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ISOLATION OF VIBRATION RESULTING FROM LOOMS

By

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1. Introduction

One of the most troublesome machines extant with regard to vibration and shock is the cloth-weaving loom shown in Fig. 1. The principal features that cause vibration and shock are illustrated schematically in Fig. 2. The loom motions are classified into

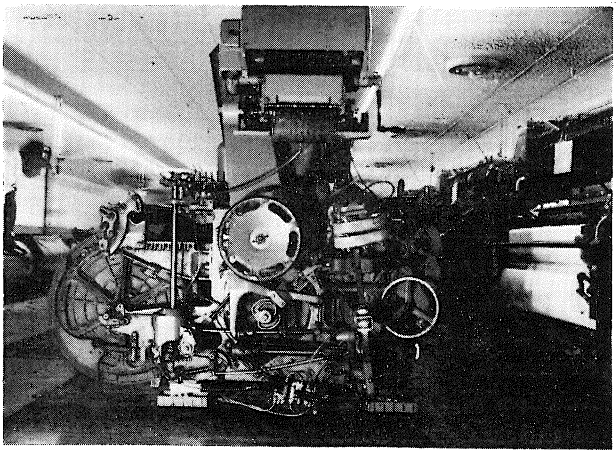

Fig. 1 Loom "a" mounted upon the isolator α

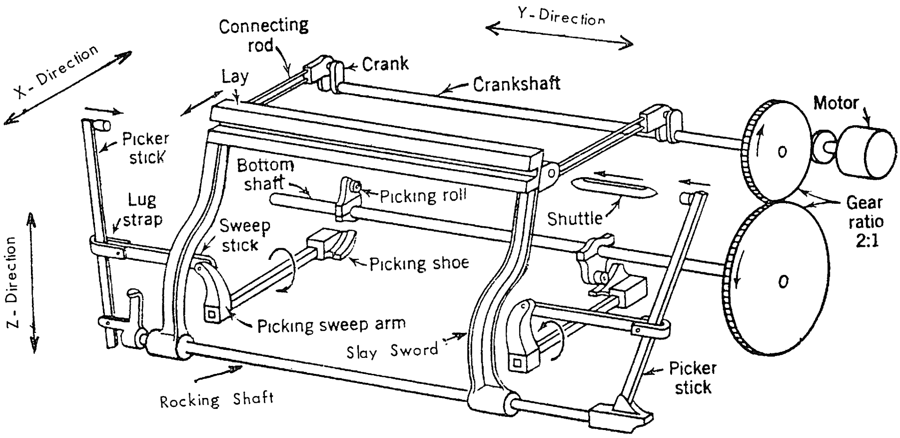

Fig. 2 Schematic diagram of cloth-weaving loom showing principal features that cause shock and vibration

three ; primary, secondary and auxilliary motions. The primary motions consist of the shedding, picking and beating motion.

(1) *Shedding Motion*

The longitudinally extending warp thread is fed continuously in many parallel strands extending in the direction of the lay movement. Combinations of warp thread are alternately raised and lowered at each cycle of the lay by a heald, which is driven by a tappet fixed to the bottom shaft. This is called the shedding motion, which recurs twice every one revolution of the bottom shaft, because two tappets in the opposite direction are fixed to the bottom shaft.

(2) *Picking Motion*

The shuttle carries the filling thread between the raised and lowered strands of warp thread. This is designated the picking motion. The details of this motion are as follows :

The shuttle, before it begins to move, rests in contact with a picker attached to the upper end of a picker stick. A picking roll mounted upon an arm carried by the bottom shaft strikes a picking shoe and causes the shaft that carries this shoe to rotate about its longitudinal axis. The resultant sudden angular movement of the picking sweep arm is transmitted to the picker stick through the sweep stick and lug strap. The sudden movement of the picker stick propels the shuttle toward the opposite shuttle box. Upon arriving at the opposite shuttle box, the shuttle is brought to rest and then propelled in the opposite direction to continue the cycle of operation.

As two picking rolls are attached to the bottom shaft every 180 degrees, the picking motion takes place twice every one revolution of the bottom shaft.

(3) *Beating Motion*

After each passage of the shuttle, the lay presses the last-woven filling thread against the previously woven threads. This is refered to as the beating motion, which recurs once every one revolution of the crankshaft and twice every one revolution of the bottom shaft, because the crankshaft rotates twice as fast as the bottom shaft. If the crankshaft rotates at the speed of N rpm, the time required for one revolution of the bottom shaft is 120/N sec.

The five principal souces of vibration and shock resulting from loom operation are :

(1) The reaction forces against pickers acting ultimately on the bottom shaft and consisting of powerful X- and Z-components (cf. Fig. 2), occur with the period of 120/N sec or at the fundamental frequency of N/120 c/s, but higher harmonics are superposed on the reaction force, because they are in the nature of impacts.

(2) The impulsive reaction forces against the shuttle boxes act in the Y-direction and have higher harmonics.

(3) The inertia force created by the reciprocating motion of the lay is almost a pure harmonic force acting in the X-direction, and the reaction upon the frame of the loom is at the crankshaft. The frequency of this force is N/60 c/s and this is twice as high as that of the picking motion.

(4) The force resulting from the reed, which presses the last-woven cross thread against the previously woven thread, acts mainly in the X-direction. The magnitude of this force depends on the thickness of the cloth being woven. The fundamental frequency is N/120 c/s.

(5) The bottom shaft suffers the reaction force against the shedding motion through the healds, treadles and tappets. This force acts in the Z-direction and has the funda-

.nental frequency of N/120 c/s.

