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DRIVE WHEEL VIBRATIONS AND DRIVER DISCOMFORT IN EARTHMOVING VEHICLES

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Earthmoving vehicles depend on the tyres for their suspension system. Thus the vibration transmitted to the driver's seat depends on the characteristics of the tyre and a very small isolation through the cab mounts which in realistic transmission terms is negligible.

The aim of this paper is to describe the results of vibration tests on the tyre/ wheel system from a J.C.B. earthmoving vehicle and to show how the vibrational modes influence the response/ at the driver's seat. It was shown in [1] that the acceleration levels for rough terrain on construction sites exceeded the recommendations of International Standard ISO2631:1978(E), see Fig.1. Another observation highlighted the fact that the frequency response at the seat was similar to that recorded at the cab and the axle, see Fig.2.

Therefore, with the exception of seat design, the driver's level of comfort appears to depend solely on the characteristics of the pneumatic tyres which act as damping agents and isolators between the road surface and the driver's cab.

The location of the driver in relation to the drive-wheel is vertically over the axle, see Fig.3. Thus the test programme is concerned with the relationship, if any, between the vibration spectra of the travelling vehicle and the static/ dynamic characteristics of the tyre system.

Test Programme

A large diameter drive-wheel for an excavator-loader was mounted in a frame. Initially the system was tested without axle movement, Fig.4, followed by vertical freedom of movement for the axle, Fig. 5. In the tests on the restrained axle the vehicle weight was simulated by an initial load of 1 tonne resulting in a tyre deflection of 30 mm. Lateral amplitudes of vibration were then measured around the tyre whilst the ram was excited through its frequency range of 1 Hz to 23 Hz. Fig. 6 shows the direction of the force and the associated modes of the tyre.

In the second series of tests, where vertical freedom of axle movement was allowed, the 1 tonne load was applied via concrete blocks cantilevered on the opposite side of the 'A' frame from the wheel, Fig. 5. A cyclic force was again applied and measurements made of axle displacement, ram displacement and ram force at each frequency.

Discussion

It is shown, in Fig.6, that an elliptical mode shape dominates the low frequencies. The mode shape at approximately 3 Hz corresponds to the frequency associated with the highest acceleration at the axle of the travelling vehicle [1], Fig. 2. When a non-rotating tyre is considered the mode shape shown at (a) in Fig. 6 may be the result of greater stiffness than either mode shape (b) or (c) thus increasing the transmissibility at this frequency. Similar mode shapes were evident in [2] for plane vibration characteristics of a pneumatic tyre model.

When the wheel was excited as in Fig. 5, the results of which are shown in Fig. 7, it was found that in order to maintain a constant ram displacement a large increase in ram force was required. This resulted in a corresponding increase in axle displacement at around 3 Hz as shown in Fig. 7. This condition is related to a vehicle travelling across an irregular surface of constant amplitude where the force required to raise the machine is higher at this frequency.

With a non-elastic tyre this vertical force would have to come from the horizontal force generated by theengine. Where an elastic tyre is concerned however the combination of the dynamic properties of the tyre and the air produce forces to lift the axle. This allows the wheel to roll over an obstruction without noticeable reduction in horizontal motion, providing that the obstruction is not too high.

Conclusions

The problems of driver discomfort in earthmoving vehicles depends on the transmission from the road. This in turn depends on the vibration characteristics of the wheel/tyre system as evidenced in this work. It has been shown that the frequency generated through the tyre system, when investigated separately, agrees with the data measured at the driver's seat when the vehicle is moving in site conditions.

References

[1] G.J. McNulty and D. Douglas: International Conference on Noise Control Engineering; Edinburgh, July 1983, pp 913, 916.

[2] J.T. Tielking: Society of Automotive Engineers Transactions, May 1965.

