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On a Relation between the Flicker Value and the Vibration

Yasuhiro KANEDA, Hirokazu ŌSAKI and Susumu KIKUCHI

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Insuring fast and precise human operation is one of the engineering requirements in the developing civilization.

Some man-machine system, when any operator is exposed himself to some kind of vibration, he may not perform his operation in good conditions. Then one of the interferring factors, there is a fatigue caused by vibration.

In this study, subjects sit on the chair which was set on the vibration table, and were shaken vertically for some given times, then were measured whether the fatigue occured or not by flicker friction tester.

Flicker patterns were analyzed according to each vibration-condition, then the authors knew that the fatigue was occured by vibration.

§ 1 Introduction

In this study, the authers try to analyze the relation between the effect of vibration and the fatigue of workers in order to know the effect of vibration upon the ability of workers.

The sinusoidal vibration-conditions act on subjects are selected from the graph of human reaction to the whole-body vibrations (report of Donald L. Parks[1]) which are leveled into four kinds, (i. e. Alarming (A), Extremly Annoying (B), Mildly Annoying (C), and Definitely Perceptible (D)). This graph is shown in **Fig. 1.**

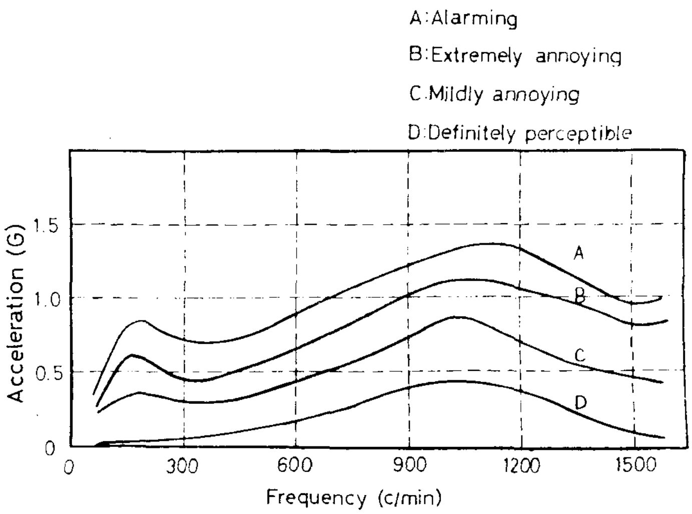

Fig. 1 human reaction to sinusoidal vibration

§ 2 Apparatus

The authers use the Shenk's material weariness tester (type PHQD) to give the sinusoidal vibration-situation to subjects, and the authors measure the degree of subject's fatigue by flicker friction tester.

a) Vibration table

This tester is composed of motor and shake table, and any frequency of vibration can be gotten from 0 to 2000 cpm (continuously), and single amplitude can be changed 0 to 3 mm at the intervals of 0.5 mm. Subjects sit on the chair fiixed upon the vibration table. The amplitude is able to check by the amplitude indicator.

b) Flicker friction tester

The sector type flicker friction tester is used, and the oculor peace is placed on the subject's side.

§ 3 Procedure

a) Subjects

The authors randomly selected 15 students, aged 21 to 28, who were all in good health for this study.

Among them, 5 to 11 subjects were selected for the tests of some given vibration-conditions of eleven cases. These eleven vibration-conditions are shown in **Table 1.**

Table 1. vibration-conditions

number	name	frequency	double amplitude
1	446	400	4.6
2	615	600	1.5
3	620	600	2.0
4	628	600	2.8
5	640	600	4.0
6	910	900	1.0
7	916	900	1.6
8	1206	1200	0.6
9	1210	1200	1.0
10	1215	1200	1.5
11	1506	1500	0.6

During the test period, subjects were allowed to be relaxed.

b) Methodology

According to the curves shown in Fig. 1, the authors got five frecuency levels and each assigned amplitude (Table 1). The double amplitude values which were measured by the amplitude indicator for each condition were shown in Table 1. The working time (i. e. the time subjects were given a vibration) was 10 or 15 minutes.

c) Measurement

FFV (i. e. flicker friction value) was measured pre-working duration and at intervals 2.5 minutes from then to 10 or 15 minutes. In other words, FFV was measured total 7 times in 15 minutes work and 5 times in 10 minutes work, and the frequency of one measurement time are 6 times.

§ 4 Method of analysis

The following method is used to analyze whether the flicker pattern of each condition have the same or not.

The mean of FFV of six times in each measuring times are the data of this study. The following notations are used in this analysis.

