

Study of the Mechanism of Accessory Drive Belt Noise

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ABSTRACT

The mechanism of noise production in engine accessory drive belts was discussed. Applying geometric considerations to the transversal vibration of the belt, which is one cause of belt noise, the research showed that vibration of the belt is affected by fluctuations in the rotational speed of the crankshaft, and that the amplitude of the vibrations fluctuates cyclically. The cycle of this amplitude fluctuation is synchronous with engine speed, and for a 3-cylinder gasoline engine, its frequency is the $(1.5 \cdot n)^{\text{th}}$ engine rotation order. The spectrum pattern of belt vibration therefore shows components of the natural frequency $\pm(1.5 \cdot n)^{\text{th}}$ orders. The research demonstrated that at engine speeds at which the natural frequency $\pm(1.5 \cdot n)^{\text{th}}$ orders and the $(1.5 \cdot n)^{\text{th}}$ order frequencies, the engine excitation orders, are identical, multiple engine orders excite resonance in the belt, producing a high degree of belt vibration.

INTRODUCTION

It is today becoming increasingly common for multiple accessories to be driven by a single belt. In this method, a series of pulleys is driven by a V-ribbed belt that is passed around them in a serpentine form. This configuration enables the width of the engine to be reduced, contributing to greater compactness. However, the loads applied to the belt are higher than in the conventional configuration, and fluttering noise is becoming an issue in an increasing number of cases. Fluttering noise is noise produced with transversal vibration of the belt as the source of excitation[1].

Research has been conducted on a method of predicting transversal vibration at the development stage in order to reduce this vibration noise[2]. In addition, a considerable amount of research has been conducted on the mechanism of transversal vibration in order to reduce the phenomenon, and papers have been published dealing with resonance and parametric vibrations in drive belts[3].

However, three-dimensional display of the drive belt vibration spectrum in a 3-cylinder engine shows multiple radial shapes centering on specific frequencies. This is a phenomenon that cannot be explained by conventional approaches that see engine excitation force as simply exciting belt resonance or that focus on parametric vibrations. The research discussed in this paper therefore considered the belt vibration waveform geometrically in order to contribute to research on the mechanism of drive belt noise that is aimed towards the reduction of belt vibration. The research showed that actual transversal vibration is a phenomenon that is influenced by fluctuations in engine speed, and which fluctuates cyclically. The spectrum of transversal vibration is made up of multiple frequencies centering on natural frequencies. The research also identified the mechanism by which transversal resonance is maximized at specific engine speed as the fact that the frequency of the transversal vibration produced by fluctuations in engine speed and the frequency of the excitation force generated by the engine are identical at these frequencies, resulting in excitation of the belt by multiple frequencies. In addition, this conclusion showed that the natural frequencies of the belt could be simply estimated from the measured belt vibration spectrum.

ACCESSORY BELT DRIVE NOISE[1]

OVERVIEW OF TEST SETUP

An in-line 3-cylinder turbo-charged gasoline engine with a displacement of 660 cm³ was used in tests. Table 1 shows the specifications of the test engine. Figure 1 shows the layout of the accessory drive belt. A five-rib V-ribbed belt with a PET filament was used. The belt was used to drive the alternator, water pump and air conditioner compressor. The initial belt tension was varied by changing the position at which the idler was fixed. Because it was necessary to measure transversal vibration with a high degree of accuracy without making contact with the belt, an optical displacement gauge was used to measure the amplitude of belt vibration. Using this method, the amplitude of vibration was calculated from a photographic image of the belt. Figure 2 shows an outline of the measurement method.