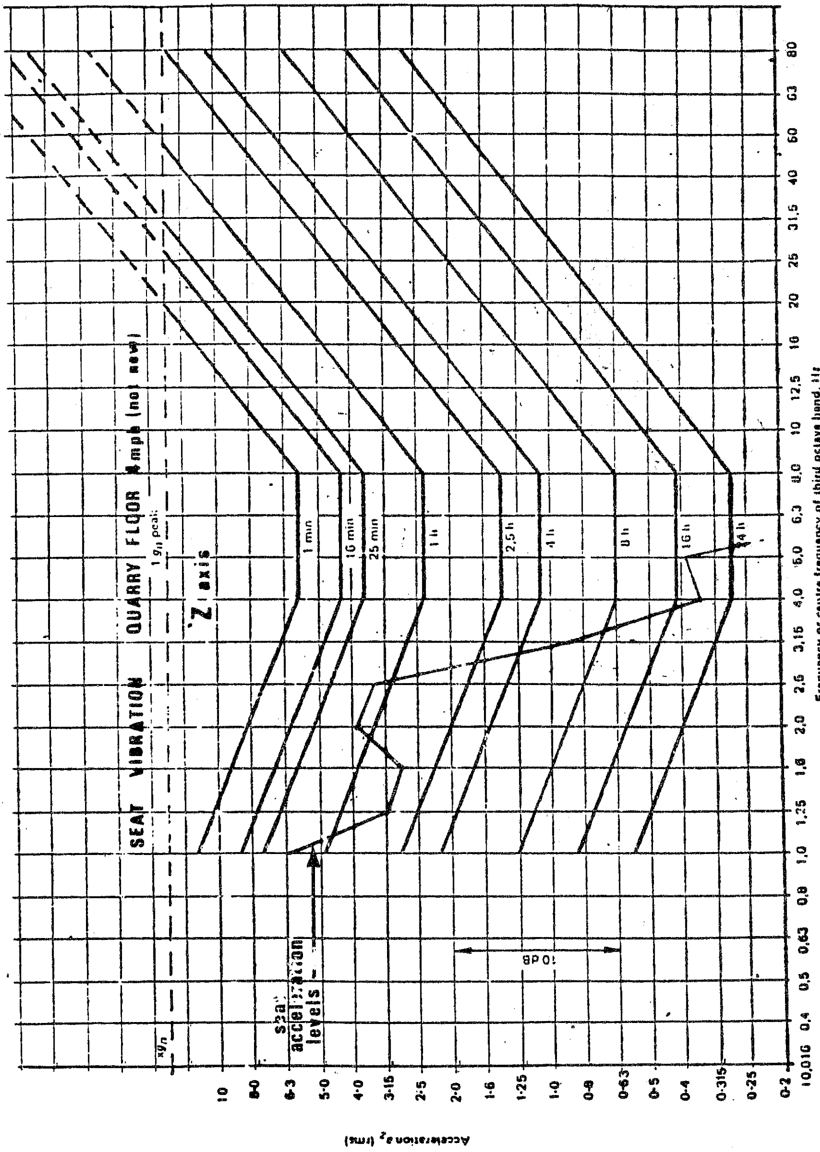


Fig 1

Exposure Limits