K: denotes the experiment order in sequence (i. e. the degree of working time).

i: denotes the number of subjects in each vibration-condition (1, 2, ……, N).

x_i: is the column vector of K-dimensions $(x_{iL}, \cdots\cdots, x_{iK})'$, and x: is the value of variation (i. e. mean value of FFV at preworking time from mean of FFV at working time),

$$\bar{x}=(\bar{x}_{\cdot L}, \cdots\cdots, \bar{x}_{\cdot K})'$$

where $\bar{x}$ is grand sample mean vector and $\bar{x}_{\cdot L}$ is the mean of x_{iL} (i. e. $\bar{x}_{\cdot L}=\Sigma x_{iL}/N$).

ζ_A: is the population mean of condition A.

When condition A and B are given, the hypothesis H_0 is put the following; $H_0: \zeta_A=\zeta_B$. Condition A has N_A subjects and grand sample mean $\bar{x}$, and condition B has N_B subjects and grand sample mean $\bar{y}$.

Then

$$F_0=(N_A+N_B-K-1)\cdot N_A\cdot N_B\cdot(\bar{x}-\bar{y})'\cdot S^{-1}\cdot(\bar{x}-\bar{y})/K\cdot(N_A+N_B)$$

is calculated and if

$$F_0>F_\alpha(K, N_A+N_B-K-1) \text{ then } \zeta_A\neq\zeta_B$$

(significant at α percent level)

$$F_0\leqq F_\alpha(K, N_A+N_B-K-1) \text{ then } \zeta_A=\zeta_B$$

where

$$S=\Big(\sum_K(x_{Ki}-\bar{x}_{\cdot i})(x_{Kj}-\bar{x}_{j})+\sum_K(y_{Ki}-\bar{y}_{\cdot j})(y_{Ki}-\bar{y}_{\cdot j})\Big)^{-1},$$

$(\bar{x}-\bar{y})'$ = the column vector of K dimension.

§ 5 Results

a) F-test of the sameness between two

Table 2. F-test between two flicker patterns

	1206	910	615	1210	916	620	1506	1215	628	446	640
640	0.45	0.84	1.80*	1.10	0.18	0.77	1.15	4.04*	0.77	0.38	
446	3.78*	1.06	6.14*	1.28	1.27	0.85	0.47	1.04	0.71		
628	1.07	0.74	0.95	2.65*	1.38	0.62	0.91	0.26			
1215	1.99*	1.51	0.67	0.85	2.77*	1.72*	0.66				
1506	1.09	1.48	1.38	0.88	1.60	0.99					
620	0.51	0.35	0.59	1.49	0.20						
916	0.56	0.17	1.01	1.41							
1210	8.06*	1.38	2.65*								
615	0.67	1.41									
910	1.29										
1206											

* significant at 25% level

flicker patterns

The above mentioned methodology is used for the synthesis of the results of each condition.

The results is shown in **Table 2,** where are 55 conditions as the result of F-test, because patterns tested between two groups.

In this synthesis, 25% significant level was used. Consequently 10 groups were estimated to have the significant difference.

It is by typical physiological changes that the significant difference is brought out by the various levels of conditions. For a special feature of FFV, this change may be caused by some fatigue. Then it may be clear that the vibration causes a fatigue in human reaction.

b) Test of variance of FFV variation in each measuring time

On each vibration level, variance were calculated by FFV variation and variance-ratio were also calculated as shown in **Table 3.**

From this results, it is shown the variance-ratio are almost equal in each time. So it is clear that the flicker pattern may use to conjecture the fatigue and the other of vibration-conditions.

c) Flicker patterns on each vibration condition

Flicker patterns are shown in **Fig. 2 to Fig.**

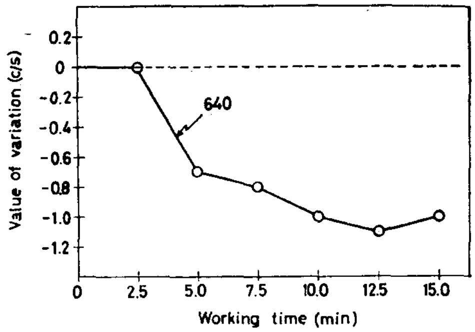

Fig. 2 flicker patterns on level A

Table 3. variance ratio of FFV variation in each measuring time.