Vibration of the loom caused by the five principal sources described above has the fundamental frequency of N/120 c/s, because the most powerful of them is the reaction force due to the picking motion, which occurs at the frequency of N/120 c/s.

This paper deals with the effectiveness of the two types of vibration isolators used at the texile mill of DAIWA Spinning Company in Izumo City.

2. Forces Transmitted to the Floor

It is assumed that a loom is only put on the floor directly and the resultant force caused by loom operation mentioned above acts on a point A, z mm distant from the point 0, which is the center of the base of the loom, as shown in Fig. 3.

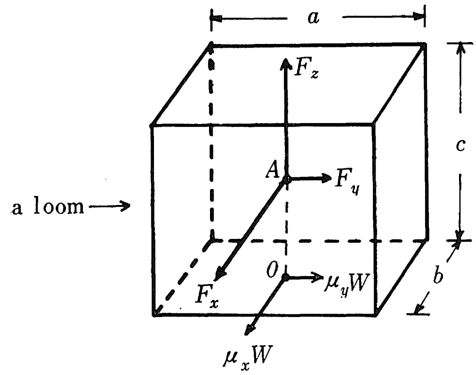

Fig. 3 Reaction forces F_x, F_y, F_z acting on a loom, and friction forces $\mu_x W$, $\mu_y W$ acting on the floor

Symbols

W = weight of a loom

μ = maximum coefficient of static friction between loom and floor

a, b, c = size of a loom

F_x, F_y, F_z = X-, Y- and Z-component of resultant force acting on a loom

If F_x, F_y and F_z are not greater than $\mu \cdot W$, the forces trasmitted to the floor are :

X-direction : F_x

Y-direction : F_y

Z-direction : $F_z + \frac{z}{b} F_x + \frac{z}{a} F_y$

This is the case without isolators.

If μ in the X- and Y-direction are reduced to μ_x and μ_y respectively so that F_x and F_y are greater than $\mu_x \cdot W$ and $\mu_y \cdot W$ respectively, then the forces transmitted to the floor are :

X-direction : $\mu_x \cdot W \,(< F_x)$

Y-direction : $\mu_y \cdot W \,(< F_y)$

Z-direction : $F_z+\frac{z}{b}F_x+\frac{z}{a}F_y$

This is the case with the isolator α to be described later. It can be known from the above equations that the isolator α decreases the X- and Y-component of forces transmitted to the floor but does not the Z-component.

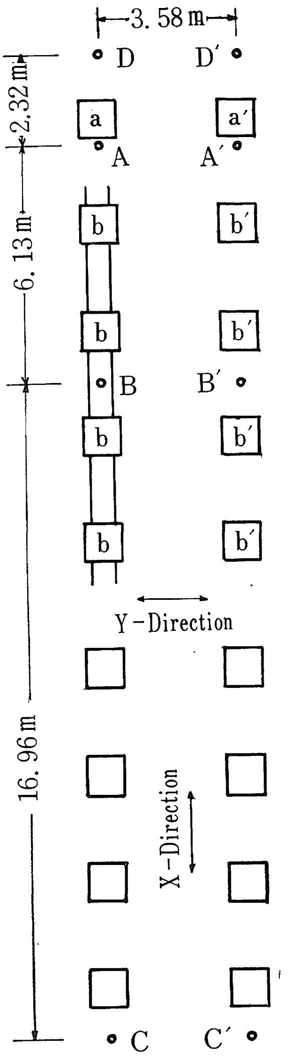

Fig. 4 Arrangement of looms and measuring stations

a, a′, b, b′ : looms
A, A′, B, B′, C, C′, D, D′ : measuring stations
Loom "a" is mounted on Isolator α.
Looms "b" are mounted on Isolator β.

3. Method of Experiment

(3. 1) Looms and Isolators

The looms a, a′, b, b′ and the measuring stations A, A′, B, B′, C, C′, D, D′ were arranged as shown in Fig. 4.