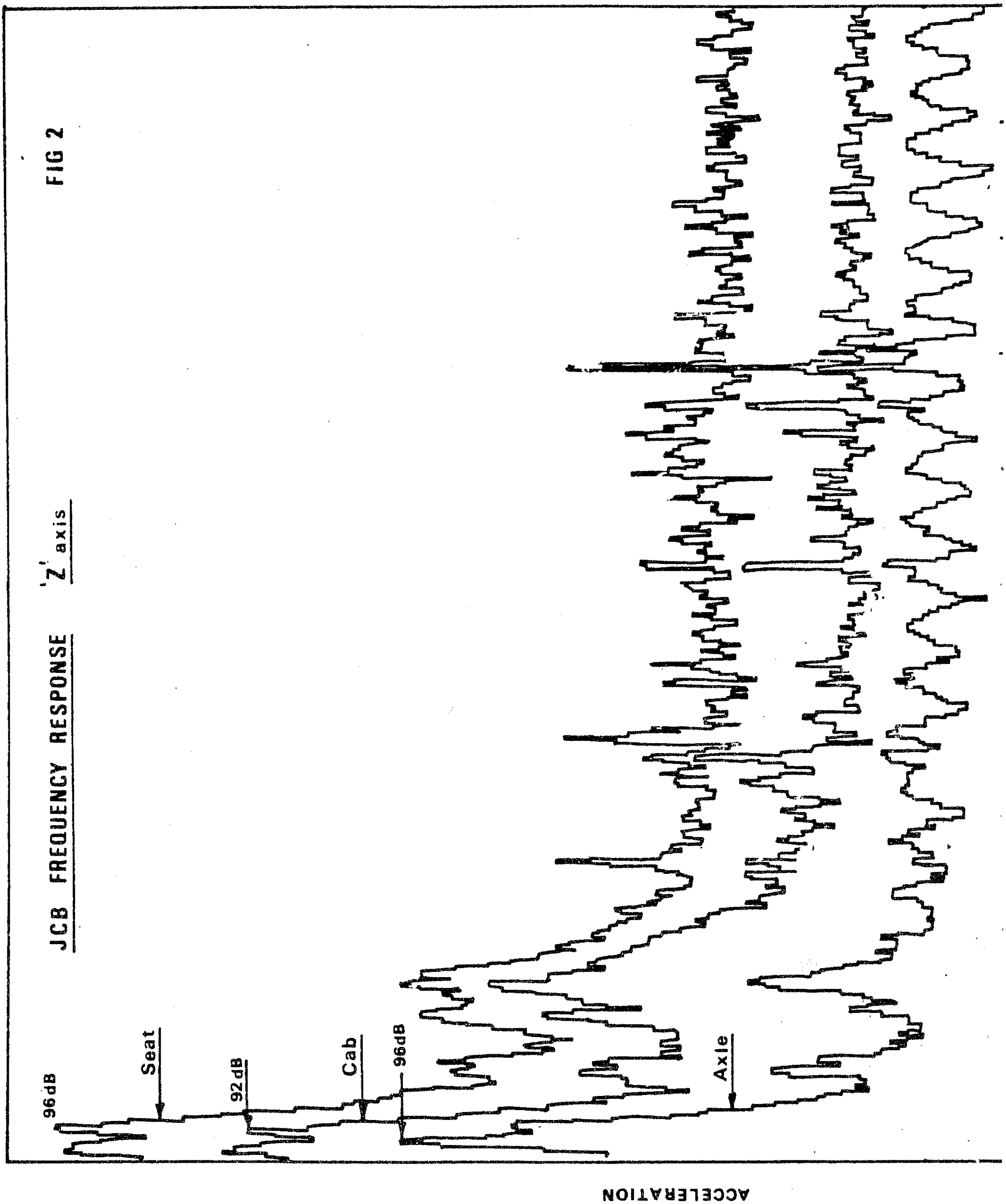
