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Development of Vibration Isolation Gloves for High Workability (Second Report)

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Abstract. Anti-vibration gloves are used as protective equipment for vibration disorder, but due to the thick anti-vibration materials of gloves, poor workability such as difficulty in manual work using fingertips was complained by operators. Therefore, in consideration of workability, we aimed to develop protective equipment whose vibration proof material's thickness is thinner than the current one, but has the same vibration isolating performance.

We used urethane as the vibration-proof material. By considering the shape of the urethane sheet and using FEM to design, we made six types of gloves with different sheet shape. The gloves were measured and analyzed for their vibration characteristics, and if they have vibration-proofing performance (vibration transmission ratio of less than 1.0) with a thickness of on their entire body, they could be developed.

1. Introduction

An operator using a portable tool such as chainsaw, brushcutter and other similar has a risk of developing a vibration disorder such as white wax disease due to long-term vibration exposure work. Once the vibration disorder developed, it is not expected to be cured, and there is no effective treatment other than trying to alleviate symptoms by symptomatic treatment.

For chain saws or brush cutters-used works that may give local vibration to arms, using gloves with anti-vibration function as a protective device for vibration disorder is recommended. Since the vibration damping effect is prioritized, vibration-proof gloves currently available on the market become thicker and thicker, and there are many complaints from workers about poor workability in performing manual work using the fingertips and difficulty in gripping of tools.

Therefore, in this research, in consideration of workability, our objective is to develop a vibration proofing tool that maintains the vibration isolating performance even if the thickness of the vibration proof material is thinner than the present one.

2. Experimental and Analytical Results

2.1 Evaluation method of anti-vibration glove

The test and measurement method of the vibration isolation performance in the anti-vibration glove is specified in JIS T8114. In the evaluation method, the vibration was generated to the handle, and by holding it with and without wearing gloves, the vibration transmission rate from the handle to the hand could be determined, and the vibration isolation performance is valuable.

The vibration axis of the handle is horizontal. As shown in Fig. 1, the vibrational direction of the vibration generator (i250 / SA5M manufactured by IMV) was switched horizontally and connected to the horizontal oscillation table on which the manufactured anti-vibration glove evaluation test jig was placed. It designed the handle as not for the resonance to occur in the frequency to evaluate.

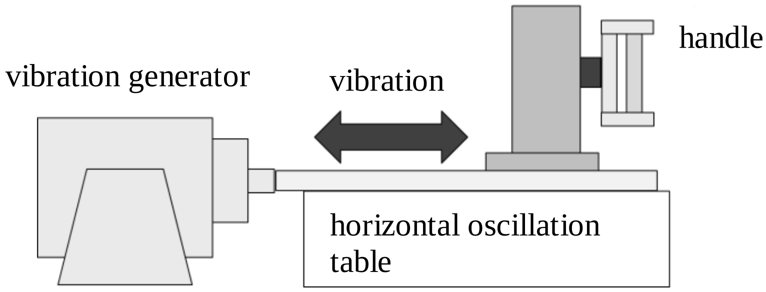


Fig. 1. Installation setup of evaluation jig

The measurement system of the evaluation test jig is shown in Fig.2. An acceleration sensor (sensor ①) was installed with the handle portion as the vibration control point. The vibrational direction is the same as the arrow in the figure. For the vibration measurement determined by the hand, the acceleration sensor (sensor ②) was held in the palm while grasping the handle. When wearing gloves, it becomes inside the glove. The pressing force of the handle was measured with a force sensor (sensor ③) and confirmed on the PC.