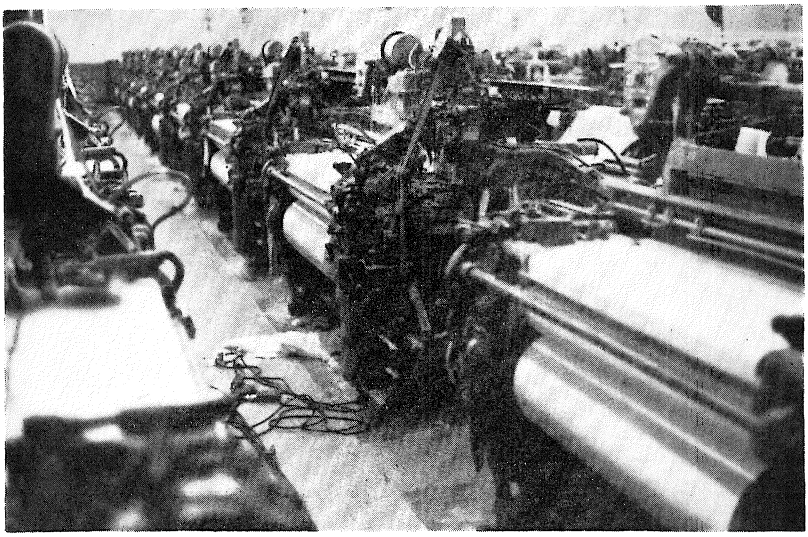

Fig. 5 Three accelometers fixed on the floor in X-, Y-, Z-direction

Fig. 6 Isolator α

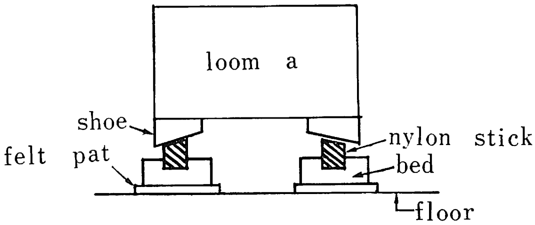

Fig. 7 Loom a and isolator α

Three strain gage transducers were fixed on the concrete floor at each measuring station to pick up accelerations in X-. Y and Z-direction, as indicated in Fig. 5. Fig. 1 shows the loom "a" mounted on the isolator α which is illustrated in Fig. 6 and shown schematically in Fig. 7. The isolator is constructed out of three parts ; a cast iron bed, four pieces of small nylon stick and a tapered shoe made of cast iron. The shoe fixed under the frame of the loom is mounted upon nylon pieces attached to the bed. A felt pad is put between the bed and the floor. The loom "a" are able to move about 15 mm in the beating direction (= X-direction).

Fig. 8 and Fig. 9 show the looms "b" mounted on the isolator β, which cosists of

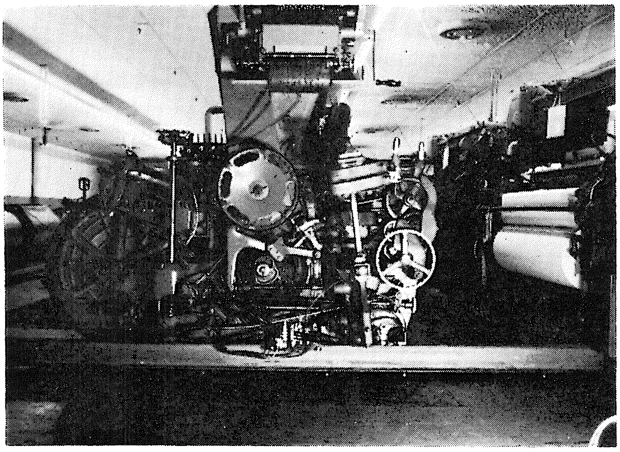

Fig. 8 Looms "b" mounted on the isolator β

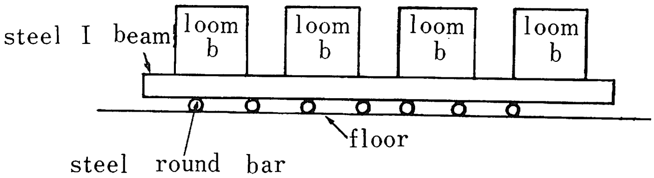

Fig. 9 Looms b and isolator β

two steel I beams parallel with one another and several steel round bars of 20 mm diameter inserted between the I beams and the floor. The combination of four looms and two I beams is able to move in the longitudinal-or X-direction. The looms a' and b′ are put only directly (without isolators) on the floor.

(3. 2) Combinations of Running Looms and Measuring Stations

In order to investigate whether the isolator α is effective or not, only the loom "a" is set in motion and the floor accelerations at the stations A, B, C are measured one after another. Then only the loom "a′" is put in motion and the accelerations at A′, B′, C′ are picked up one by one.

Next, in order to compare the vibration of the floor resulting from looms "b" and "b′", only "b" or "b′" are operated and the accelerations at the stations B, C, D, or B′, C′, D′ respectively are recorded in the magnetic oscillograph.

Table 1 indicates the combinations of operating looms and measuring stations, and the distances between them.

Table 1. Combinations of operating looms and measuring stations. Small letters and capitals represent looms and stations respectively. Distances between looms and corresponding stations are indicated.

Experiment number	Combination	Experiment number	Combination	Distance (m)
No. 2	aA	No. 4	a′A′	0
No. 5	aB	No. 13	a′B′	6.2
No. 9	aC	No. 11	a′C′	23.
No. 6	bB	No. 16	b′B′	0
No. 21	bD	No. 24	b′D′	8.5
No. 8	bC	No. 10	b′C′	17.

4. Experimental Results

(4. 1) Data Processing

As an example, Fig. 10 shows the floor acceleration-time curves for the combination

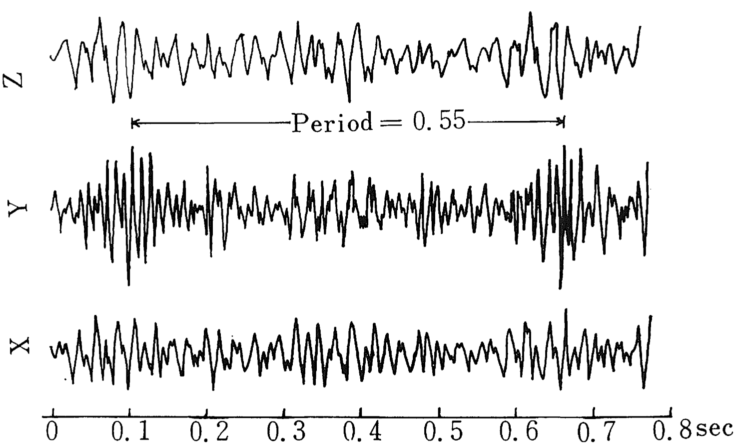

Fig. 10 Acceleration-tıme Cures. for combination (aA)

(aA), detected on the concrete floor under the running loom "a". It is known from Fig. 10 that the vibration of floor caused by the loom "a" is a periodic stationary random process with the domestic period $T = 0.55$ sec. The acceleration-time curves such as Fig. 10 are digitized through the curve reader, where the time intervals between sampled data are about 2.4 msec. These sampled data are integrated numerically by the computer FACOM 270−20, thus the corresponding velocity and displacement are obtained.

