Analyzing Difference Mechanical Vibrations Effect between Male and Female to Psychological Responses

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Abstract. Vibrations can be exposed to human in the form of Whole Body Vibration (WBV) or Tool Hand Vibration (THV). This study explored how difference mechanical vibrations affect between men and women to cognitive and psychological aspects. The value of the acceleration was obtained from the value of Root Mean Square (rms) of acceleration which is the square root of the squares of the three directions of vibration. Ten male and ten female respondents participated in this study, each worked with a computer on a simulator and was exposed to WBV. This research will analyze effects of vibrate and noisy condition to human and explore difference effects of that condition to male and female. Based on the research vibration and noise will effect mental workload of male and female altogether. Human mental workload is higher in vibrate and noisy condition. Mental workload increase from level light to level moderate on NASA TLX scale. Meanwhile there is not difference effect of vibrate and noisy condition between male and female.

Index Terms : Whole Body Vibration, mental workload, noisy

1 INTRODUCTION

The development of machinery technology has helped people's work in various fields. In the production industry, the use of machinery has replaced human labor to enable mass production. However, the use of machinery in processing of production also result in a bad physical work environment for human. Mechanical vibration is a physical effect that almost always occurs to machines in operation. Vibration can be exposed to operators in the form of Whole Body Vibration (WBV) or Tool Hand Vibration (THV). Several studies have been conducted to investigate effects of vibration. WBV may cause complaints of discomfort on operators, an increase of mental burden [1], [2], [3], [4], effects on back muscle activities [5] to balance disorders [6] depending on the amplitude, acceleration, and length of exposure to vibration.

In addition to the frequency and magnitude of vibration, impacts of vibration received by human are also influenced by the direction of vibration [7]. When vehicle such as forewarder, cars, motorcycles, trucks, tractors, compactors are used, the dominant vibration that occurs is in the vertical direction [8], [9], [10], [11], [12], [12], [13], [14], [15], [16]. Passangers of electric and diesel rail trains in Indonesia are exposed to vibration with acceleration that is almost comparable between the vertical and horizontal directions [17].

The impacts of vibration on human are widely studied based on the frequency of vibration. Dizziness and nausea while driving are caused by exposure to vibration at low frequencies below 0.5 Hz. Vibration will further increase the speed of human reaction to the increase in the vibration frequency of 4 to 8 Hz as studied by Notbohm and Gross in [18]. Vibration frequency equal to the natural frequency of the human body provides resonance effect on the body part. Hand resonance occuring at a frequency of 4 to 5 Hz affects the decrease in the ability of hand precision motion at this frequency. Eyeball resonance occuring at a frequency of 20 to 70 Hz causes people having difficulty seeing. High frequency vibration of 30 to 50 Hz, which can accelerate blood circulation thus speeding the recovery of muscle fatigue, is widely used for massage with vibration. Human cognitive ability is not affected by vibration [19], [20], [21]. Similarly, arithmetic ability is not affected by vibration at low frequencies. On the other hand, however, vibrations function as general stressors. Human will work harder to keep the speed of his reaction when being exposed to vibrations. As a result, the speed of human reaction is higher after being exposed to vibrations than before or at the time of exposure to vibrations. International Standardization Organization (ISO has issued safety limits of exposure to vibration based on vibration effects on humans. Human response in vertical vibration is greater at frequency intervals of 4 to 8 Hz and human response in lateral vibration is greater at frequency intervals of 1 to 2 Hz.

The effects of vibration on humans in regards to acceleration value have only been rarely researched. Acceleration and frequency are two different vibration measurements. Acceleration measures the magnitude of vibration that describes the amount of energy while frequency is the amount of vibration per time unit. Vibration exposure on humans is not only influenced by frequency but also by acceleration. Vibration acceleration is predicted to influence the aspects of physiology, performance, and level of discomfort.

The purpose of this study is to analyze difference of mechanical vibration effect between men and women on psychological responses.