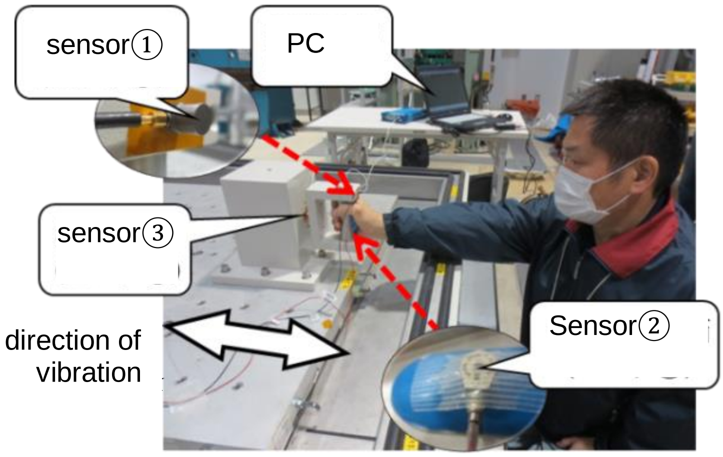


Fig. 2. Vibration measurement scenery of bare hand

The vibration generated in the handle is regarded as band-limited random noise. For two vibration spectra (M and H in Fig. 3) with different frequency bands, we make a vibration measurement transmitted to the hand. Fig.4 shows the operation screen of the shaker. As shown in Fig. 4, the vibration spectrum M was created with the vibration control device software (manufactured by IMV: K2 Sprint / RANDOM). Vibration conditions are a frequency 16 Hz to 400 Hz, an effective acceleration value of 16.5 m / s^2 rms, and a test time of 30 s.

For the vibration isolation performance, the vibration transmission rate must satisfy TRM < 1.0 in the vibration spectrum M and TRH < 0.6 in the vibration spectrum H.

Vibration transmission ratios of 10 types of materials with different materials and shapes (4 types of rubber system, 3 types of urethane system, 3 types of gel system) were compared.

The appearance of the rubber type material is shown in Fig. 1, the external appearance of the urethane type material is shown in Fig. 2, and the external appearance of the gel type material is shown in Fig. 3. The shape of the measurement material was a circle with a diameter of 45 mm, matching the diameter of the uppermost part of the vibration generator (manufactured by Emic: 514-A) used for vibration measurement. For natural rubber 1, natural rubber 2 and natural rubber 3, groove processing is performed on the surface of the material.

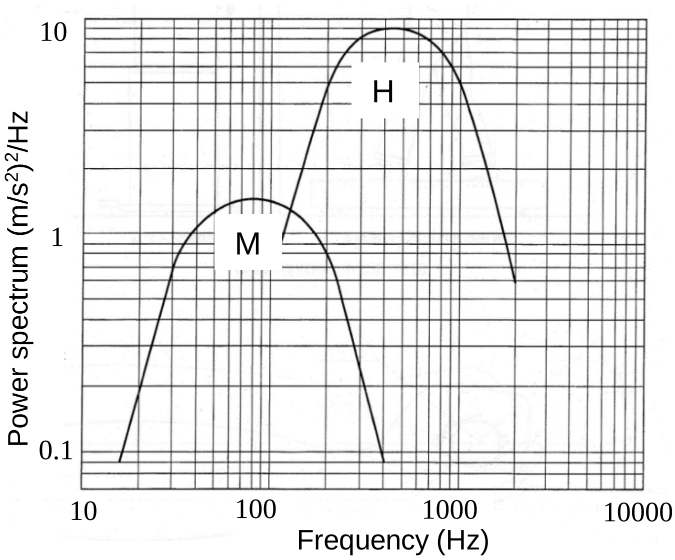


Fig. 3. Vibration spectrums (M and H)