Fig. 11 and Fig. 12 show the acceleration-, velocity-, and displacement-time curves calculated in this way. Moreover the power spectral densities of these accelerations, velocities and displacements are computed through their autocorrelation functions. Fig. 13 and Fig. 14 show the estimated Hamming-window spectral densities.

(4. 2) Amplitude of Floor Vibration Caused by One Loom

The floor vibration induced by a loom has three components, X (beating direction), Y (picking direction) and Z (shedding direction). As for the amplitude of acceleration and velocity, Z-component is larger than X- and Y-components, but Z-component of the displacement is not always the greatest of the three components.

(4. 3) Frequency of Floor Vibration Caused by One Loom

When a loom is running at N rpm, the dominant frequency of the velocity and displacement in the X-, Y-, Z-direction is N/120 c/s, which is equal to that of the picking and shedding motion as described above. If $N = 216$, then $N/120 = 1.81$.

On the contrary, the accelerations in the X-, Y-, and Z-direction do not contain the harmonic component of frequency 1.81 c/s, but consist of harmonics of frequencies 20 c/s or more. Especially the X-component of acceleration has more harmonics than the Y- and Z-components. On the contrary, the Z-component has only a few harmonics of

Table 2. Amplitude and frequency of floor vibration caused by one loom

Direction				X	Y	Z
Acceleration	Amplitude		(mm/s²)	96∼120	140∼240	200∼300
	Frequency	range	(c/s)	20∼120	20∼100	20∼60
		dominant	(c/s)	40∼55	40∼55	40∼55
Velocity	Amplitude		(mm/s)	0.5∼0.6	0.4∼0.5	1.2∼1.3
	Frequency	range	(c/s)	1.8∼60	1.8∼40	1.8∼20
		dominant	(c/s)	1.8	1.8	1.8
Displacement	Amplitude		(μ)	14∼30	11∼18	47
	Frequency	range	(c/s)	1.8	1.8	1.8
		dominant	(c/s)	1.8	1.8	1.8

rather low frequencies.

As an example, the peak to peak amplitudes and frequencies of the floor vibration for the experiments No. 2 and No. 4 are given in Table 2. Generally at measuring stations distant from the running loom, floor vibration has less harmonics than at nearby stations.

(4. 4) Amplitude of Floor Vibration Caused by Four Looms

The floor vibration amplitudes resulting from four looms are the same degree as that from one loom. The reason for this may be that four looms, operating nominally at the same but actually at slightly different speeds, change phase relations. The amplitudes of the Z-component of acceleration and velocity are larger than the X- and Y-component.

(4. 5) Frequency of Floor Vibration Caused by Four Looms

Although the displacement curves have a dominant frequency 1.81 c/s as in the case of one looms, the velocity curves have many harmonics and its dominant frequencies are equal to the frequencies of the corresponding acceleration curves.

The Vibration caused by the loom "a" or the looms "b" have somewhat lower harmonics than vibration caused by the loom "a′" or the looms "b′" respectively, because the isolator α or β prevents the transmission of forces to the floor by permitting looms to move in relation to the floor.

5. Conclusions

(1) It is apparent from Section 2 that one method of preventing the transmission of the horizontal reaction forces from the loom to the floor is to decrease the friction between the loom and the floor, and to permit the loom to move in relation to the floor. Both of the isolator α and β aim at this effect.

(2) Fig. 11 shows that the amplitude of X-, Y-, Z-component of acceleration, velocity, and displacement of the floor vibration resulting from the loom "a" with the isolator α are smaller than that of the loom "a′" without an isolator. Consequently it is known that the isolator α is effective in decreasing fundamental frequency component (i. e., displacement and velocity) as well as higher harmonics (i. e., acceleration).

Table 3 indicates that the isolator reduces the magnitude of the floor displacement resulting from loom operation by 1/(1.8～2.1) in the X-direction, 1/(1.2～1.7) in the

Table 3 Peak to peak amplitude of displacement (X-, Y-, Z-direction) and ratio No.4/No.2 and No.13/No.5

Experiment number	Combination	Distanse (m)	Displacement (μ)		
			X	Y	Z
No. 2	aA	0	14.2	10.7	46.7
No. 4	a′A′	0	29.7	18.0	46.8
No.4/No.2			2.1	1.7	1.0
No. 5	aB	6.2	4.9	3.5	6.8
No. 13	a′B′	6.2	9	4.4	7.6
No.13/No.5			1.8	1.2	1.1

Y-direction and 1/(1.~1.1) in the Z-direction. This means that the isolator α, which is designed to decrease the transmissibility of forces to the floor by means of reducing the friction between loom and floor, is effective especially in the X-direction, but in the Z-direction it is not so effective as in the X-direction.

(3) The isolator β is also effective to remove higher harmonics, but owing to the phase relation of four looms "b" or "b'", it is not clear from the present experiment whether the isolator β prevents the transmission of the low frequency components to the floor or not.

6. Acknowledgement

The authors are grateful to Mr. S. Yamamura, Mr. Y. Ota, Mr. K. Yasunaga, and Mr. Y. Mikuni of DAIWA Spinning Campany, who kindly allowed to investigate the vibration of the loom and offered us photographs of the looms and isolators. Thanks go to Mr. T. Nozaki for his useful suggestions and devoted help. They also owe much to Professor H. Sato at Tokyo University and Mr. A. Horie at Computing Center of Shimane University for their constructive suggestions.

