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AN INVESTIGATION INTO CONDITION MONITORING OF STICK SLIP MOTION

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

(1) Anti Sonics Ltd
(2) Sheffield City Polytechnic

SUMMARY

The effect of stick-slip and its associated acoustic and vibration output has been studied for a specimen of commercial brake material. The stick slip motion is described and details of how the parameters of torque, velocity and friction are controlled is given. The aim of the study is to show how the material behaves under sustained stick-slip motion. In order to achieve this end the vibration and acoustic output resulting from the stick-slip together with the surface changes detected by taly surf were studied.

INTRODUCTION

Stick-slip motion has already been described for various materials combinations in [1-6] but a brief description will be given here for completeness.

When a vibrational motion between two slow moving bodies in frictional contact is set up then the condition of stick-slip exists. By definition of stick-slip one of the members in frictional contact is driven elastically. The motion is the result of forces in the elastic member reaching a magnitude greater than the static frictional force between the two bodies. When the driven body is rotated as a result of these forces the slip phenomenon occurs. The bodies move against each other and the frictional force between them is reduced to a lower level called the kinetic friction force. The drop in the frictional force means that the elastic member still has enough stored energy to overcome it, so rotation continues, when this is not the case the rotation ceases and the friction goes back to the elastic level. This is the stick phase. As long as one member continues to be driven the process will be repeated.

The paper will show the result of an investigation of the noise and vibration during stick-slip motion using a hardened steel disc and brake material the product of a well known manufacturer. The tests will be sustained over a time period in order to study the relationship between the parameters of stick-slip and acoustic output against any surface changes which may occur.

There is a dearth of published work relating to the condition monitoring during the stick-slip phenomenon. The material used is a fibrous material used in brakes. It has a high friction characteristic with excellent fade and wear resistance, and is silent in operation according to the specification. This proved a useful material to study in stick-slip contact with the hardened steel disc mainly due to its friction characteristics. The instrumentation and experimental procedure have already been detailed in references [1-5] and need not be repeated here. Suffice to say that the stick-slip machine is purpose built for this study. The vibration and noise output were measured by accelerometers mounted near the rolling member in the stick-slip machine and the noise was monitored from a microphone situated and directed to the contact. Precision grade instrumentation (B&K) was used.

RESULTS

Analysis of vibration and noise characteristics during stick-slip motion and parameters pertaining to torque friction and velocity are given for the brake material 3904f in contact with hardened steel disc. Surface contact is analysed by Taly surf and a qualitative inspection of the surface by electron microscope was carried out. The test lasted 90 minutes after which the parameters remained reasonably constant. Analysis was made at 15 minutes intervals.
Figures 1 to 7 show the vibration output against frequency at 15 minute intervals. Details of the method of measurement have already been described in [1-5] and will not be repeated here, also in these references it was shown that a dominant frequency of the apparatus elastic cantilever system is approximately 600 Hz. This frequency again is evident in every graph. However, the other peaks provide an indication of the stick-slip vibrational activity. Figure 1 to 6 show that there is relatively high vibration energy typified by intermediate peaks 4, 7 and 12 kHz. As the stick-slip proceeds this energy increases up to 45 minutes. Thereafter at 60,75 and 90 minutes there is a definite reduction in vibrational energy highlighted by the diminution or absences of the intermediate peaks especially at 90 minutes.

No acoustic output resulted until 75 minutes of stick-slip. The acoustic output for 75 and 90 minutes is shown in Figures 8 and 9. At 75 minutes there is a dominance of pure tones given by the discrete nature of the spectra. Subjectively this noise emission resembles that of a combination of whistles at different frequencies. Figure 10 gives the Torque - Time graph which indicates that there is a rapid change in characteristics at 60 minutes. Torque time curves for 75 and 90 minutes Figures 11 and 12 respectively shows evidence of overslip and micro slip. At this stage in the investigation this is the only indication of a possible correlation between the stick-slip and the acoustic output.

The taly surf readings show that there is an expected reduction in the surface undulations. This is numerically outlined in Table 1 where an explanation of the terms RA and RT are given in Figure 13.

STICK-SLIP MOTION

TABLE 1

TALYSURF READINGS

Time Elapsed minutes	R_A µm	R_T µm
0	3.679	45.40
60	1.852	32.45
90	1.546	12.89

Figure 14 gives a typical talysurf trace after 90 minutes and Figures 15 and 16 show the electron microscope scan at two different times. At this stage in the investigation no detailed analytical quantising of the scans is possible but the Figures highlight that there is contrast which gives potential for a criterion to be established.

DISCUSSION

The statement that the pads are silent in operation suggest that during the experiment acoustic output will not be witnessed even if stick-clip is occurring. This expectation is true until the 75 minute time elapsed, traces are observed, when acoustic output commences.

