

Handlebar vibration of a motorcycle during operation on different road surfaces

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YOKOMORI M, NAKAGAWA T, MATSUMOTO T. Handlebar vibration of a motorcycle during operation on different road surfaces. *Scand J Work Environ Health* 12 (1986) 332—337. In Japan daily motorcycle mail deliverers have been exposed to vibration from the handlebars of their motorcycles. Handlebar vibration was measured during the operation of a motorcycle in order to evaluate the hazardous effects of vibration and to identify preventive measures against the vibration hazards. Tests were made on asphalted, unpaved, and packed-snow road surfaces. The tested motorcycles were selected from the many motorcycles in daily use. The test motorcycle was a 1-cylindere, 89-cm³, 4-cycle machine. The direction showing the maximum value of vibration acceleration was not always in the directions of X, Y, and Z proposed by the International Organization for Standardization (ISO). The maximum vibration acceleration level exceeded the exposure guideline of ISO, while its frequency corresponded to that of the engine speed during operation. Vibration of > 20 Hz was transmitted through the front forks from the road surface and tires.

Key terms: acceleration level, engine, exposure guideline, frequency, mail deliverers, tire, unsprung mass, vibration hazards, vibration level.

In Japan motorcycles are widely used for daily postal deliveries and bill collections (5, 6). The symptoms caused by vibration hazards are on the increase. In the past, motorcycle vibration was studied to evaluate riding comfort and safety in terms of handling and stability. Reports which refer to this subject are fewer than those which refer to four-wheeled vehicles because the factors which relate to the aforementioned problems are many and complex, and making measurements is difficult while the motorcycle is in motion. Nevertheless, there have been a few studies concerned with the hygiene of the rider (1, 2, 7).

We have been studying the vibration of motorcycles since 1975 in order to evaluate the hazardous effects of vibration and also to propose measures which will reduce the risk of vibration damage from motorcycles used in postal service for prolonged periods of time (8). The main factors involving vibration hazards of motorcycles are the vibration coming from the motorcycle itself, the posture of the hands and arms during the gripping of the handlebars, the surrounding environment, and the period of time during which the motorcycle is ridden.

Vibration is transmitted from the motorcycle along the following three paths: (i) from the handlebars to the hand-arms and the body; (ii) from the saddle to the buttocks, the waist, and the body; and (iii) from the foot rest to the feet, the legs, and the body. The vibration of the handlebars is caused by the engine vibration, the roughness of the road, and the vibration of the frame and the chasis.

The roads for delivering mail have been asphalted in the cities and, usually, in the mountain villages. But there are many unpaved roads still remaining, and, in cold areas, deliveries are made on snow-covered and frozen roads for a rather long period in winter.

In this report, we studied the vibration of the handlebars of a motorcycle moving over level asphalted, unpaved, and packed-snow covered roads. The exposure guidelines of the International Standardization for Organization (ISO) were used for comparison with the results (13).

Tests

The test motorcycle, which we used for postal deliveries, has a four-stroke, single-cylindere engine with an 89-cm³ stroke volume. It was tested on three different road surfaces (asphalt, unpaved surfaces, and packed snow). The asphalt road was smooth and even. The unpaved road was made of packed soil and loose gravel, and the packed-snow surface consisted of 4—5 cm of snow, packed on top of about 2 cm of ice, which covered an asphalted road surface.

The mean vehicle speed was determined from the running time along 100 m of asphalted and unpaved roads, or 50 m of snow-covered roads. The selected speeds on the asphalted and unpaved surfaces were

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from 10 to 50 km/h in 10 km/h intervals for each test. A maximum speed of 30 km/h was used on the packed snow because of safety considerations.

Table 1 shows the different front and rear tire combinations used in our tests on packed snow and, except for the test 2 combination, on asphalted roads. The combinations of normal, snow, chained snow, and studded snow tires that we used in this test are generally used in winter by motorcycle riders. In our tests on asphalted and unpaved roads, normal treaded tires were also used.