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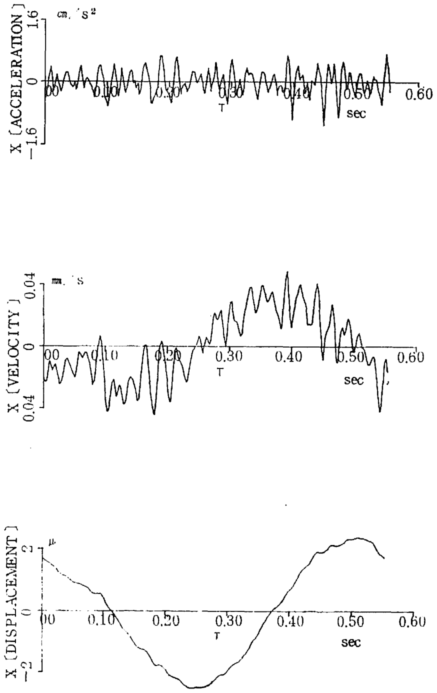
Fig. 11−1 No. 5 (aB) 6.2m X-direction



No. 13 (a′B′) 6.2m X-direction

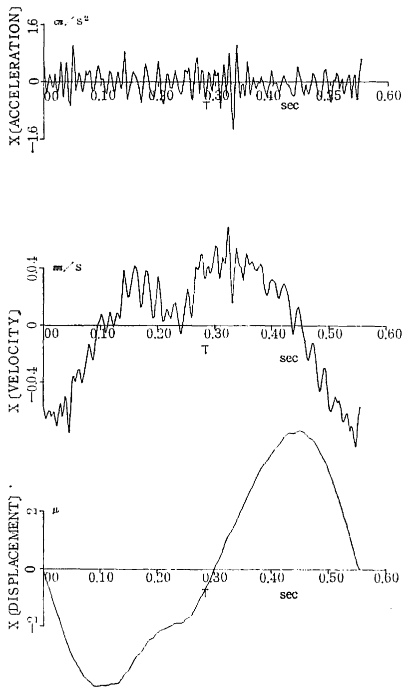
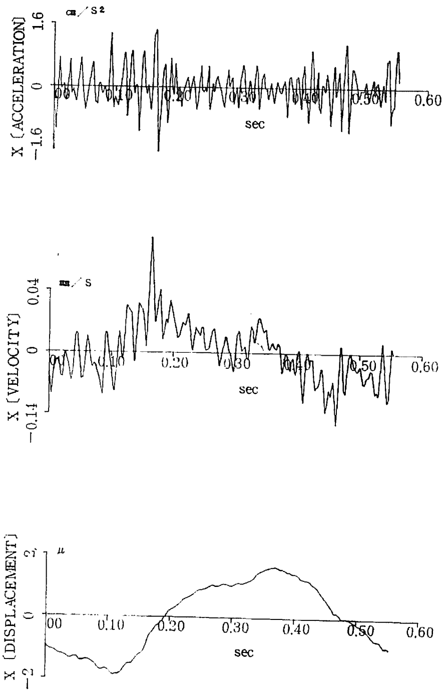


Fig. 11−2 No. 5 (aB) 6.2m Y-direction



No. 13 (a′B′) 6.2m Y-direction

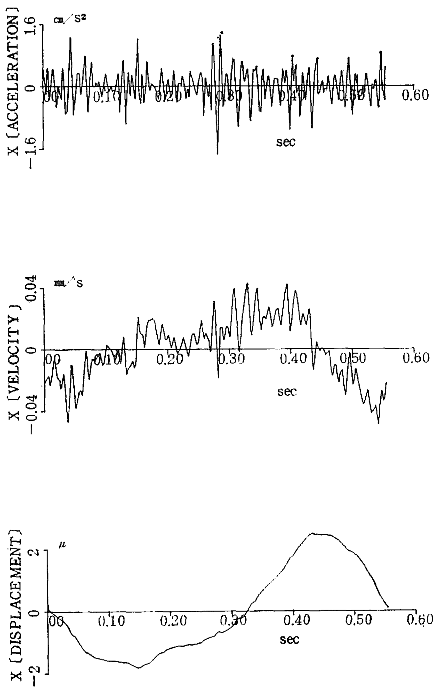
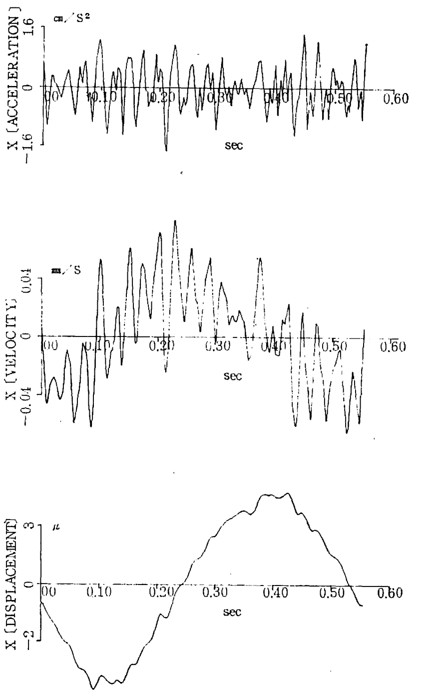


