Proceedings of The Institute of Acoustics

ACOUSTIC OUTPUT FROM STICK-SLIP MOTION FOR SELECTED MATERIALS

G J McNulty (1) G R Symmons (2)

1 and 2 Sheffield City Polytechnic

Summary
A description of stick-slip motion is given and the resultant Acoustic Signal for a number of materials in stick-slip contact is presented. The stick-slip apparatus is described.

Introduction

Stick-slip motion is a vibrational motion set up between two slow moving bodies, in frictional contact, when one or both are driven through an elastic member.

Initially the bodies are in contact and there is a static friction force between them, acting against any motion. If one of the bodies is driven by an elastic member the bodies will remain stationary as the elastic member deforms. As it deforms the elastic member stores up energy until a point is reached when the elastic member can exert a greater force than the static friction force between the bodies. Now the driven body rotates and is in the 'slip' phase. However, since the bodies are moving against each other, the frictional force between them is reduced to a lower level called the kinetic friction force. The dropping of the frictional force means that the elastic member still has enough stored energy to overcome the frictional force so rotation continues. When this is not the case, rotation ceases and the friction goes back to the static level. This is the stick phase. The whole process is now repeated as long as one member continues to be driven.

This paper is one of a long term research investigation into stick-slip acoustic relationships. Some of the work has already been published (1-3). It is the aim of this investigation to describe materials in stock-slip motion and record the parameters relating to this. Namely, torsion, velocity, friction, and noise. A description of the stick-slip apparatus is also given.

Measurement Method

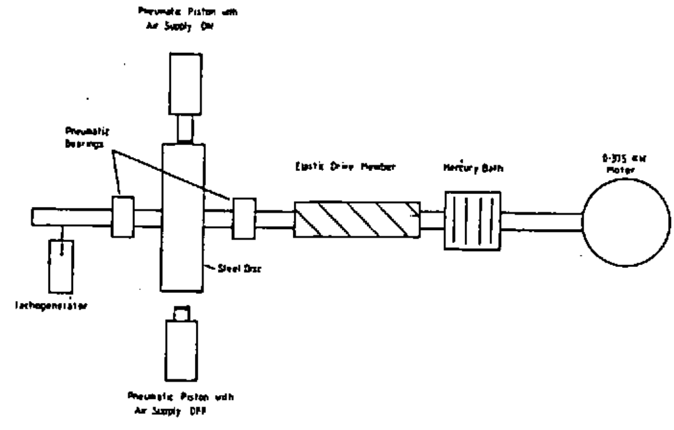
Figure 1 shows in diagrammatical form a sketch plan of the stick-slip apparatus. The air pressure on the pistons is such that they hold the wheel from turning until a certain amount of tension is built up in the elastic member. Torsion is measured using strain gauges attached to the elastic drive member, velocity is measured by the tachogenerator, friction is measured indirectly using strain gauges attached to cantilever arms which hold the pistons. Monitoring of the acoustic signal was achieved using a B and K 2033 high resolution analyser from a microphone located close to the two materials in stick-slip contact. For vibration measurement an accelormeter was situated on the piston disc near the friction contact. Figure 2 shows a typical Torque-Friction-Velocity Relationship and Figure 3 outlines the Acoustic Signal build up over time. These have been fully described in previous research

ACOUSTIC OUTPUT FROM STICK-SLIP MOTION FOR SELECTED MATERIALS

papers (1–3). This paper will summarise the main characteristics of the materials in stick-slip contact and highlight the salient features of each.