2 METHODS

It has been found in various studies that vibration affects human performance; however, little is known about the extent of its effect. The study was conducted in the laboratory using vibration simulators that have been designed in a preliminary study. Mechanical vibrations were generated with the acceleration values between 1.5 to

2.2 m/s2 and the frequencies investigated were below 50 Hz.

2.1 Experimental Set Up

The experiment in the laboratory was conducted on a simulator that generated vibrations in translational directions. The simulator was in the form of a table that vibrated in various directions and magnitudes. A chair was placed on the vibration table which also vibrated along with the vibration of the table. The table vibration was vertical vibration which corresponded with the vertical position of the respondents whose vibration direction was up and down while the horizontal direction was the front-rear direction (fore-aft) of the respondents. A total of 20 respondents worked on the simulator in seven conditions of vibration acceleration.

In a simulated, the acceleration generated was to remain at a certain value. The length of the simulation for each condition was fiveteen minutes. The respondents who worked on the table were exposed to acceleration in the form of Whole Body Vibration (WBV).

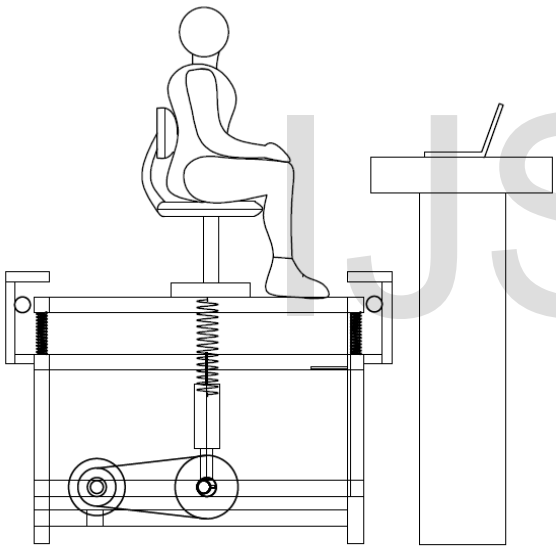

Figure 1: Schema of the simulation process

Measurements of vibration were performed directly on the operator's chair. During the simulation, the respondents operated a computer instead of controling machines that are commonly performed by operators in a factory. The computer ran a program that contained the cognitive test.

The operator sat while observing the computer screen. The operator examined simple cognitive test. The kinds of test are basic arithmetic and basic verbal. The size of the font was big enough to be clearly seen from several meters, a close viewing distance was not necessary to observe the stimulus. In this simulation, the distance between the operator's eyes and the display was 1 meter.

For a ten-minute simulated vibration condition, the first two minutes were used to sense and adjust to vibrations. According to Marjanen (2010), it takes 5 seconds for a period of adjustment for the operator exposed to vibration. The next eighth minutes responders simulated the cognitive test. The picture above is a schematic simulation process.

2.2 Hypothesis and Variables

This study is classified as an exploratory study as it examines more deeply the existing theorems. This study test a hypothesis. Hypothesis is there is difference Mechanical Vibration Effect between men and women to psychological responses. Dependent variables value are psychological aspects, meanwhile independent variable is mechanical vibration. The acceleration of simulator exposed to each respondent was 1.5 to 2.2 m/s2.

2.3 Measurement

There were two types of data collected over a ten minute period of simulations namely data on vibration acceleration and psychological response. Vibration was measured using accelerometer and sensor setup using a magnetic sensor. A magnetic sensor contained in a metal mounting plate was attached to the the seat of the respondents. Each simulator performed one vibration condition and the measurement using an accelerometer was performed three times to obtain the vibration on the three directions of vibration.

Psychological levels were measured using subjective method, NASA TLX method. NASA TLX questionnaire consist of six dimension aspects : Mental demand , Physical demand, Temporal demand, Performance, Effort, Frustation level. After each completed vibration condition for fiveteen minutes, respondents got off from the vibration simulator and answered a NASA TLX questionnaire. Mental workload is a subjective assessment made by the respondents on the vibration that is felt. Respondents were asked to rate the level demand of every dimension that was felt after exposure to an acceleration condition for fifteen minutes. The level of discomfort was in the form of a scale from 0 to 10, with the value of 0 for lower demand aspect and 10 for higher demand aspect.