Fig. 11−3 No. 5 (aB) 6.2m Z-direction



No. 13 (a′B′) 6.2m Z-direction

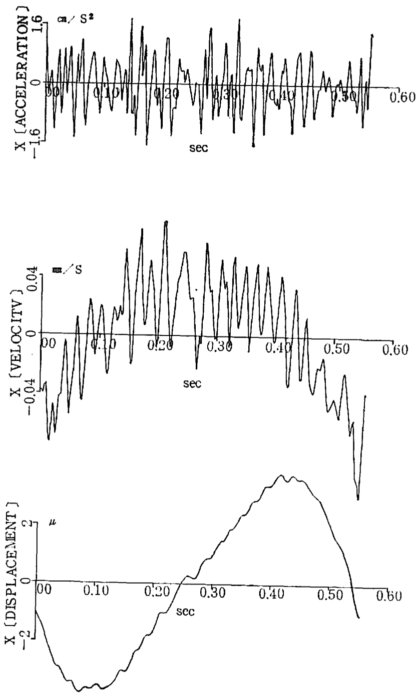
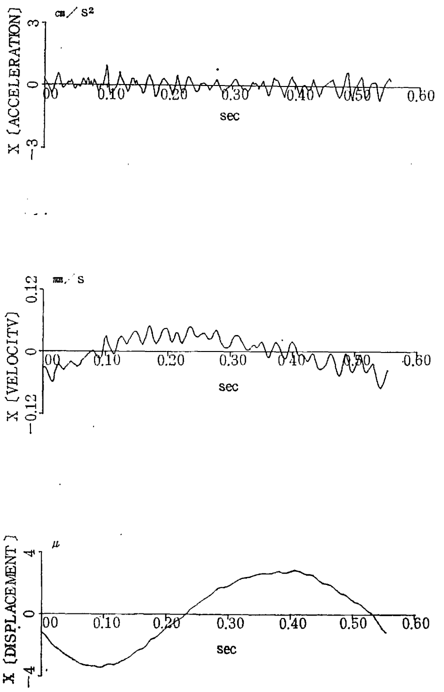


Fig. 12−1 No. 8 (bC) 17m X-direction



No. 10 (b′C′) 17m X-direction

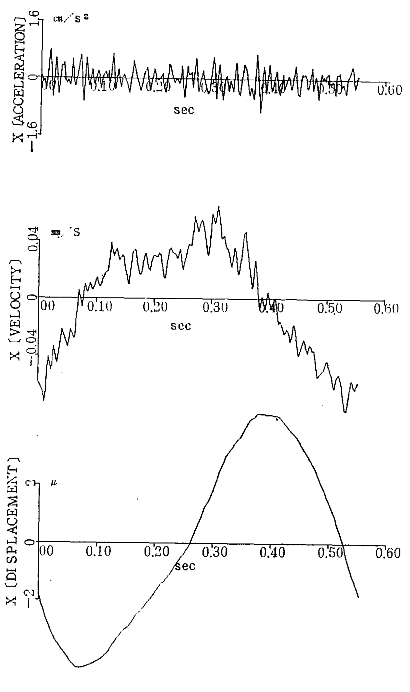
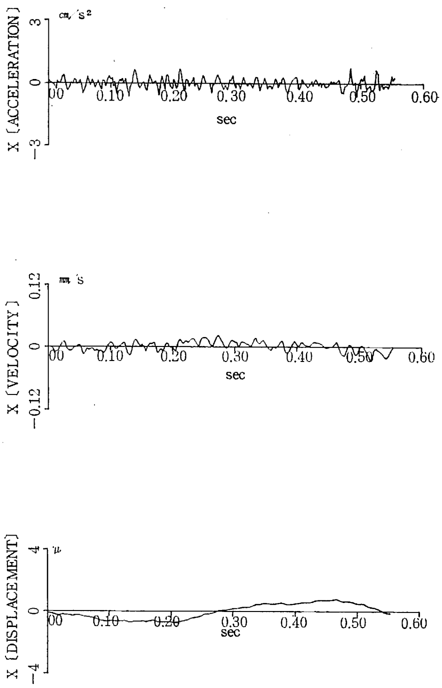


Fig. 12−2 No. 8 (bC) 17m Y-direction



No. 10 (b′C′) 17m Y-direction

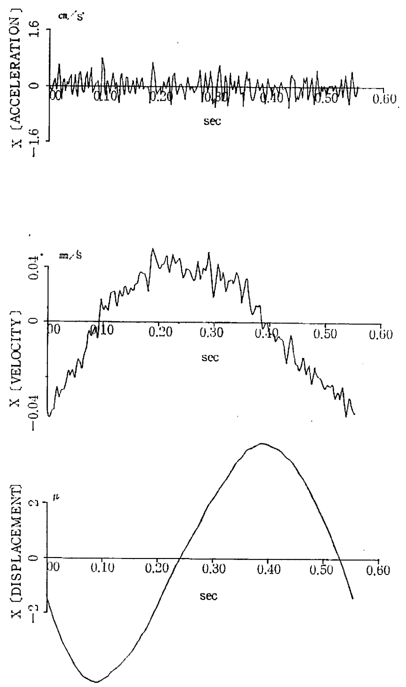
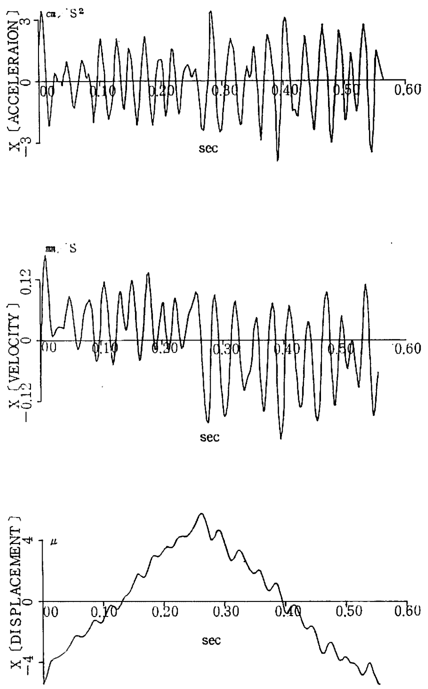