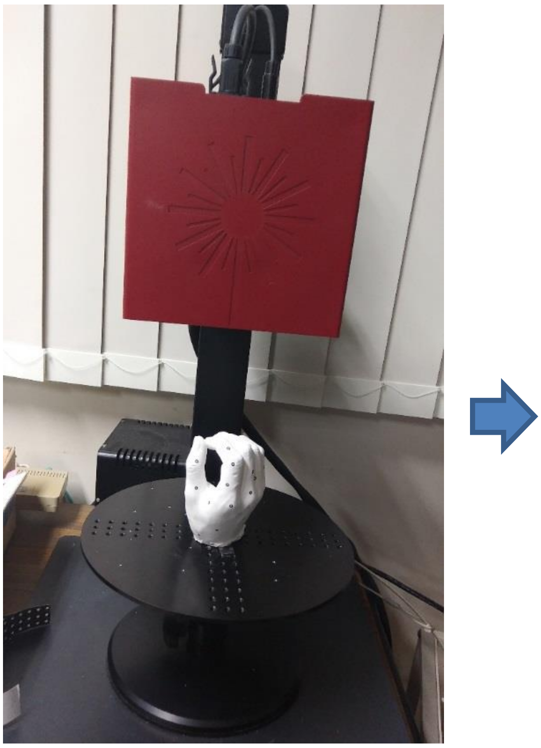
The vibration transmission rate TR was simulated according to JIS standard and determined by the following calculation. The measurement values of each acceleration sensor with bare hands and wearing gloves are defined as follows.

- The sensor at the handle side measured with bare hand ① measured value: a1 m/s^2
- The sensor at the palm side measured with bare hands ② measured value: a2 m/s^2
- The sensor at handle side measured with gloves ① measured value: a3 m/s^2
- The sensor at the palm side measured with gloves ② measured value: a4 m/s^2

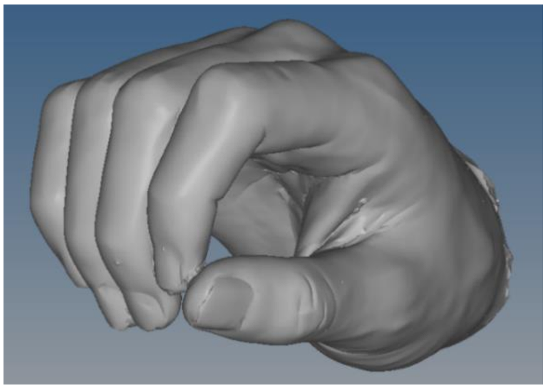
From the above, the vibration transmission rate of bare hand TRb = a2 / a1 to the vibration signal and vibration transmission rate of glove TRg = a4 / a3 were calculated. The modification vibration transmission rate TR is equal to TR = TRg / TRb.

2. 2 Design of anti-vibration glove by FEM

According to JIS standard, the handle is specified as a circular cross-section with a diameter of 40 mm. As shown in Fig. 4, a model of a hand holding a handle with a diameter of 40 mm was made of gypsum clay. Using a three-dimensional laser scanner (Gom core 200 5M : Fig.4. a.) shape data of the hand model was created. Based on the shape data, FE modeling of the glove holding the handle was made. Regarding the urethane sheet embedded in the palm side of the glove, we modeled four types of gloves (no hole, $\phi 4$ (Fig. 5.) , $\phi 6$, $\phi 8$) by changing the punching aperture. In modeling, we used Altair’s Hyper Mesh.