The trend graph, Figure 10 shows that there appears to be some irregularity in the results either at the 60 minutes elapsed observation or at the successive observations, ie the 75 and 90 minutes elapsed observations at which acoustic output is present. Consider the 75 and 90 minute results, it can be seen that the vibration acceleration traces change their characteristics, and from the oscilloscope traces, overslip and microslip becomes very apparent which affect the torque and angular velocity values obtained. This trend changed and the appearance of acoustic output suggests that the results do not contain irregularities but that there is a direct link between the two.

CONCLUSION

The results show that there are certain salient features in the vibration spectra which correspond to characteristics in the stick slip graphs to indicate incipient noise emission from the 3904f - Steel combination.

Initially the vibration spectra was characterised by a 'broad band' spectra intrinsic in this were 5 identifiable bands of frequency. As the stick slip motion progressed in time the spectra was reduced to one dominant frequency band. Simultaneously the Torque-Time characteristic curve exhibited micro slip and at this juncture the acoustic output developed. These indications if repeated for other combinations of dissimilar metals... in stick slip motion would suggest that the control of noise in braking materials can be reasonably predicted by well controlled laboratory experiment.

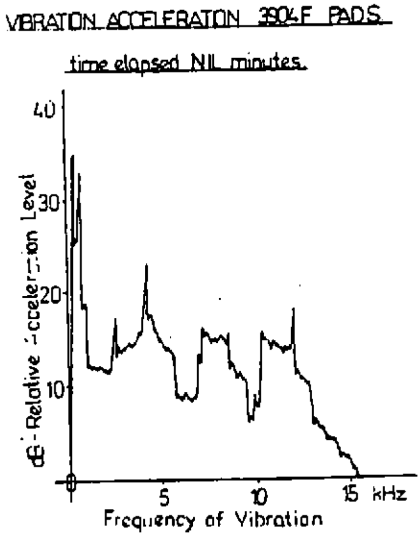


FIGURE 1

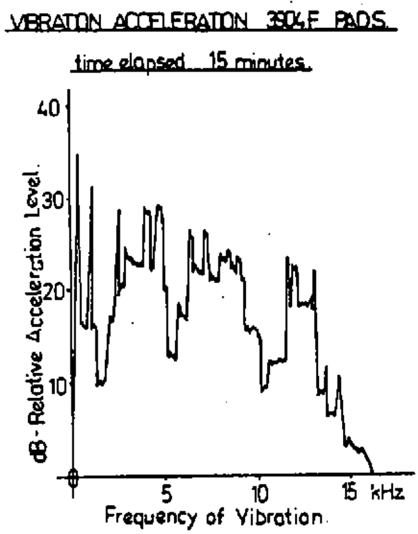


FIGURE 2

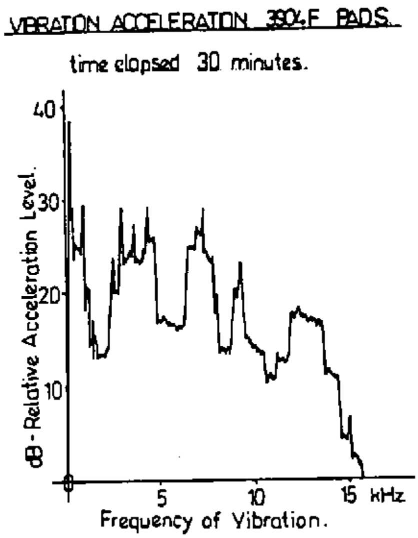


FIGURE 3

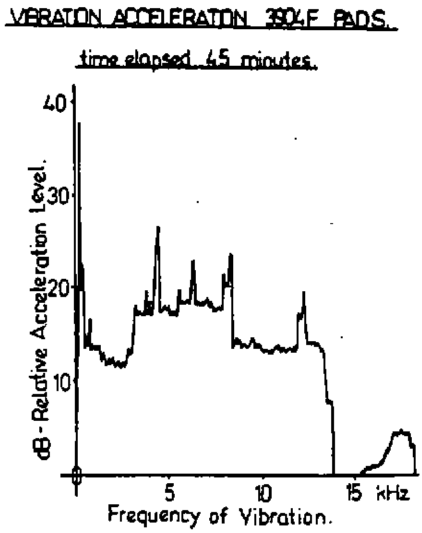


FIGURE 4

STICK SLIP MOTION

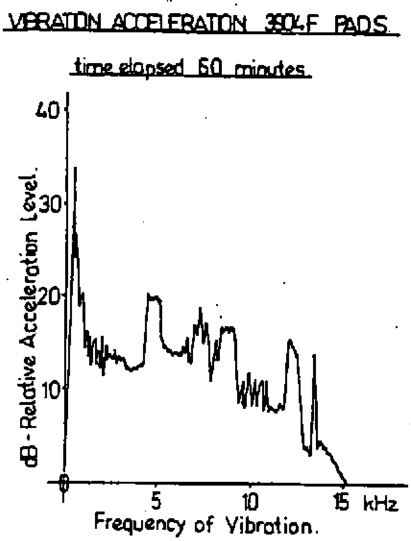


FIGURE 5

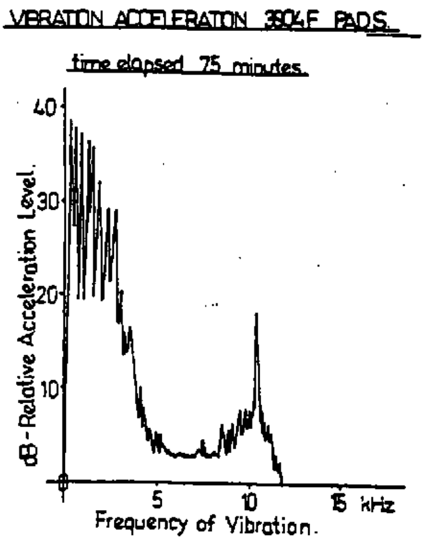


FIGURE 6

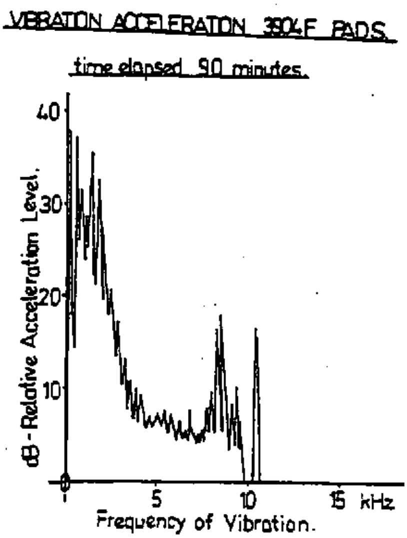


FIGURE 7

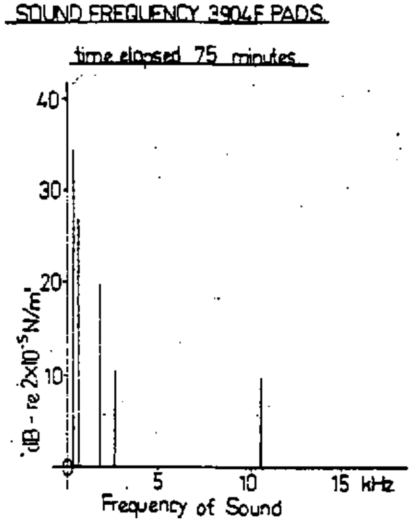


FIGURE 8