The level of cognitive ability will be recorded directly on the computer during the course of the simulation. The Simulation provides ten questions about simple arithmetic and ten questions about simple verbal. Every question displayed on a computer screen in thirty seconds. Each time a question appears, respondents will react by choose one of multiple choices by writing on a paper.

Simulations without vibration were performed at the end of the simulation after the respondent underwent simulations with vibration. Psychologically, people will try to defend themselves against environmental disturbances. Simulations without vibration were performed at the end in order that the respondent possess a prime psychological condition.

The simulation was conducted in the morning at 9 a.m. In the morning, the condition of the respondents was still fresh that it was expected that the results of the simulation were not affected by the fatigue factor. After the simulation, for the next 15 minutes, the respondents rested to eliminate the effect of simulation. Than test be continued

on the without vibration test. The whole activities would be completed before lunch time every day. This was also preferred because the effect of lunch was not expected to affect the physiology of the operators.

2.4 Operator Sampling

Respondents were males and females aged between 20 to 25 years. At this age span a human being is in the productive age. Age affects performance, while gender affects psychological aspects (Shibata 2012). Women tend to feel more uncomfortable to vibration. This is due to the tendency that the occupation preferred by women is the job that does not put out much power and that women do not like jobs with machines, unlike men who many of them like working with machines. The age factor affects the speed of response and physiology. Response time will be longer and physical fatigue is higher with age over thirties. To reduce the influence of age, the respondents selected aged 20 to 25 years.

3 RESULT AND ANALYSIS

Difference of vibration on male and female effects were investigated on mental workload. All data from the results of simulation went through test the uniformity before being processed further. A uniformity test was performed to ensure that all the data in one interval were caused by the same condition of vibration. Limits of control were used based on $\alpha = 0.01$ with the range of control area between 2σ below average values up to 2σ above the average value. Data that are beyond the control area discarded and are not used in data processing.

The average value of the acceleration was obtained from the value of Root Mean Square (rms) of acceleration which is the square root of the squares of the three directions of vibration namely vertical, fore-aft, and lateral. The value of Vibration Dose Value (VDV) was not used because the value generated crestfactor was below 1. In order to ensure uniformed conditions of vibration for an interval of simulation, the value of vibration crestfactor was calculated. Crestfactor is the ratio between the maximum acceleration (amax) of the aRMS. If crestfactor is more than 9 then VDV value is used as the average of acceleration to ensure that the effects of shock vibration are taken into account. Shock vibration does not occur in this simulation because the simulator was not designed to produce shock vibration, as evidenced by the value of the crest factor of less than 9.

The vibrations propagated to the respondents through the chair, backrest, and legs. The vibrations calculated were only those which propagated through the respondent's chair because the effects of the propagation from the backrest and legs were less than 1.6% (Marjanen, 2010).

3.1 Effects of Acceleration on Mental Workload

Respondent psychological load were measured after respondent completed cognitive test on normal condition without vibration and noise. This condition is called first condition. Meanwhile on the second condition respondent completed cognitive test in vibrate and noisy condition. Psychological load were measure using NASA TLX methods. This measurement scoring respondent mental workload after completed cognitive work in two conditions.

Noise was measured using sound level meter. Average of noise calculated from noise score at some points based on noise equivalent. (Leq). Score of noise equivalent on vibrate and noisy condition simulation was 95 dBA.

Measurements of vibration were performed directly on the operator's chair. During the simulation, the respondents operated a computer instead of controling machines that are commonly performed by operators in a factory. The computer ran a program that contained a simulation to examine the human cognitive ability. The average value of the acceleration was obtained from the value of Root Mean Square (rms) of acceleration which is the square root of the squares of the three directions of vibration namely vertical, fore-aft, and lateral. Score of vibration during simulation a_{RMS} is 2 m/s^2.

Table 1 contains the average mental workload on first condition and table 2 contains the average mental workload on second condition.