The vibration acceleration was measured on the iron parts of the handlebar near the left handgrip. The direction of the measured vibration was between the X and Z directions as defined by ISO; this is the direction associated with the highest vibration and was nearly the same as that adopted by the rider's fore-arms during the riding of this motorcycle. In addition, when the motorcycle was test-run on asphalt with the wheel conditions given in table 1, the vibration in the X direction was also measured, because there were occasions when the maximum vibration occurred in the X direction. The directions are shown in figure 1. The handgrips were held by the rider's hands while the motorcycle was operating at normal power.

The atmospheric temperature and the temperature and hardness of the snow required for obtaining the physical properties of snow were measured every 30 min during the work period. The snow hardness was tested with the Kinoshita tester (4), the pole head having a cone vertical angle of 45°.

Results and discussion

Vibration acceleration

Figures 2 and 3 show the results obtained from a one-third octave-band analysis of vibration acceleration when the motorcycle was running on the asphalted and unpaved roads with tires with normal treads.

The 4- to 8-h exposure guideline of ISO (3) (subsequently, referred to as the A line in this paper) is shown

by a broken line in the figures [$A_{ref} = 10^{-5} \text{ m/s}^2$ (according to Japanese industrial standard JIS C 5020), root-mean-square (RMS) value].

Asphalt road. The frequency 31.5 Hz showed the maximum acceleration level on asphalt when the speed was 10 km/h. At speeds of 20, 30, 40, and 50 km/h,

Table 1. Pairs of front and rear tires used in tests with packed snow as the road surface.

Test	Front wheel	Rear wheel
1	Snow	Studded snow
2	Snow	Snow & chain
3	Snow	Snow
4	Normal	Studded snow
5	Studded snow	Studded snow

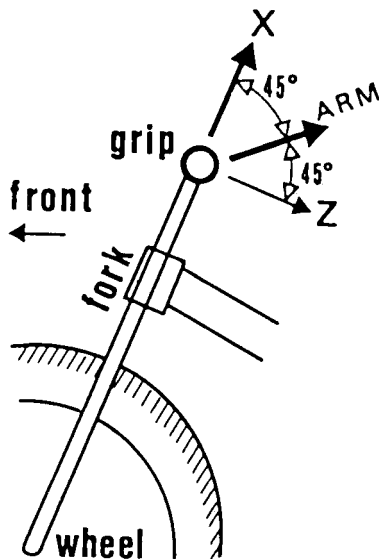


Figure 1. Directions of the measured vibration.

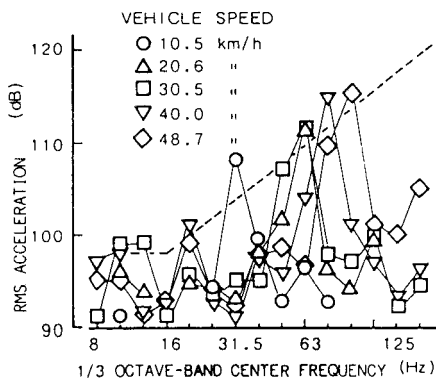


Figure 2. Components of the handlebar vibration in the arm direction on asphalted roads. (RMS = root mean square)

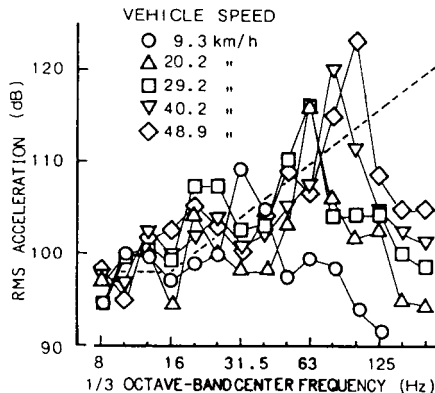


Figure 3. Components of the handlebar vibration in the arm direction on unpaved roads. (RMS = root mean square)