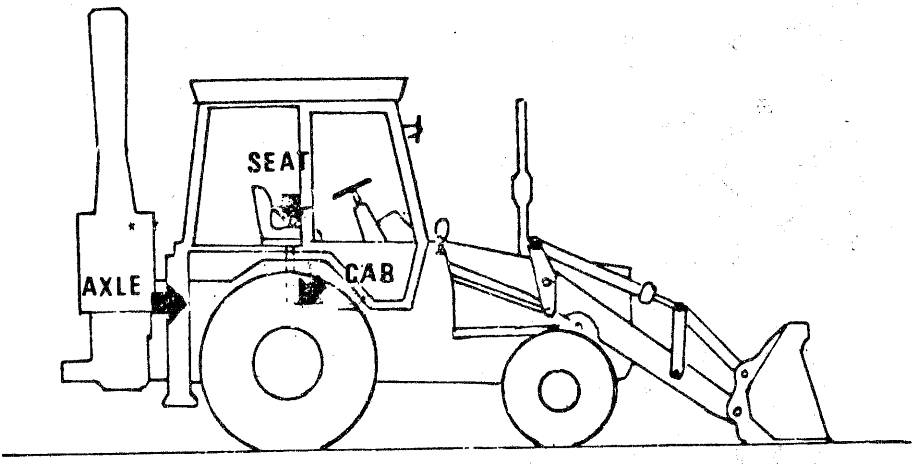
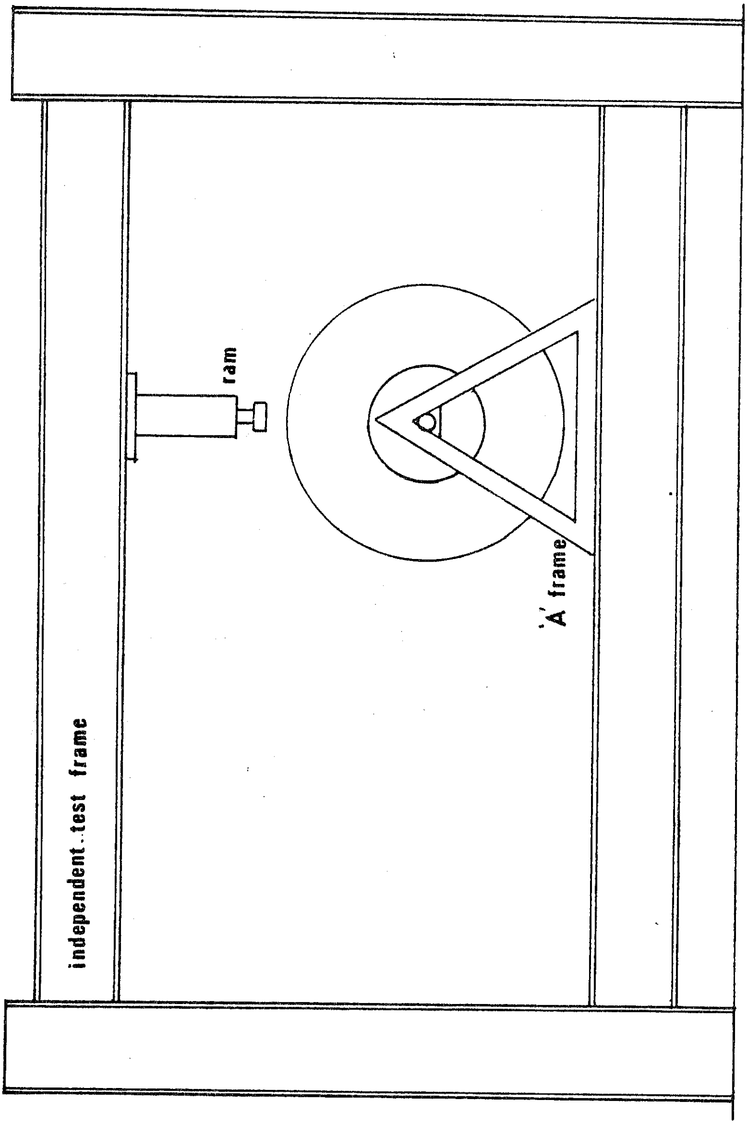