CORRELATION BETWEEN BELT NOISE AND BELT VIBRATION

Figure 3 shows the results of measurements of belt vibration and sound pressure. Sound pressure measurement results are shown in Fig. 3(a), and belt vibration measurement results in Fig. 3(b). The horizontal axis of both graphs show engine speed. These results indicate that there is a high level of correlation between belt vibration and belt noise. Figure 4 shows a comparison of the spectra of belt vibration and belt noise. Figure 4(b) shows the velocity of belt vibration, with the results A-weighted to match the characteristics of human hearing. There is a resemblance between the belt vibration spectrum in 4(b)

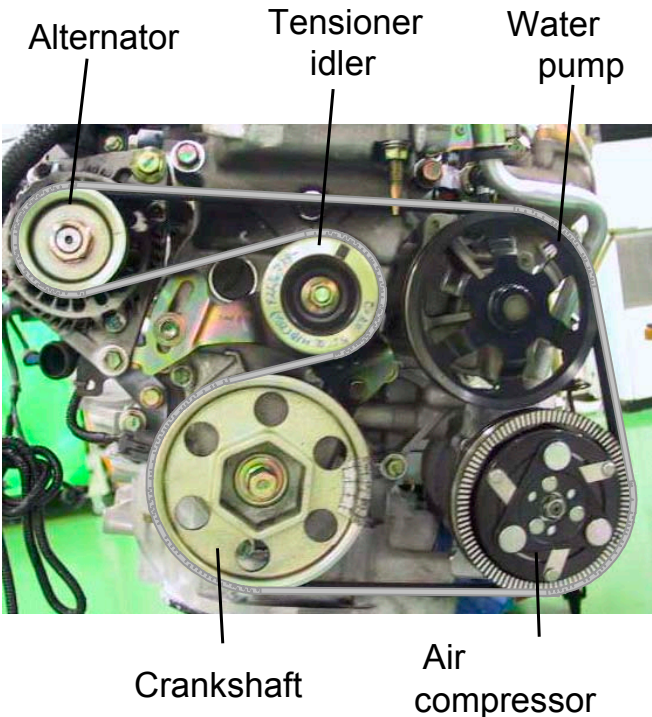


Figure 1: Accessory drive layout

Table 1 General specifications of test engine

Engine type	Liquid-cooled 3-cylinder turbo-charged engine
Flywheel	Single-mass flywheel
Crank pulley	Rigid pulley
Displacement	660 cm ³
Accessory drive belt	Serpentine V-ribbed belt
Filament of belt	Polyethylene terephthalate (PET)
Number of ribs	5
Material of rubber	Alkylic chlorosulfonated polyethylene rubber (A-CMS)
Tensioner	Fixed tensioner

and the belt noise spectrum in 4(a). This result indicates that belt noise is generated by belt vibration.

BELT VIBRATION IN A 3-CYLINDER ENGINE

Figure 5 shows a three-dimensional display of the measured belt vibration spectrum. The vertical axis shows engine speed and the horizontal axis shows frequency. The level of vibration is indicated by the brightness of the colors. The noteworthy characteristic of this figure is the fact that multiple radial spectra centering around 250 Hz can be observed. This phenomenon is believed to be a result of the effects of resonance. Parametric vibrations produced by

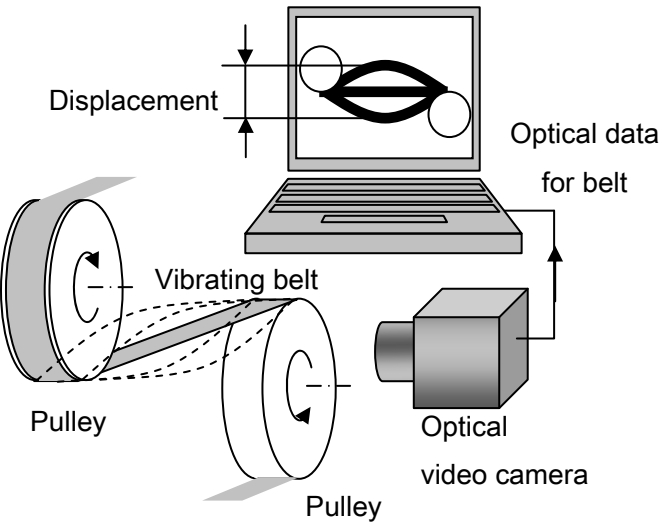


Figure 2: Measurement of transverse vibration