Figure 1

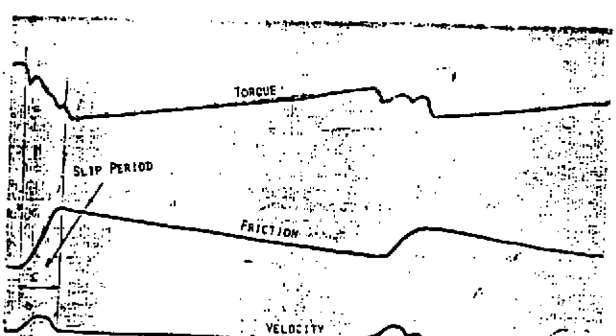
Plan Sketch of Stick-Slip Apparatus



PLAN SKETCH OF STICK-SLIP APPARATUS

Figure 2

Mild Steel on Hard Steel



ACOUSTIC OUTPUT FROM STICK-SLIP MOTION FOR SELECTED MATERIALS

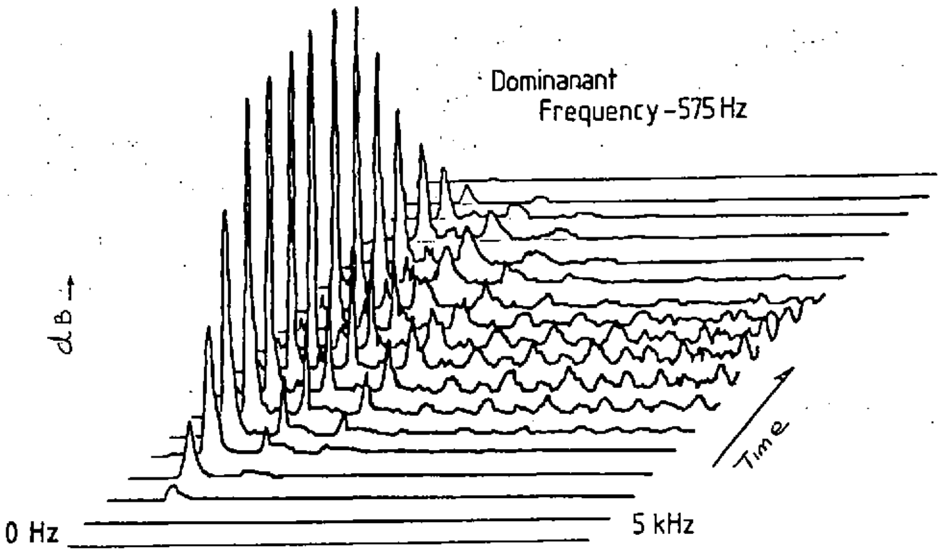


Figure 3

Acoustic Signal Build-up.

Results

The aim of this investigation, as stated before, was to contact two materials in stick-slip motion and record the parameters outlined above. In particular, the core of the work was to detect the presence and observe the magnitude and frequency of the acoustic signal associated with the stick-slip motion. Several different combinations of materials were used for this research, these being;

Brass on Steel
Lead on Steel
Aluminium on Steel
Perspex on Steel
Steel on Steel

The characteristics of each combination of materials are presented and commented on below.

Brass: Of all the materials tested, brass was the most difficult to test, and the least interesting and informative. For the first fifteen or twenty minutes, brass didn't stick-slip, it just turned. Finally when the pistons were worn in, it gradually began to stick for small values of torsion.

ACOUSTIC OUTPUT FROM STICK-SLIP MOTION FOR SELECTED MATERIALS

Even when stick-slip motion did occur, the slips were very small and very irregular. In fact, so small and irregular that it was impossible to get any information on the first three parameters (torsion, velocity and friction) that was at all intelligible or useful.

The acoustic signal was almost as uninformative and just as hard to obtain. The wheel, in fact turned for well over an hour before any acoustic signal was given off. When a signal was given off, not only was it quiet (sometimes inaudible), the frequency varied so much from one slip to the next that no pattern or set of diminant frequencies could be distinguished. The only bit of possibly useful information that could be detected was that there was generally two dominant frequencies of about the same amplitude. The lower frequency was usually between 200 Hz and 300 Hz and the upper frequency was usually between 650 Hz and 750 Hz. But as stated before, there was no real consistency in any of the acoustic signals.

