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BACKLASH AND LOW FREQUENCY VIBRATION IN VEHICLES DRIVE LINES

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1. Introduction

Low frequency vibration of a vehicle drive line which may arise during and/or immediately after clutch engagement is usually described as "clutch judder". The reason for the occurence of this undesirable phenomenon is not understood with any certainty.

Over the years several 'causes' of judder have been proposed and opposed usually with some empirical justification but controlled experimental evidence has not yet provided a complete and positive solution to the problem.

Clutch judder has been commonly attributed to the friction/sliding speed characteristics of the clutch lining material in relation to the dynamic properties of the drive line. Unfortunately, it has been shown(2) that although such vibrations would certainly arise, with appropriate values for the system parameters, these values are not normally present in vehicle clutch-transmission system.

Clutch judder has been regarded(1) as a classic resonance phenomenon since it appears to occur at a natural frequency of the drive line but no satisfactory explanation is forthcoming for the source of the cyclically varying torque necessary to excite such a resonance.

Other factors which have been suggested as possibly affecting the problem include drive line stiffness(3), engine speed and rate of clutch engagement(4) and clutch torsional rigidity(5).

Arising mainly from practical experience, features such as clutch capacity and state of wear of linings are also regarded as having a bearing on the problem. A further 'cause' in the same category is an underpowered prime mover which was said by some to give rise to 'engine fight' rather than clutch judder but there is an area where the distinction between the two is debatable.

2. Experimental work

Fig. 1. shows a schematic presentation of test equipment.

The procedure for all tests was substantially the same. The driving side was brought up to speed with the clutch disengaged and the drive side stationary; the clutch was then engaged mechanically at a predetermined constant rate. The angular velocities of the driving and final driven rotors were monitored by feeding the outputs of the tachometer into the computer which processed the information and subsequently provided the results in digital and graphical forms.

The features which the tests attempted to cover were as follows:
Clutch malalignment, underpowered prime mover, high temperature, clutch plate (involving tests using an old plate, solid plate and a plate lined with so-called anti-judder woven material), driving speed and rate of engagement, clutch capacity and finally backlash in the driven system.

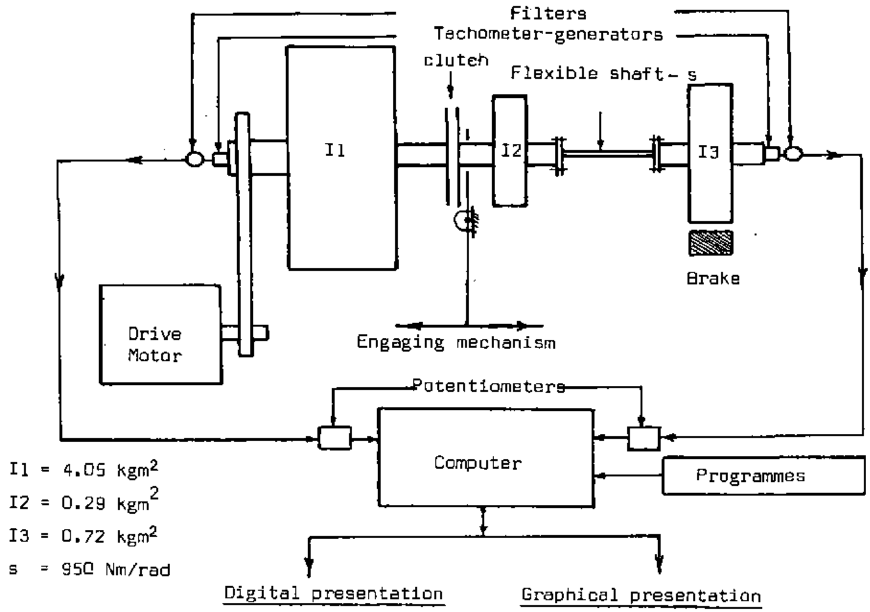

Fig. 1. Schematic Presentation of Test Equipment

None of the foregoing tests was exhaustive; their purpose was to cover a range of conditions and any indication, however small, of a feature introducing abnormality in the take-up pattern could be followed by a more detailed investigation. This proved the case when backlash was introduced between the two rotors of the driven system and in addition to a repeat of all the previous tests with backlash present, further tests relating to backlash were performed as follows:

a - The natural frequency of the driven system was altered by changing the flexible shaft.

b - The backlash was taken up before engaging the clutch.

c - A constant torque loading was applied (approximating to starting a vehicle on a hill)

d - The location of backlash between the two rotors of the driven system was altered.

3. Theoretical work

The problem was then theoretically analysed by formulating the equations of motion of the system and solving them numerically using a digital computer to asses the results of the previous experimental work.

4. Results and discussion

Within the range of the tests performed, none of the factors, with the exception of backlash, and to some extent, malalignment, gave any departure from the normal engagement pattern (Fig. 2.). The vibration present immediately after synchronisation is attributable to 'unwinding' of the flexible parts of the system.

The presence of backlash in the system had a significant effect on the engagement pattern prior and after complete synchronisation (Fig.3.)