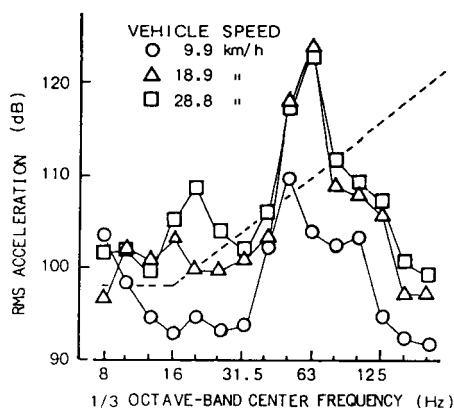


Figure 4. Components of the handlebar vibration in the arm direction on packed snow, test 1 (atmospheric temperature -2.7°C , snow temperature -1.5°C , snow hardness 3.2 kPa). (RMS = root mean square)

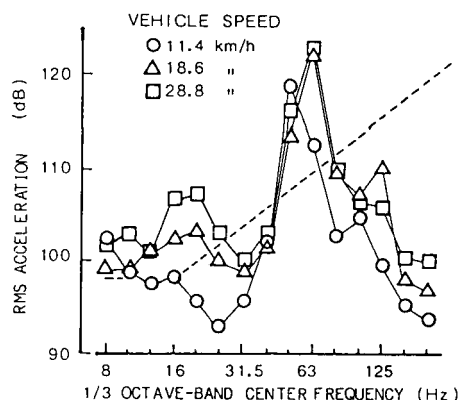


Figure 5. Components of the handlebar vibration in the arm direction on packed snow, test 2 (atmospheric temperature -1.3°C , snow temperature -1.8°C , snow hardness 7.2 kPa). (RMS = root mean square)

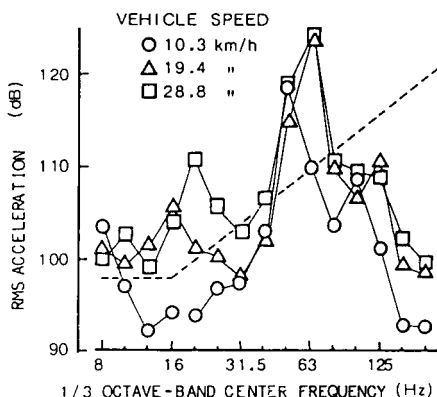


Figure 6. Components of the handlebar vibration in the arm direction on packed snow, test 3 (atmospheric temperature -2.5°C , snow temperature -0.9°C , snow hardness 6.2 kPa). (RMS = root mean square)

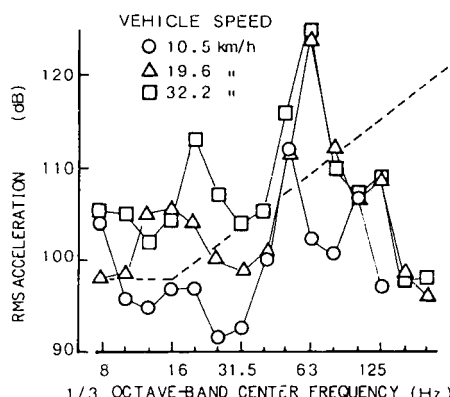


Figure 7. Components of the handlebar vibration in the arm direction on packed snow, test 4 (atmospheric temperature -5.8°C , snow temperature -2.4°C , snow hardness 5.8 kPa). (RMS = root mean square)

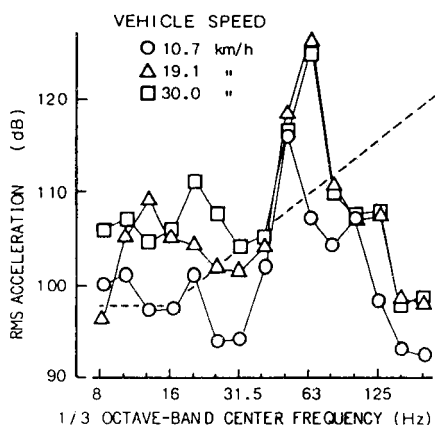


Figure 8. Components of the handlebar vibration in the arm direction on packed snow, test 5 (atmospheric temperature -4.0°C , snow temperature -2.0°C , snow hardness 4.6 kPa). (RMS = root mean square)

the frequencies associated with the maximum acceleration were 63, 80, and 100 Hz, respectively. These frequencies corresponded to that of the engine speed in each test run and the levels all exceeded the A line.

