0.0       3.0
```

Fig. 6 Tukey's test result for questionnaire scores

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Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Type
Individual confidence level = 99.34%

Type = 1 subtracted from:
Type Lower  Center Upper   +---------+---------+---------+
2    -3.149 -0.677  1.795          (---------*---------)
3    -3.722 -1.250  1.222       (---------*---------)
4    -4.117 -1.646  0.826     (--------*---------)
5    -4.930 -2.458 -0.013   (---------*---------)
                           +---------+---------+---------+
                         -5.0     -2.5       0.0      2.5

Type = 2 subtracted from:
Type Lower  Center Upper   +---------+---------+---------+
3    -3.045 -0.573  1.899        (---------*---------)
4    -3.440 -0.969  1.503      (---------*---------)
5    -4.253 -1.781  0.690    (---------*---------)
                        +---------+---------+---------+
                        -5.0     -2.5      0.0      2.5

Type = 3 subtracted from:
Type Lower  Center Upper   +---------+---------+---------+
4    -2.867 -0.396  2.076          (--------*---------)
5    -3.680 -1.208  1.263       (---------*---------)
                           +---------+---------+---------+
                           -5.0     -2.5      0.0      2.5

Type = 4 subtracted from:
Type Lower  Center Upper   +---------+---------+---------+
5    -3.284 -0.813  1.659        (---------*---------)
                           +---------+---------+---------+
                           -5.0     -2.5     0.0      2.5
```

Fig. 7 Tukey's test result for reaction time

### *C. Post-ANOVA comparisons*

When the null hypothesis was rejected, post-ANOVA comparison using Tukey's test was then analyzed. Results of response of questionnaire scores and reaction time are shown in Fig.6 and Fig.7, respectively.

From Fig.6 and Fig.7, it can be seen that mean of type 1 was not different from mean of type 2, 3, and 4, since the Tukey confidence intervals included zero. However, mean of type 1 was different from mean of type 5. Mean of type 2 was not different from mean of type 3, and 4. Mean of type 3 was not different from mean of type 4. Mean of type 5 was not different from mean of type 2, 3, and 4. Therefore, it could be conclude that, working continuously without resting time and, working 1 or 2 hours with 5 or 10 minute-resting, make no difference in the mental fatigue reduction. However, 2 hour-working with 15 minute-resting time is better in reducing worker mental fatigue than working with no resting period.

## IV. Conclusion

Results showed that after the rest, mental fatigue in workers decreased. The work-rest period type significantly affects the mental fatigue reduction as measured by questionnaire scores and reaction time. However, the work-rest period type significantly does not affect the mental fatigue reduction as measured by CFF. Further study could be conducted to determine if whether or not other factors such as shift work, work content or types of work reduce worker mental fatigue differently.

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