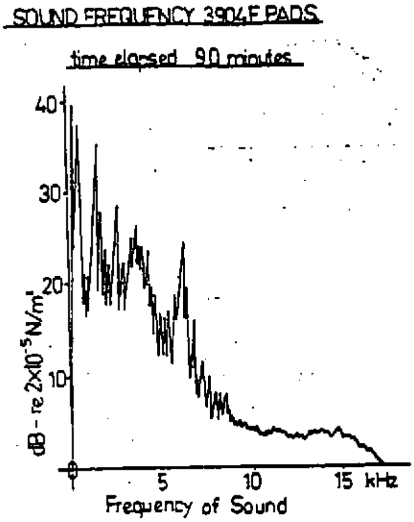


FIGURE 9

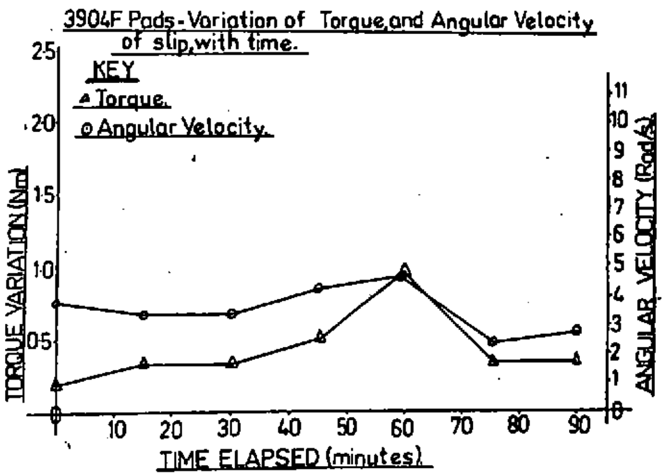


FIGURE 10

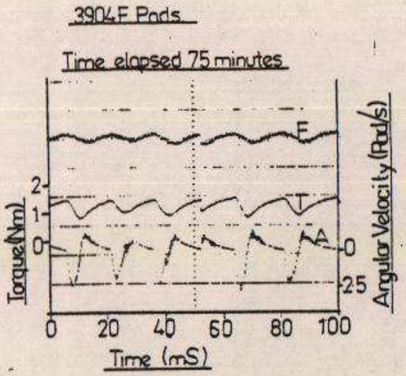


FIGURE 11

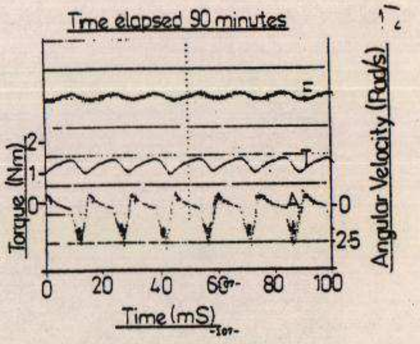
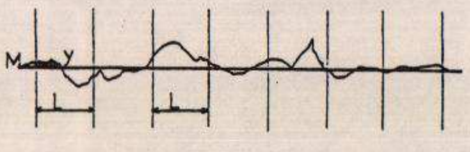


FIGURE 12

Talysurf Measurements

RA-the arithmetic mean of the departure of the profile from the mean line. It is usually determined as the mean result over several sampling lengths L as shown.



$$RA = \frac{1}{L}\int_0^L y(x)\,dx$$

RT-the maximum peak-to-valley height of the profile within the assessment length.

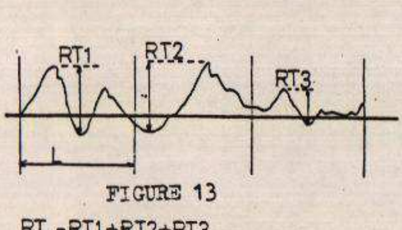
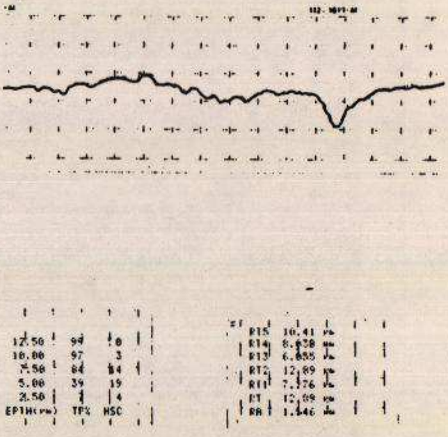


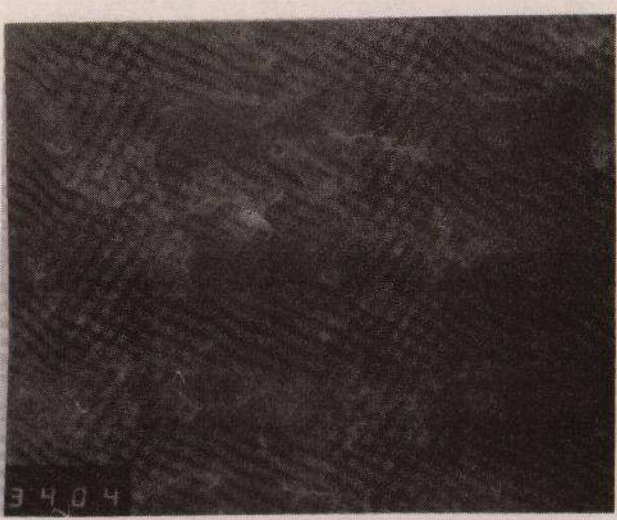
FIGURE 13

$$RT = \frac{RT1+RT2+RT3}{3}$$



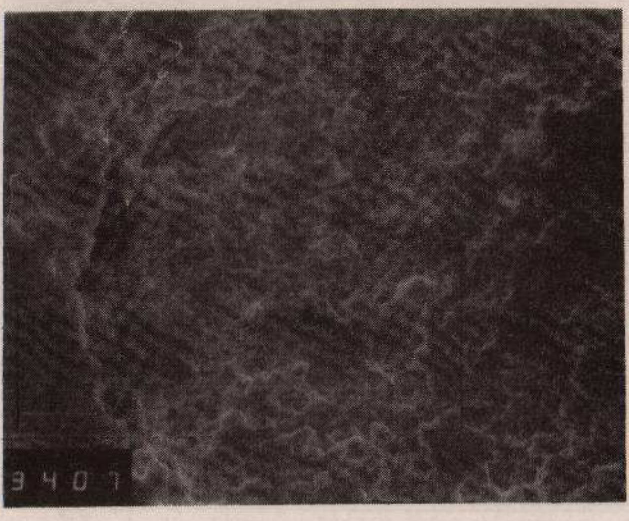
Talysurf Trace for 3904F Pad-Time elapsed

FIGURE 14



ELECTRON M
MICROSCOPE
SCAN
AT START

FIGURE 15



ELECTRON
MICROSCOPE
SCAN
AFTER 60 MINUTES

FIGURE 16

REFERENCES

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