JCB FREQUENCY RESPONSE 'Z' axis
96dB
Seat
92dB
Cab
96dB
Axle
ACCELERATION

FIG 2

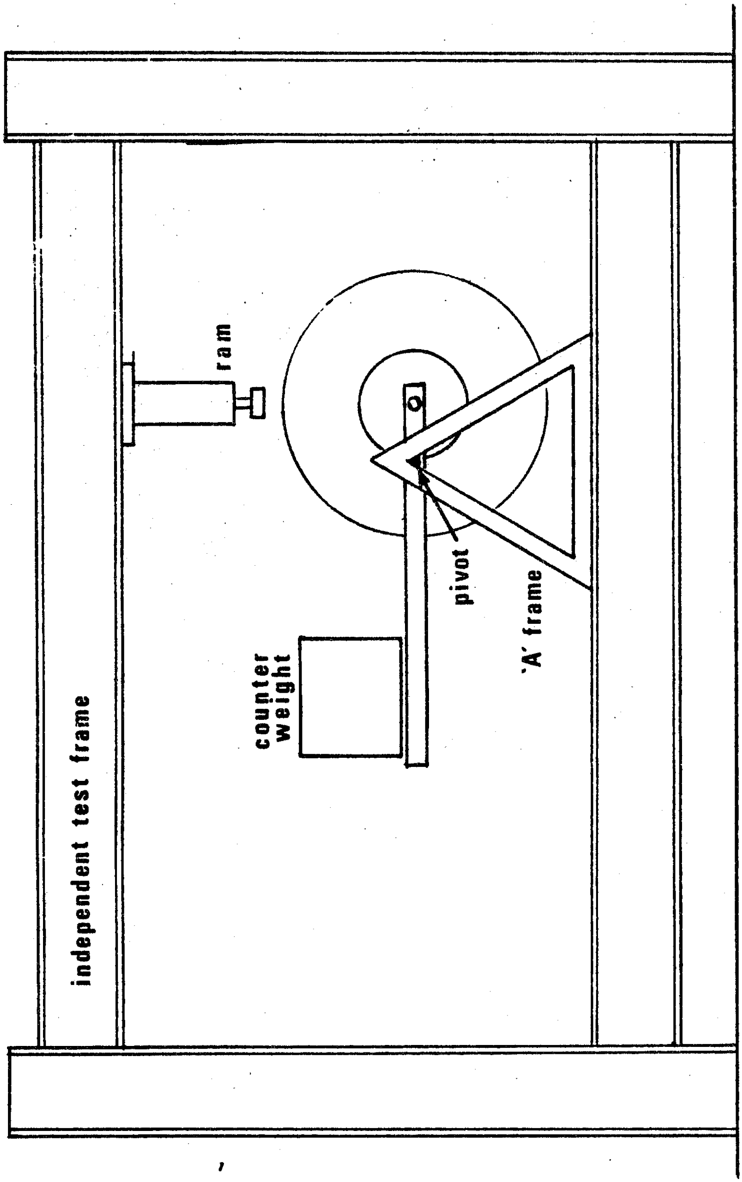


JCB EXCAVATOR-LOADER Fig 3

Accelerometer locations



DRIVEWHEEL TEST RIG (fixed axle) Fig 4



DRIVEWHEEL TEST RIG

Fig 5