a. Gom core 200 5M (3D laser scanner)
and gypsum clay of hand



b. Shape data of the hand model

Fig. 4. 3D shape measurement for gypsum clay of hand

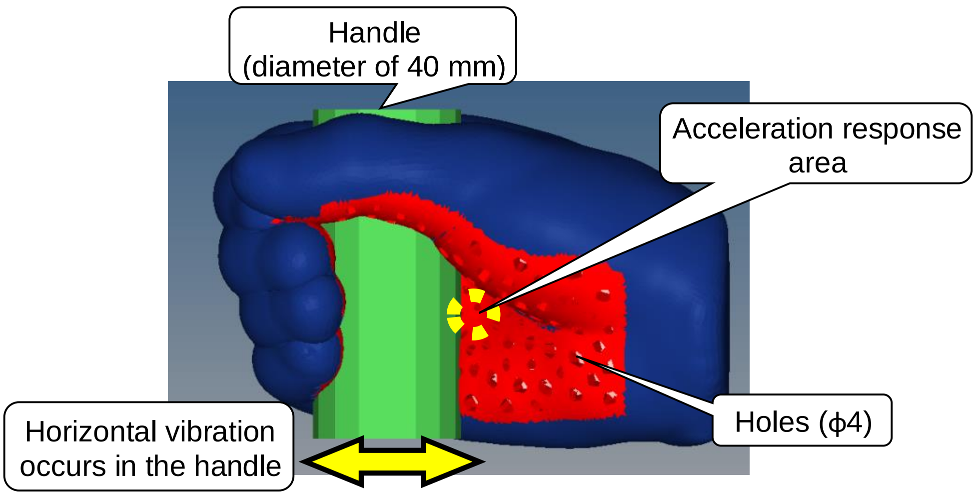


Fig. 5. FE model of glove.

During wearing gloves, the simulation of vibration receiving by hand was run when horizontal vibration occurs in the handle by changing the model of the gloves. As shown in Fig. 2, the vibration response point was set to the same palm surface as the acceleration sensor (sensor ②) used in the evaluation test jig. From the simulation results, we made a comparison of the vibration reduction effect of 4 types of gloves.

Fig. 6. shows the results of vibration response calculation by FEM. The transfer function of each glove is averaged by the vibration responses of 18 places near the palm measurement position. It can be seen that the punching sheet tends to have a lower transfer function and better vibration damping performance than a sheet without punched holes. Particularly the glove of $\phi 6$ is considered to have a vibration reduction effect.

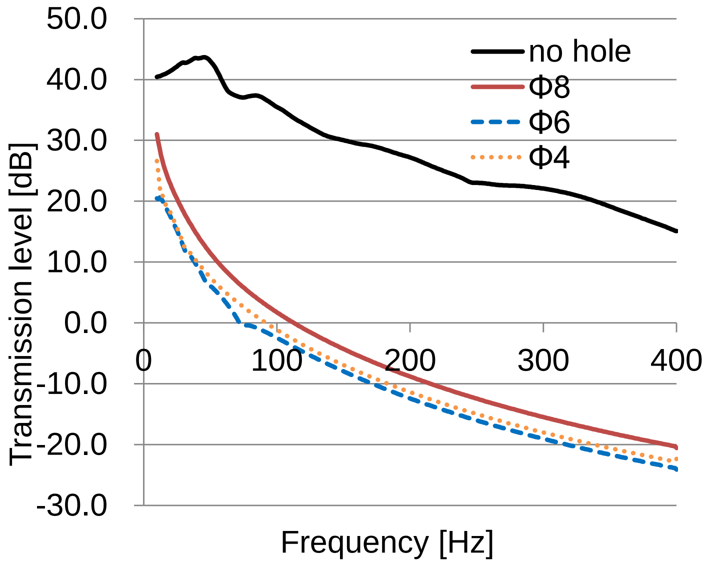
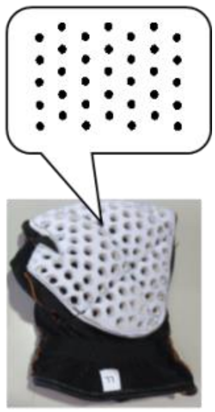


Fig. 6. Analysis results of FEM

2.3 Vibration measurement results of prototype gloves

5.0 mm thick urethane sheet was used as the vibration isolating material inserted inside the glove. The sheets were regularly punched out with the same diameter hole. By making a hole in the sheet, we think that it becomes flexible and convenient when using the tool, so workability is improved. In Fig.8. shows five types of prototype gloves ($\phi 4$, $\phi 5$, $\phi 6$, $\phi 7$, $\phi 8$: Fig.7. a.) with different punching apertures. The punching arrangement of the sheets was made into a lattice shape at intervals of 10.0 mm. We also made a prototype glove (zigzag punched shape: Fig.7. b.) in which the punching was arranged zigzag. The thickness of the entire glove was 7.0 mm.

a. Five gloves with lattice interval punched



b. Glove with zigzag punched

Fig. 7. 6 types of prototype gloves. As for a, the holes is lattice interval. The size of the holes are different. As for b, holes arranged zigzag.