Lead: Lead, when tested, was more informative ie, more consistent and better results, than brass. Piston wear was rapid. Although the stick-slip pattern of lead was quite regular, the noise emitted by the slips was very quiet. The build up and decay of the acoustic signal at the dominant frequencies was not linear.

Aluminium: Aluminium turned out to be one of the loudest materials tested, although it wasn't one of the most consistent. The pistons took longer to wear in, and eventually grooves developed in the wheel since aluminium is a fairly hard material, and with no lubrication, the smallest dirt particles can cause a scratch which soon develops into a groove.

As mentioned above, the stick-slip wasn't very regular. With respect to frequency, the lowest dominant frequency had a large variance from slip to slip (400 - 450) Hz while the higher one (812 Hz) remained much more constant. The amplitude of the sound varied also, but the average level of sound was quite high, usually somewhere about 60 dB. The most uncommon variance of all though was the growth and decay of the acoustic signals with respect to time. These varied from nearly linear to most distinctly non linear.

Perspex: Perspex was the best material to work with as far as consistent and audible slips. It was also very good because it was soft enough to wear in quickly and not cause scratches on the wheel, yet it was hard enough not to wear out quickly.

Acoustically the slips were very consistent as well, both the amplitude and the frequency varied minimally. In fact, perspex was the best material tested for consistency of frequency and amplitude. The first dominant frequency always showed up between 350 and 360 Hz. The build up and decay of the acoustic signal was also very consistent, being almost perfectly linear every time and having a maximum amplitude of about 60 dB.

ACOUSTIC OUTPUT FROM STICK-SLIP MOTION FOR SELECTED MATERIALS

Steel: Working with steel had to be done very carefully. Due to the equal hardness of the wheel and the pistons, the smallest dirt particle would cause a scratch in both which soon developed into a groove. The slips, although usually quiet, were fairly consistent as far as acoustic growth and decay were concerned. Periodically, there was a slip that was longer and much louder than normal, this was probably due to scratches which had developed in the wheel.

The frequency of the acoustic signals was also quite regular, with the lowest dominant frequency always falling somewhere in the range of 375-395 Hz. The amplitude of the slips (except for the louder ones) was usually in the range of 48 - 52 dB.

Interpretation

An aim of this work is to attempt a correlation between various material combinations, which include density, hardness peak frequency peak amplitude and the difference between static and kinetic friction (T_s - T_k). The following table summarises the findings, each column delineates the parameters from the lowest to highest. It is important to obtain further material combinations before difinitive conclusions are drawn as to the prediction of the onset of good acoustic signals due to stick-slip motion.

Density:	Hardness:	Peak Freq:	Peak Amp:	T_s-T_k:
Perspex	Lead	Perspex	Lead	Lead
Aluminium	Perspex	Steel	Steel	Steel
Steel	Aluminium	Lead	Aluminium	Aluminium
Lead	Steel	Aluminium	Perspex	Perspex

As can be seen from the list, there doesn't seem to be much correlation between some of the characteristics. But if we look at T_s-T_k, amplitude and density, notice that the order of the lists is either the same or reversed. This may suggest that amplitude (loudness) of the squeak is related inversely to density, and that T_s-T_k is related inversely to density and/or directly to amplitude. These possible relationships, are the most important part of the findings to date.

References

[1] G R Symmons and G J McNulty (1985) Stick-slip friction characteristics and Noise emission. Seminar on Friction and Contact noise techniques Hughesschool, Delft, Holland, 20 to 22 June 1985.

[2] G R Symmons and G J McNulty (1986) Acoustic Output from stick-slip friction, International Journal of Wear 113 1. pp 79-82 December 1986.

[3] G R Symmons and G J McNulty (1986) Relationship between stick-slip friction and its acoustic signal. Proc INTERNOISE M.I.T. Cambridge Mass, USA pp 365-370.