Measurement and Diagnostic of Engine Belt Physical Condition from Acoustic Signals

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Background

Timing belt transmission is a key subsystem of international combustion engines. Faults in such belt systems lead to power loss, increased emissions and, in case of failure, may even cause severe damage to the whole engine. The assessment of belt condition in engines is problematic. The most common diagnostic methods use visual inspection of the belt which has to be carried out with the engine switched off and is prone to error. Some non-contact diagnostic methods such as laser scanning are available but these are prohibitively expensive to implement in commercial applications[1,2,3].

Acoustic diagnosis, as a non-contact method for measuring the condition of physical systems, has been demonstrated to produce very promising monitoring results[4,5,6]. A diagnostic system is being developed that uses a highly directional acoustic probe to capture acoustic signals emitted from the belt. These 'near field' signals are contrasted to 'far field' acoustic signals captured in the enclosure in order to identify the differences in belt radiation when belt faults are introduced. The system under test considers a belt mounted on a series of pulleys, where the simplest case consists of two pulleys and a belt stretched between them. The span of the belt between the pulleys vibrates according to the physical parameters of the system and produces a signal that may be captured using an acoustic probe. In this work, the fault under scrutiny is that arising from loss of tension which may be directly related to the degradation of belt material over its life span.

Results

Results have been obtained that show a significant difference between acoustic signals captured close to the belt and those captured in the enclosure, when a fault is introduced (Fig 1). These differences serve as evidence to suggest that the acoustic signals from the belt are useful in diagnosing the development of a fault.

A further analysis of belt signals shows evidence of alteration in the belt spectrum when the tension varies. This is in contrast to signals captured in the enclosure where no evidence of differences between test cases is found. The differences identified match the frequency range indicated in previous studies.

Further signal analysis has been employed to determine a method of fault detection. The error spectrum has been obtained by evaluating the differences in spectrum between the belt under both test conditions(Fig 2). Large values at specific frequencies indicate where differences in belt radiation may have developed due to the development of the fault. A further analysis technique looks at the coherence between the signals under the two test conditions – a spectrum comparison of two frequency domain data sets. The average coherence value is used to detect a fault when coherence drops below a set value. Currently the coherence technique is strongly affected by effects introduced by the engine enclosure. This is subject for further work.

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Development

Most of the uncertainties from the system being presented stem from unknown parameters of the belt system such as natural frequencies, tension and resonant regimes of the belt (strongest modes being excited). Additionally, the positioning of the near field acoustic probe needs to be guided by a further study of 'hot spots' indicating which areas are most likely to radiate useful acoustic emissions. The developments below describe the work being undertaken in each topic with the aim of supporting the performance of the diagnostic system under development.

<u>Analytical Model of belt:</u>

In order to predict the behaviour of the belt under different excitation conditions, a theoretical model is developed based on the vibration of an elastic band of known properties between two simply supported points representing the belt pulleys. This analytical model allows the determination of belt natural frequencies and resonant regimes which are responsible for most of the belt vibration. An analysis of belt physical properties is necessary to identify the mass per unit length. The tensions applied on the belt are also measured and used as input in the model.

<u>Measurements:</u>

A second phase of measurements is undertaken. A number of belt conditions (under different tensions) is now investigated in order to allow the tracking of a developing fault and understand its behaviour over the life span of the belt.

These measurements are now being obtained not only using the acoustic technique described above but also employing laser interferometry to profile the vibration regime of the belt. This method allows a visualisation and description of belt behaviour with sufficient detail to adjust the analytical model. It also allows the identification of 'hot spots' where the acoustic method under test is likely to provide better results for the diagnostic process.

Measurement of acoustic intensity close to the belt is also being undertaken. This type of measurement is more robust to corruption from background noise and as such proves a good solution to guide the more practical acoustic pressure measurement that will form the final system.

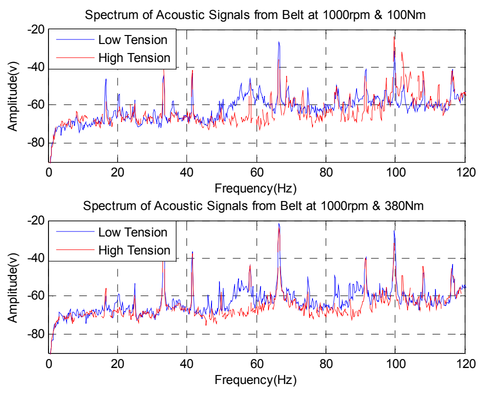

Figure 1

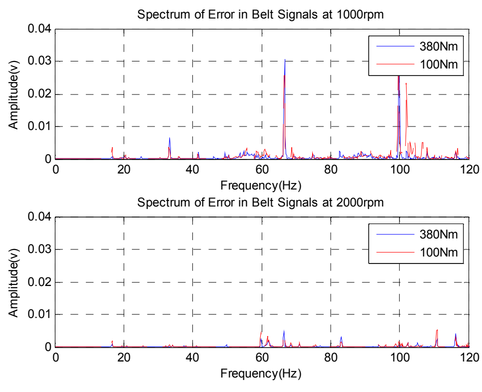

Figure 2