TABLE 1
MENTAL WORKLOAD ON FIRST CONDITION

	Female respondent		Male respondent	
N	Mental Workload	Condition	Mental Workload	Condition
1	51	Average	38.67	Light
2	75	Average	44	Light
3	68	Average	66	Average
4	49.33	Light	75.66	Average
5	42.67	Light	50	Average
6	50.6	Average	32.33	Light
7	36.67	Light	60.67	Average
8	57.33	Average	45.33	Light
9	54.67	Average	53.3	Average
10	48.66	Light	44.67	Light

TABLE 1
MENTAL WORKLOAD ON SECOND CONDITION

	Female respondent		Male respondent	
N	Mental Workload	Condition	Mental Workload	Condition
1	51	Average	38.67	Light
2	75	Average	44	Light
3	68	Average	66	Average
4	49.33	Light	75.66	Average
5	42.67	Light	50	Average
6	50.6	Average	32.33	Light
7	36.67	Light	60.67	Average
8	57.33	Average	45.33	Light
9	54.67	Average	53.3	Average
10	48.66	Light	44.67	Light

Zero hypothesis (H0) is there are not effect of vibrate and noisy condition to mental workload. Hypothesis one (H1) is there are effect of vibrate and noisy condition to mental workload.

Based on the paired sample t-test, there was a significant difference on mental workload as a result of being exposed to vibration and not being exposed to vibration. Average of mental workload during second condition is higher than first condition. Significant score (2 tailed) of paired sample t-test is 0.000, its mean hypothesis one (H1) was accept, there are significant effect of vibrate and noisy to mental workload at $\alpha = 0.05$.

The increase of human mental workload due to exposure to vibration is caused as psychologically human is disturbed by the vibration and noise energy. Vibration causes discomfort and disturb human concentration.

Figure 1 shows plot of the human mental workload on two condition and upper boundary of moderate and light mental workload base on NASA TLX methods.

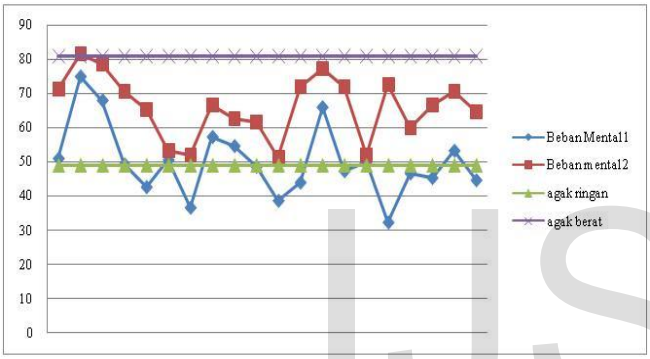

Fig. 1. Human Mental Workload on First and Second Condition

3.2 Difference of Acceleration Effect on Male and Female Mental Workload

The paired sample t-test was used to difference effect of vibrate and noisy condition between male and female. Mental workload measured after respondent do cognitive work on computer. Based on the paired sample t-test, there was not a significant difference on mental workload as a result of being exposed to vibration and not being exposed to vibration.

Zero hypothesis (H0) is there are not difference effect of vibrate and noisy condition between male and female mental workload. Hypothesis one (H1) is there are difference effect of vibrate and noisy condition between male and female mental workload. Significant score (2 tailed) of paired sample t-test is 0.912, its mean hypothesis one (H1) was reject, there are not significant difference effect of vibrate and noisy to mental workload at $\alpha = 0.05$.

Women rarely have job on machinery with vibrate and noisy environment. This is due to the tendency that the occupation preferred by women is the job with does not put out much power and bad environment, unlike men who many of them like working with machines. This tendency is not caused by environment factor, this research result that human mental workload on vibration and noise environment was not effected by gender.

4 CONCLUSION

Based on the research vibration and noise will effect mental workload of male and female altogether. Human mental workload is higher in vibrate and noisy condition. Mental workload increase from level light to level moderate on NASA TLX scale. Meanwhile there is not difference effect of vibrate and noisy condition between male and female.

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