working time	446 F=3.79		615 F=3.79		620 F=4.28		628 F=3.79	
	variance	variance ratio	variance	variance ratio	variance	variance ratio	variance	variance ratio
2.5	0.36		1.01		0.83	1.74	0.54	
5.0	1.53	4.25*	1.02	1.01	0.49		3.81	7.06*
7.5	0.45	1.25	1.04	1.03	1.09	2.32	1.19	2.20
10.0	0.89	2.47	1.08	1.07	1.53	3.25	1.91	3.54
12.5	0.85	2.36			1.56	3.32	1.87	3.46
15.0	0.68	1.89			1.78	3.79	1.45	2.69

working time	640 F=6.39		910 F=3.79		916 F=3.79		1206 F=4.28	
	variance	variance ratio	variance	variance ratio	variance	variance ratio	variance	variance ratio
2.5	1.80	2.20	1.25	1.95	1.34		0.23	
5.0	0.82		0.68		1.93	1.44	0.62	2.70
7.5	2.15	2.62	0.93	1.45	2.13	1.59	0.57	2.48
10.0	3.41	4.16	0.65	1.02	4.28	3.19	1.01	4.39*
12.5	4.55	5.55	0.98	1.53	3.87	2.51	0.83	3.61
15.0	2.24	2.73	0.79	1.23	3.24	2.42	0.86	3.74

working time	1210 F=3.79		1215 F=2.97		1506 F=3.79			
	variance	variance ratio	variance	variance ratio	variance	variance ratio		
2.5	0.67	1.72	1.11	2.58	1.23			
5.0	0.41	1.05	0.43		2.10	1.81		
7.5	0.83	2.13	2.05	4.77*	2.28	1.85		
10.0	0.39		2.50	5.81*	3.76	3.06		
12.5	3.46	8.87*			2.82	2.29		
15.0	2.23	5.72			2.74	2.28		

* significant at 5% level

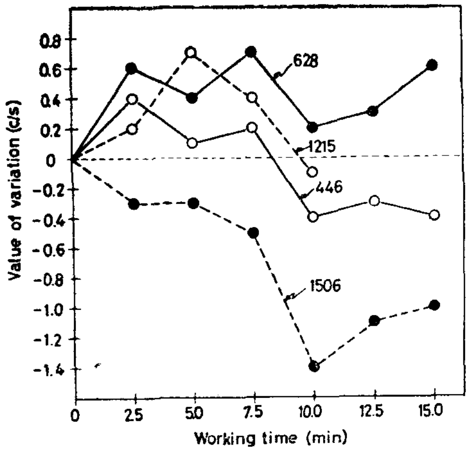

Fig. 3 flicker patterns on level B

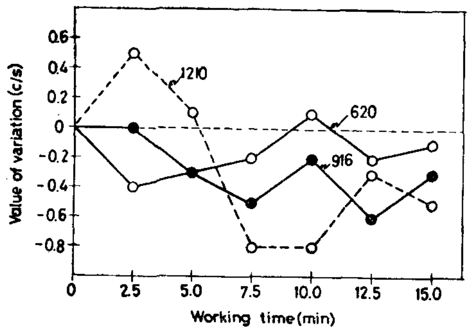

Fig. 4 flicker patterns on level C

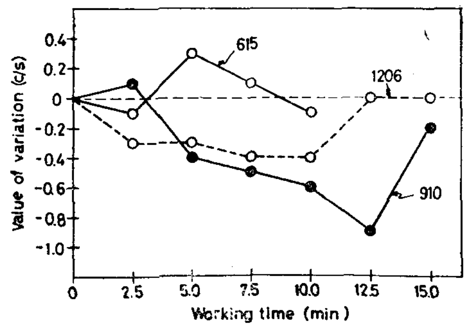

Fig. 5 flicker patterns on level D

5, if the value of variation at 2.5 min. is a positive, so it may be clear that the work-lord is balanced. But if the pattern at the 2.5 min. value tends negative, it shows that the work-load is too great or small.

The time at which FFV shows once rise and after then it downs great is decided the beginning time of fatigue.

In groups of same frequency, the consciousness of fatigue becomes greater with the increment of the amplitude. Similarly in groups of same amplitude, the consciousness of fatigue becomes greater with the increment of the frequency.

Then it is clear that the consciousness of fatigue becomes greater with the increment of the acceleration G ($G = (2\pi f)^2 \cdot a/980$; f: frequency (cps), a: amplitude (cm)).

And it makes clear that the state of shown in Fig. 1 is appropriate for the expriment which would study a relation between the vibration and ability of human work.

§ 6 Discussion

From the above results, the following conclusion was obtained.

I. The fatigue is occured by the vibration. But in case of the moderate load of the vibration is given, the ability of the work is stabilized early, and the level of the faculty did not so much decrease.

II. The vibration-conditions on the curve D (Fig. 1) is suited for the precise work because the degree of fatigue is small and stability time is early. The condition on the curve C is not suited for the precise work required swiftness, because the stability time is not early. The conditions on the curve B is suited for the precise work required swiftness, or the work of simple and long.

Acknowladgements

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References

1) The Human Factors Society of America. *Vibration Research.* Pergamon Press. (1963)
2) M. OSIMA. *Ergonomics.* Asakura Press. (1965)
3) M. OSIMA. *The study of fatigue.* Tokyo Dobun Press. (1964)