DRIVE WHEEL VIBRATIONS AND DRIVER DISCOMFORT IN EARTHMOVING VEHICLES

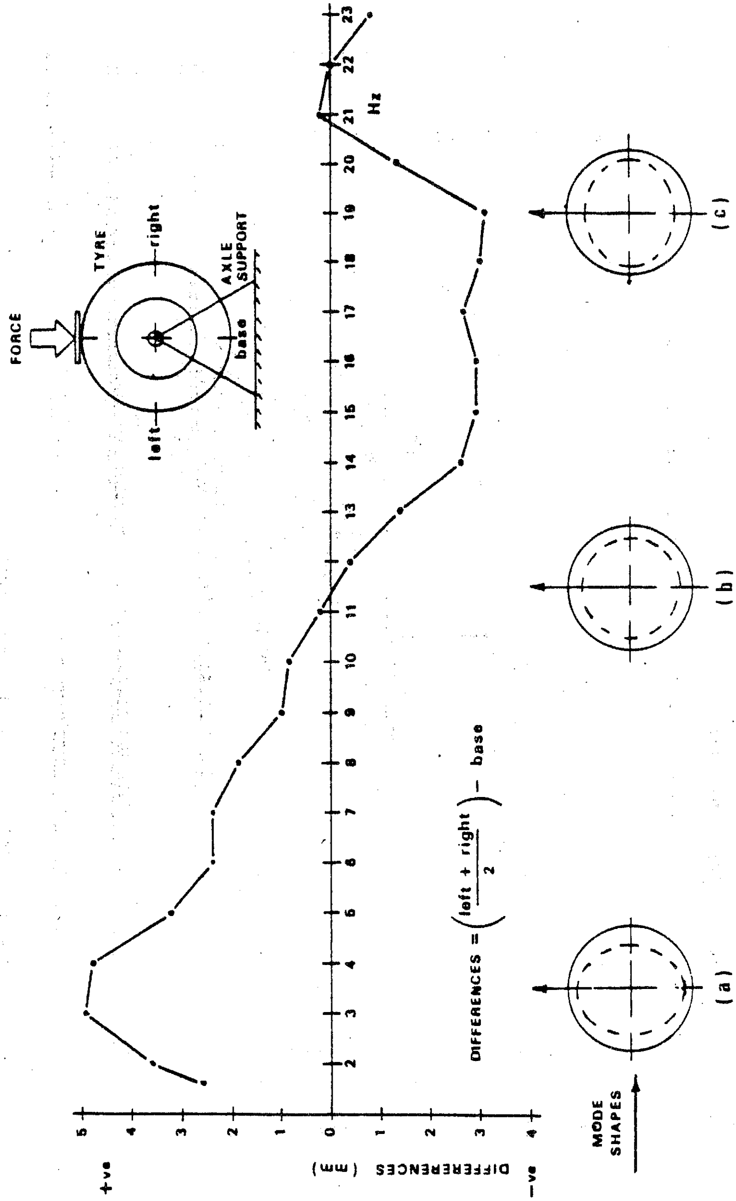


Fig 6

TRANSVERSE DISPLACEMENTS AND TYRE MODE SHAPES

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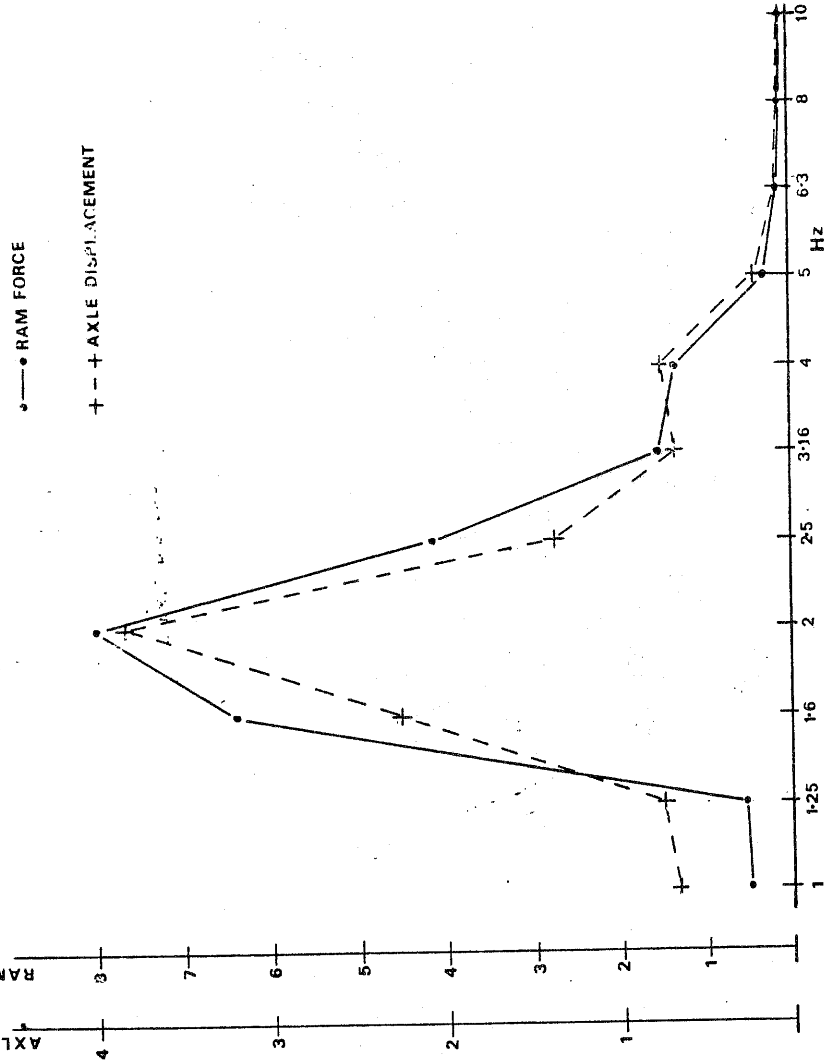

DRIVEWHEEL DYNAMIC TEST

FIG 7