In the lower frequency regions, below 25 Hz, the significant levels at 18 Hz and near 10 Hz seemed to be associated with the fundamental and second harmonic of the natural frequency of the unsprung mass containing the wheel when the speed was above 20 km/h. Even in the lower frequency regions of less than 25 Hz, the A line was exceeded.

Unpaved road. The frequency associated with the maximum acceleration level on unpaved road again corresponded to that of the engine speed in the same manner as occurred on asphalt roads. These frequencies were 31.5 Hz at 10 km/h, 63 Hz at 20 km/h and

Table 2. Regions of frequency exceeding the exposure guideline while the motorcycle was in operation on asphalt under the same wheel conditions as those used on packed snow. (In the arm direction)

Test	Low frequency (< 25 Hz)				High frequency (> 25 Hz)			
	10 km/h	20 km/h	30 km/h	40 km/h	10 km/h	20 km/h	30 km/h	40 km/h
1	—	—	10	10—12.5	50—63	50, 100	80	100
3	—	10	10	10—12.5	50—63	50—63	80	100
4	—	—	10	10	50—63	80	80	100
5	—	10	10—12.5	10—20	40—50	80—100	80	125

30 km/h, 80 Hz at 40 km/h, and 100 Hz at 50 km/h. They all exceeded the A line. At 50 km/h, a peak of 50 Hz occurred that was associated with one-half the engine speed. It also exceeded the A line.

As on the asphalt road, the significant levels occurred at frequencies near 12.5 Hz (10 Hz at 10 km/h). They all exceeded the A line. Thus, the vibration of the unsprung mass was increased due to the effect of the roughness of the road surface, and the levels of the lower frequency vibration increased accordingly.

Packed-snow surface. The frequency components that are shown in figures 4 to 8 relate to measurements made during operation on packed snow under the wheel conditions described in table 1. It is apparent that the major factor causing the handlebars to vibrate is the engine of the motorcycle. The same effect occurred on the asphalt and the unpaved road because the maximum vibration level was in the frequency band associated with the engine speed, irrespective of the different wheel conditions.

At 20 km/h and 30 km/h, the levels exceeded the A line by between about 12 and 16 dB. At 10 km/h, the maximum levels exceeded the A line, but the differences were dependent upon the wheel conditions.

In this test, it was found that there were some significant peaks in the acceleration level in the lower frequency region below 25 Hz. The excess over the A line was between about 9 and 13 dB. These peaks were caused, as was the case with the normal tires, by the vibration of the unsprung mass containing the wheels. They occurred as a result of the fundamental vibration of the unsprung mass at 10 and 20 km/h, and as a result of the fundamental and the second harmonic at 30 km/h.

Asphalt road under the same wheels conditions as on the snow-packed surface. Table 2 shows the frequency region in which the magnitude of vibration measured in the arm direction for each test, apart from test 2, exceeded the A line.