Fig. 12−3 No. 8 (bC) 17m Z-direction



No. 10 (b′C′) Z-direction

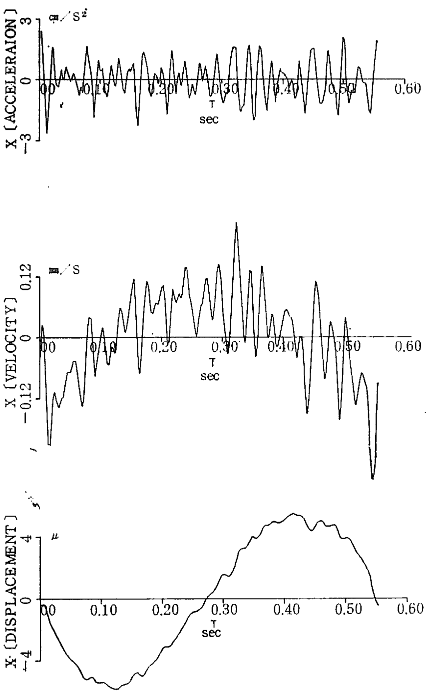
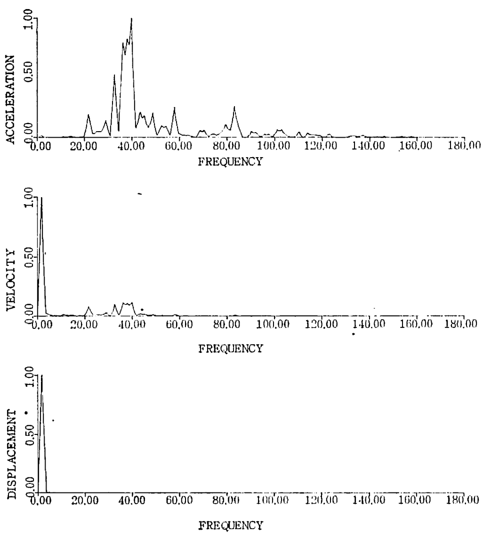


Fig. 13—1 Power spectral density for loom "a" and "a′"

No. 5 (aB) 6.2m X-direction



No. 13 (a′B′) 6.2m X-direction

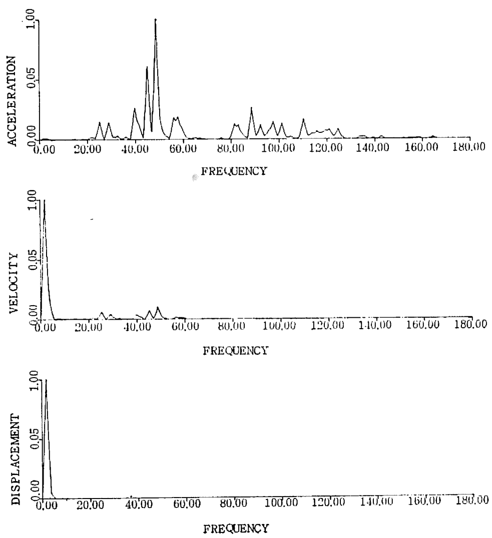
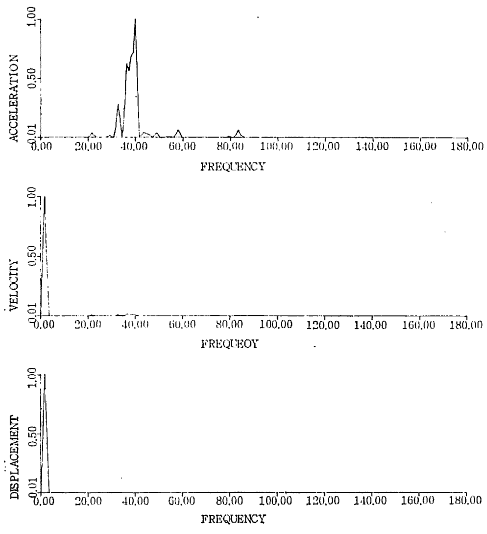


Fig. 13—2 Power spectral density for loom "a" and "a′"

No. 5 (a, B) 6.2m Y-direction



No. 13 (a′B′) 6.2m Y-direction

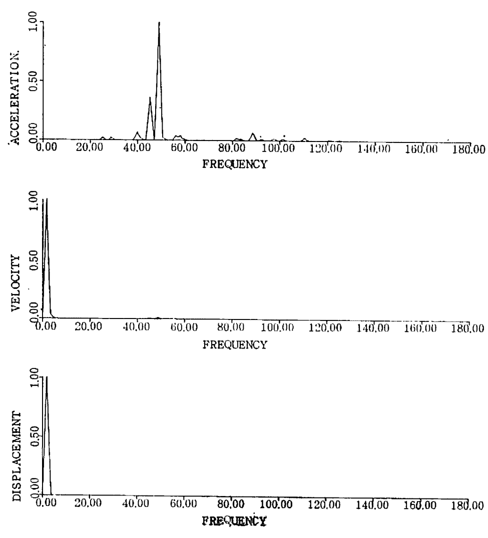
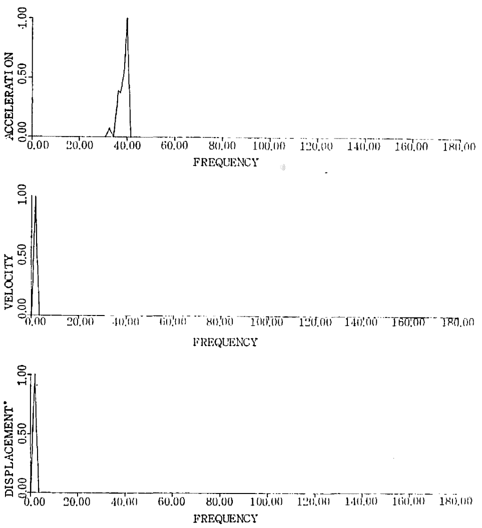