Table 1. shows the results of vibration measurement and analysis of vibration damping characteristics by adding vibration spectrum M (frequency: 16 Hz to 400 Hz) to 6 types of gloves.

After three times measurements in the state of bare hands, each glove was worn and measured twice. Although the pressing force was set to 50 ± 8.0 N according to JIS standard, it was within the range of 50 ± 3.0 N. As a result of averaging the modified vibration transmissibility, $TR_M < 1.0$ is satisfied except for $\phi 8$. From the test results, gloves with a punch size of $\phi 4$ and $\phi 6$ zigzag are considered to have a special vibration reduction effect.

Therefore, the vibration spectrum H (frequency: 100 Hz to 2000 Hz) was not carried out due to restrictions on facilities.

Table 1. Correction vibration transmission rate of prototype gloves

Hole diameter	Measurement number	Transmisson rate			Average	Result $TR_M < 1.0$
		bare hand①	bare hand②	bare hand③		
Φ4	①	0.93	0.89	0.95	0.91	○
	②	0.91	0.85	0.92		
Φ5	①	0.99	0.96	1.01	0.98	○
	②	0.96	0.97	1.00		
Φ6	①	0.95	0.93	0.97	0.94	○
	②	0.92	0.90	0.94		
Φ7	①	0.98	0.94	1.00	0.95	○
	②	0.94	0.89	0.96		
Φ8	①	1.04	0.99	1.06	1.01	×
	②	1.00	0.96	1.02		
Φ6 zigzag	①	0.92	0.89	0.94	0.91	○
	②	0.91	0.86	0.92		

2.4 Questionnaire survey on gloves

To evaluate workability when wearing gloves, we conducted a questionnaire survey to five people involved in forestry work in the prefecture. As shown in Fig. 8. the gloves to be surveyed have 6 prototypes. Scoring was done in 5 grades, good : "5", slightly good : "4", ordinary : "3", somewhat bad : "2", bad : "1". For the scoring method, gloves used by the respondent during the chainsaw operation were set to "3" as a reference, and the workability was compared.

Table 2. shows the results of a questionnaire survey on workability when gloves are worn. Subject A used (JIS standard compliance) vibration-proof gloves in operation, and other four used vibration reduction gloves. By averaging of each of gloves, the average point tended to increase as the punching diameter got larger. In terms of workability, the evaluation was not good when punching diameter of $\phi 4$ and $\phi 5$ had the vibration reduction effect. Since the flexibility of the glove changes depending on the punching aperture, it can be estimated that the workability such as the grip condition of the tool has been affected.

Table 2. Questionnaire result about the workability of six kinds of gloves by five examinee

Hole diameter [mm]	Examinee A	B	C	D	E	Total	Average
ϕ4	3	2	2	2	1	10	2.0
ϕ5	3	2	2	2	2	11	2.2
ϕ6	4	3	3	2	2	14	2.8
ϕ7	4	3	3	2	3	15	3.0
ϕ8	4	4	3	3	3	17	3.4
ϕ6 zigzag	4	3	3	3	2	15	3.0

3. Conclusion

Regarding the 6 types of gloves with different sheet shapes, through vibration measurement, analysis of vibration damping characteristics, design by simulation and conducted questionnaire survey, we obtained the following results.

(1) In the vibration analysis of the vibration signal M, it was found that the glove with the punched holes on the urethane sheet satisfied the corrected vibration transmission rate TR_M < 1.0 depending on the condition.
(2) While the thickness of vibration-proof gloves currently on the market is 10.0 mm or more, gloves with vibration isolation performance at 7.0 mm could be made.
(3) From the questionnaire survey, it was found that workability is related to the flexibility of gloves.
(4) In the future, we will also observe the change in the vibration isolation performance of the gloves after used and their appearance.

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