Once again, the frequencies at which the maximum levels occurred corresponded with that of the engine running speed. All these levels were lower than those measured during the operation of the motorcycle on packed snow at speeds above 20 km/h, except at 40 km/h in test 5. However, they all exceeded the A line. At frequencies of less than 25 Hz the acceleration levels were lower than those measured on the packed snow,

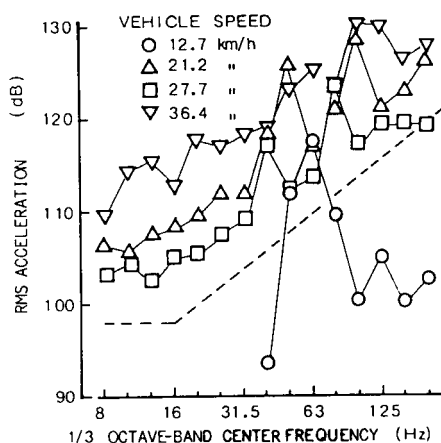


Figure 9. Components of the handlebar vibration in the X direction on asphalted road under the same conditions as on packed snow in test 1 (figure 4). (RMS = root mean square)

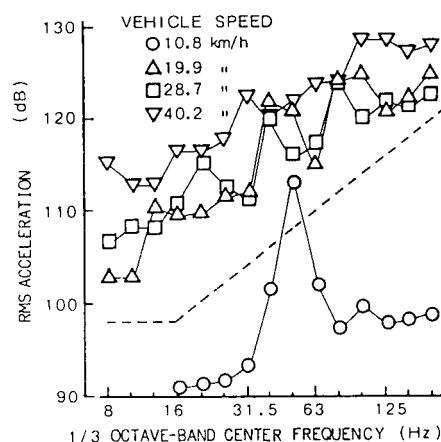


Figure 10. Components of the handlebar vibration in the X direction on asphalted road under the same conditions as on packed snow in test 5 (figure 8). (RMS = root mean square)

and the frequency region over which the A line was exceeded became narrower.

Examples of the frequency analysis in the X direction are shown for test 1 in figure 9 and for test 5 in figure 10. The frequency regions at which the acceleration levels exceeded the A line are shown in table 3.

Table 3. Regions of frequency exceeding the exposure guideline while the motorcycle was in operation on asphalt under the same wheel conditions as those used on packed snow. (In the X direction)

Test	Low frequency (< 25 Hz)				High frequency (> 25 Hz)			
	10 km/h	20 km/h	30 km/h	40 km/h	10 km/h	20 km/h	30 km/h	40 km/h
1	—	All	All	All	50—63	All	All	All
3	—	—	All	All	50—63	63	40—125	All
4	—	—	All	All	50—63	40, 80	40—125	All
5	—	All	All	All	50	All	All	All

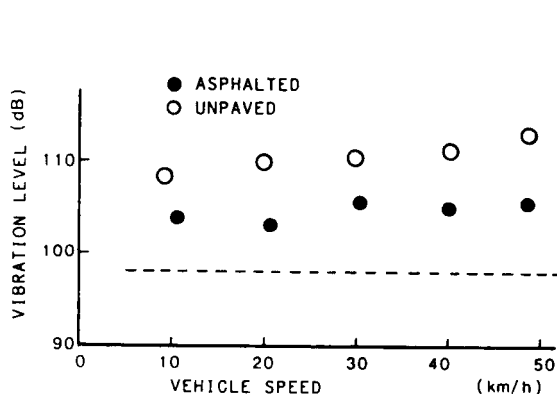


Figure 11. Vibration levels in the arm direction on asphalted and unpaved roads.

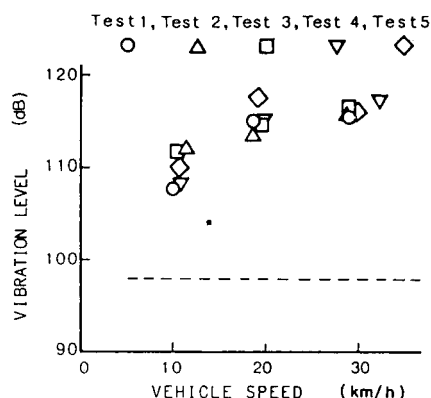


Figure 12. Vibration levels in the arm direction on packed snow.

The frequencies at which the acceleration is at a maximum level were the same as those measured in the arm direction. These levels exceeded the A line but were higher than those obtained in the packed-snow tests. The peak levels were found in one-half of the frequency showing the maximum level under all the conditions at 30 and 40 km/h, and at 20 km/h except in test 3.