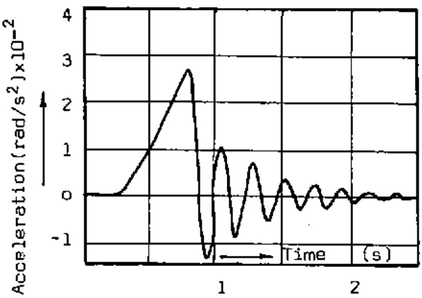

Fig.2. Engagement without backlash

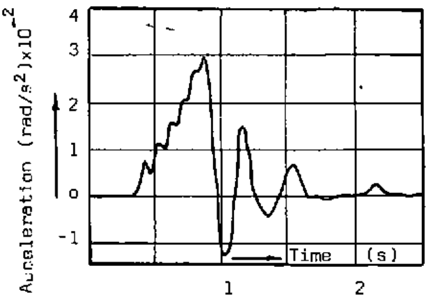

Fig.3. Engagement with backlash

The frequency of the vibration associated with backlash was found to be the same as the natural frequency of the two rotor driven system (Fig.4)

The vibration was slightly changed in character by the presence of clutch malalignment which appeared to produce a more sustained oscillation (Fig.5). The extended time of engagement was associated with the axial clearance produced by the insertion of the thin washers on one side between the clutch cover assembly and the fly wheel to provide the malalignment.

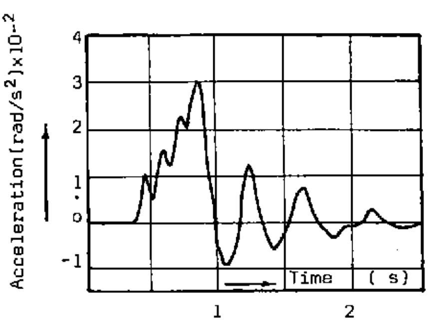

Fig.4. Engagement with backlash and 446Nm/rad flexible shaft

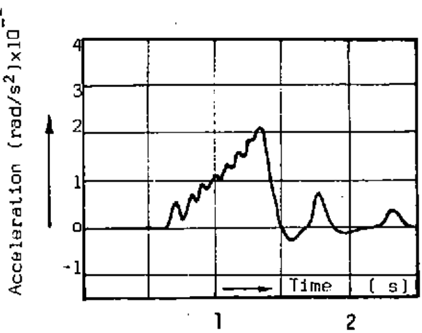

Fig. 5. Engagement with backlash and malalignment

It will be noted from Fig. 6 that when the backlash was taken up before engaging the clutch, no vibration developed. Fig. 7 also suggests that the static loading increases the effect on vibration rather than decreasing as might at first be expected. Both results are consistent with practical observation of actual clutch judder: the first in that judder, when present does not necessarily occur every time and the second that it is more likely to occur on a hill start.

When the between-rotor backlash was replaced by clutch plate clearance no vibration developed but the motion after completion of engagement was affected with a pattern similar to that in Fig. 6.

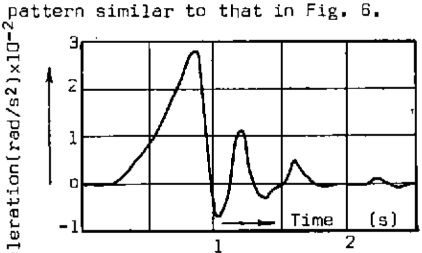

Fig.6. Engagement with backlash taken up

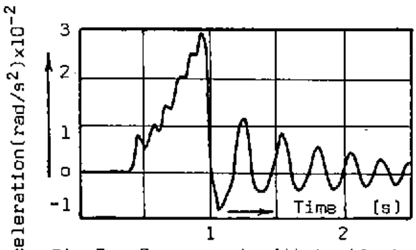

Fig.7. Engagement with backlash and 28.1 Nm static torque

The often quoted influence of clutch lining material on the incidence of clutch judder may be explained by the effect of the lining material on the shape of the torque curve, particularly in the early stages of engagement which in turn may decide whether a vibration due to backlash is of a purely transitory nature or whether it builds up into an undesirable one.

The theoretical and experimental results when compared came in close agreement (Fig.8) and confirmed the role of backlash in generating low frequency vibration in a multi-rotor driven system.

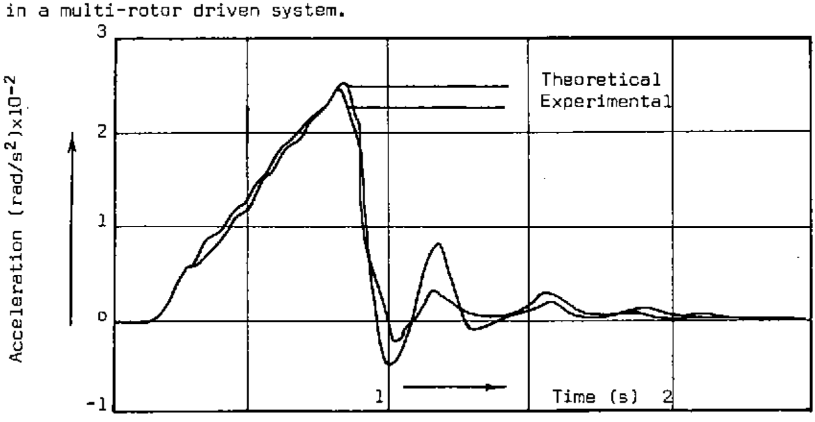

Fig.8. Comparison of Experimental and Theoretical results of I3.

6. Conclusions

The results clearly identify backlash between the rotors of a dirven system (provided it was not previously taken up) as a source of a system vibration at its natural frequency and with an amplitude depending on the constructional and operating parameters. This vibration was sensed experimentally and confirmed theoretically.

In a more general way, the results obtained with backlash may be regarded as moving the emphasis in the analysis of this type of system away from the classical ideas of forced vibration due to cyclic torque variation towards the concept of an oscillatory motion due to discontinuities or nonlinearities in the system. Backlash can be regarded both as a discontinuity and also an extreme case of a non linear spring in which the stiffness goes from zero to a finite value. Other forms of discontinuity and non linearity may well produce similar effects and work is continuing along these lines.

Acknowledgement

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