Fig. 13−3 Power spectial density for loom "a" and "a′"

No. 5 (aB) 6.2m Z-direction



No. 13 (a′B′) 6.2m Z-direction

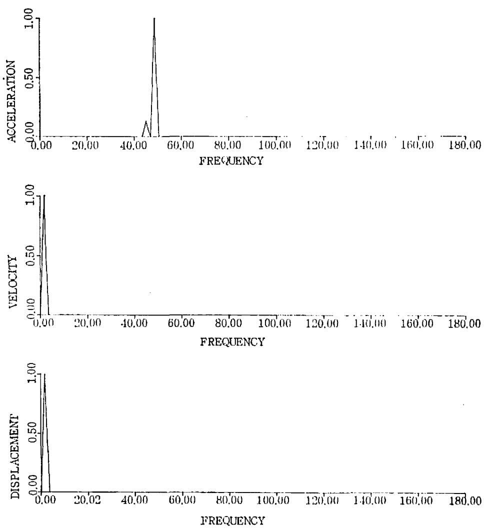
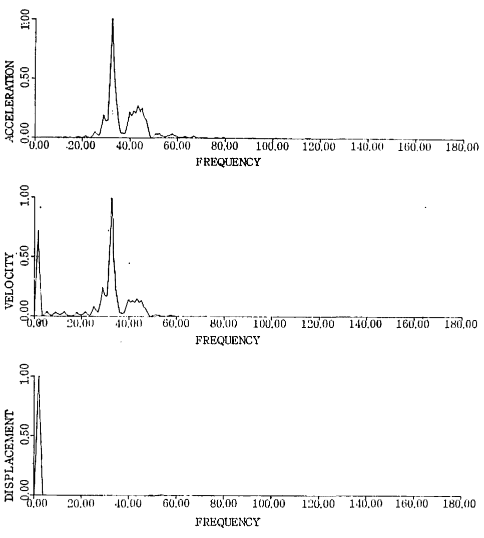


Fig. 14−1 Power spectral density for looms "b" and "b′"

No. 8 (bC) 17m X-direction



No. 10 (b′C′) 17m X-direction

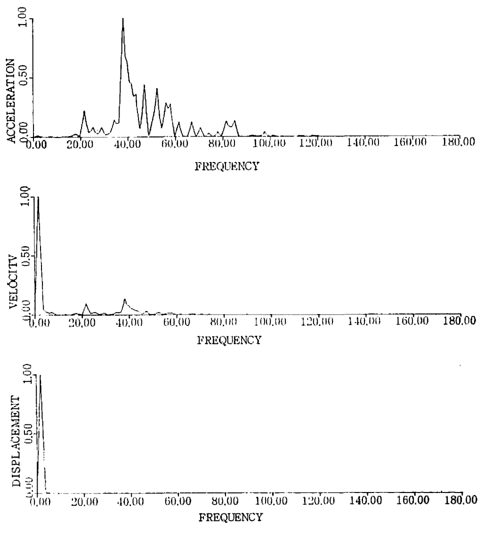


Fig. 14−2 Power spectral density for looms "b" and "b′"

No. 8 (b, C) 17m Y-direction

No. 10 (b′C′) 17m Y-direction

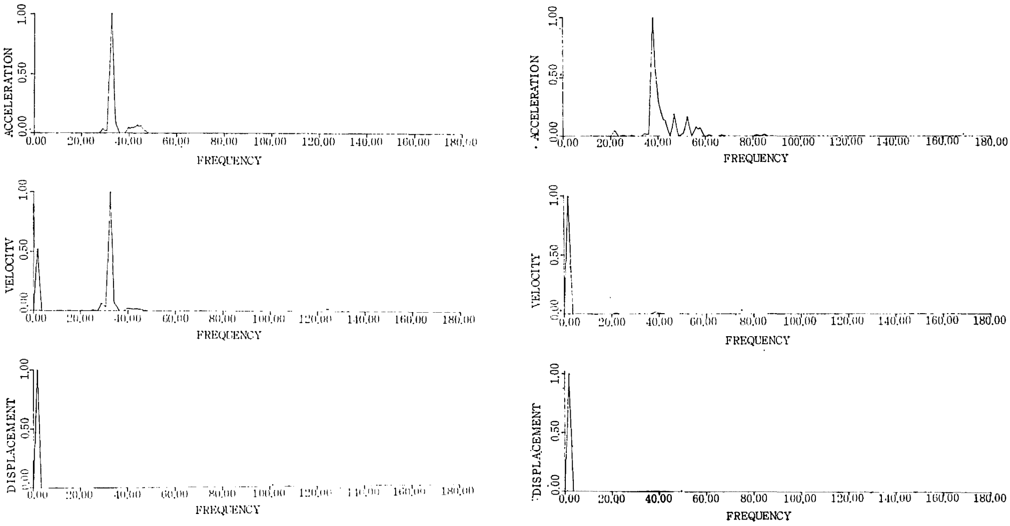


Fig. 14−3 Power spectral density for looms "b" and "b′"

No. 8 (bC) 17m Z-direction

No. 10 (b′C′) 17m Z-direction