At less than 25 Hz, the levels exceeded the A line at 20 km/h at all frequencies in tests 1 and 5 and at between 12.5 and 20 Hz in test 4, and at all frequencies at speeds above 30 km/h. The levels at 10 km/h were lower and under the A line.

Vibration level

The vibration levels (3) obtained by the weighting of the vibration acceleration levels are shown for the measurements on asphalt and the unpaved road with normal tires in figure 11, and in figure 12 for measurements on the packed snow. In figure 13 the levels in the arm and the X directions are shown for the asphalted roads under the same conditions as were used on the packed snow. The 4- to 8-h weighted exposure level of ISO is represented by a broken line. There was a tendency for the vibration level to increase with the vehicle speed when normal tires were in use on the asphalt and the unpaved road. All the vibration levels exceeded the weighted exposure level.

On the packed snow, the levels were higher than those recorded on the asphalt and the unpaved road,

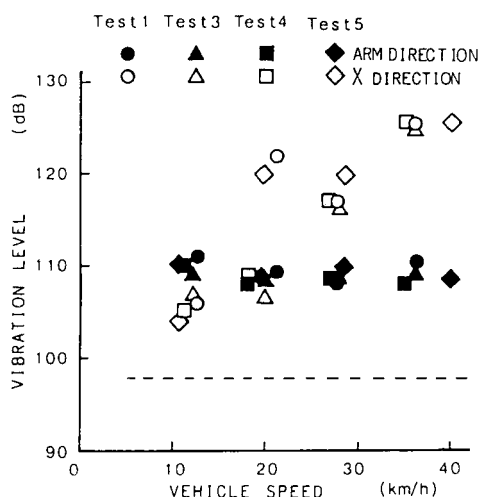


Figure 13. Vibration levels in the arm direction and in the X direction on asphalted road under the same wheel conditions as on packed snow.

and they were also higher at 20 and 30 km/h than at 10 km/h. When the motorcycle was operated on asphalt under the same wheel conditions as on the packed snow, the vibration levels measured in the arm direction did not vary much with differences in the speed and wheel conditions. The vibration levels in the X direction were higher at speeds of 20 km/h and above (except at 20 km/h in tests 3 and 4) than in the arm

direction. The corresponding levels in the X direction at 10 km/h were lower than in the arm direction. All these levels exceeded the recommended weighted exposure level.

Conclusions

The results of our study can be summarized as follows:

1. On all the tested road surfaces, the maximum level of the vibration acceleration occurred at the same frequency as one-half the frequency of the speed of the running engine. This occurrence indicates that the vibration at the handlebars of the motorcycle is mainly caused by the engine. All the maximum levels measured exceeded the 4- to 8-h exposure guideline of ISO.
2. The direction in which the maximum vibration acceleration on the asphalted, the unpaved, and the packed-snow roads occurred corresponded to that of the rider's arm direction. It was at a 45° angle below the X direction of the ISO standard and was directed towards the rider. When the motorcycle was operated on asphalt under the same wheel conditions as on packed snow, the maximum level occurred in the X direction at speeds of 20 km/h or more.
3. The effects of the vibration of the unsprung mass, which includes the front wheel, are apparent in the frequency range below 25 Hz. The vibration acceleration levels and the peak levels measured in this frequency range exceeded the 4- to 8-h weighted exposure level of ISO, apart from the level measured at speeds of 10 km/h on asphalt with the use of normal tires and at 10 km/h on asphalt under the same wheel conditions as on the packed snow (< 20 km/h in test 3).

4. The vibration levels measured exceeded the 4- to 8-h weighted exposure level of ISO under all the measurement conditions.

Acknowledgments

The authors wish to thank Professor S Yamada of the Department of Public Health, Nagoya University, for his advice with these studies and the students of the Meijo University, who helped with this experiment.

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