Experimental Investigation of The Friction-Induced Instabilities at the Origin of Wet Belt Squeal

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Summary. Under wet conditions, V-ribbed belts of the Automotive Accessory Belt Drive System might emit a typical squeal noise. Possibly involved friction-induced instabilities are investigated on a test rig that reproduces the with water lubricated contact between the pulley (whose rotation is controlled) and a static v-ribbed belt. From the measurements, a decrease of the friction coefficient with respect to the sliding velocity is observed. Moreover a typical phase plot witnesses the appearance of a stick-slip motion.

Industrial and Scientific Context

During the last decades, the global noise emission of vehicles has decreased from 82 to 74 dB. This let emerge parasite noises such as brake or wiper blade squeal. A typical squeal noise can also be emitted by v-ribbed belts in the Automotive Accessory Belt Drive System. Previous studies has allowed the suppression of noise in the case of a dry belt. However a solution is still needed in the presence of humidity. Friction-induced instability features have been widely used to explain belt squeal both for dry and wet belt noise. Sheng has recently highlighted the role of the transition in a mixed lubrication regime and the associated negative slope of the friction versus sliding velocity curve as the main features triggering noise. The present work aims at investigating further the friction-induced instabilities that could appear at the interface between belt and pulley and their link with the occurence of belt noise.

Experimental Setup

The test rig presented in figure 1 is the minimum setup necessary to observe the squeal noise. The contact between the v-ribbed belt and the pulley is reproduced . The specificity is that the belt remains static so that sliding exist all along the wrap angle which not the case on motor. The rotation of the pulley is controlled so that the sliding velocity is known. The lubrification of the contact is regulated with a peristaltic pump. Sensors measure the evolution of the tensions in both slack and tight free spans. A minimum tension is maintained in slack span thanks to a belt tensioner. The coefficient of friction is computed from the measurement of the tensions using Euler's formula. Measurements of the vibrations have been carried out with both accelerometers and laser vibrometers. The sound is recorded with a microphon 30 centimeters far from the pulley. Experiments consist to progressively increase the rotational velocity with a constant supply in water. The belt initial tensions, the ramp of velocity are modified and 4-ribbed belts with different coatings are used. The rotational velocity can be stationnary or with a sinusoÃŕsal form in order to reproduce the phenomenon of acyclism. Main results and interpretations are given in the following sections.

Main Results

Conditions for the Occurence of Noise

The first results set the main parameters that influence the appearance of the squeal noise of the belt. Experiments without supply in water had showed no noise and confirmed the necessity of humidity to trigger the noise. Secondly the noise had appeared only in a specific domain of tension and sliding velocity. That highlighted the influence of both parameters

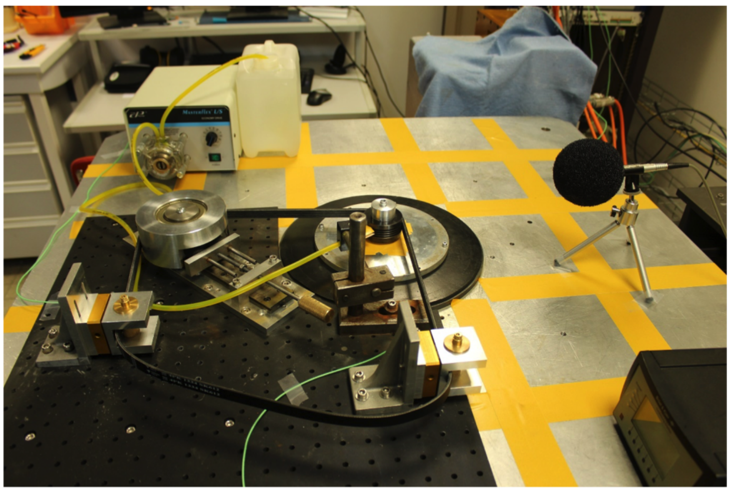

Figure 1: Experimental Setup with at its center : a *pulley* and the *v-ribbed belt* clamped in *2 tension sensors*, plus a tensionner(left of the middle), a microphon (right) and a peristaltic pump (bottom left)

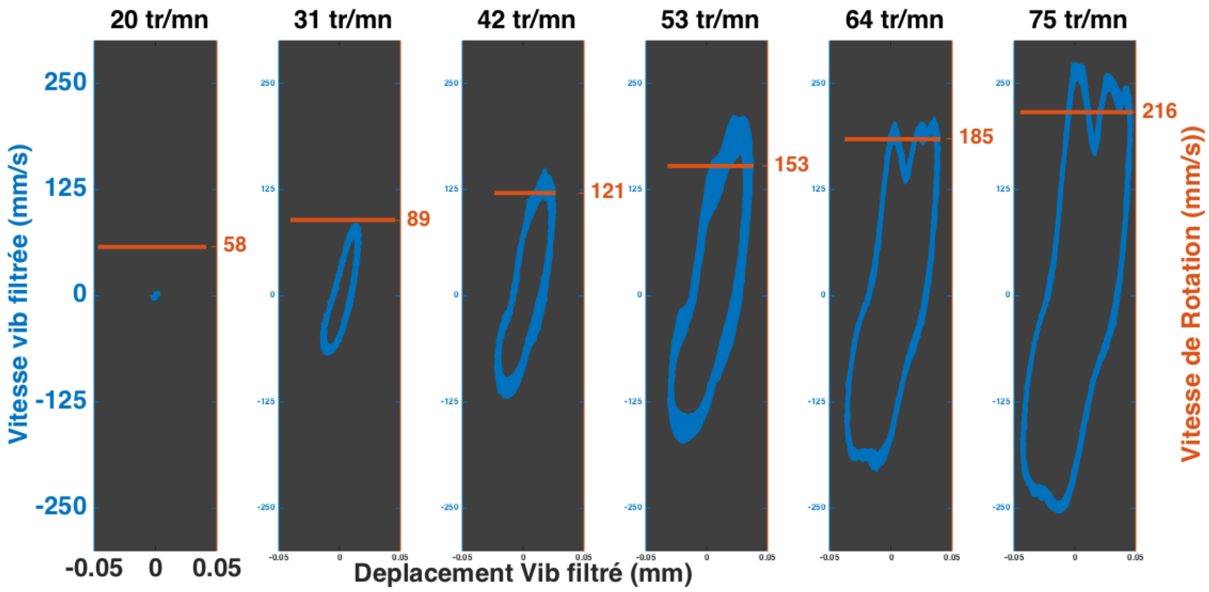

Figure 2: Evolution of the *Phase Plot Displacement-Velocity (BLUE)* of the belt in parallel of an increasing *Pulley Linear Velocity (ORANGE)*

for the occurence of noise. Last the form of the domain was especially dependent on the type of coatings of the belts, that incited to think on the importance of the friction conditions at the interface. Next results focus on the detection of friction-induced vibrations occuring at the lubricated interface between belt and pulley.

Velocity Dependent Friction and Instability linked with the transition in a mixed lubrication regime
A transition in the mixed lubrication regime is often followed by a large decrease in the coefficient of friction that can produce a negative damping of the system and thus its instability. The dependency of the coefficient of friction on the sliding velocity has so been investigated. Considering the mean coefficient of friction for each step of velocity, the evolution of the mean Sound Pressure Level on the step and the derivative of the coefficient of friction with respect to the sliding velocity it has been concluded that the slope isn't steep enough to generate a negative damping.Further investigations has lead to better estimate parameters such as the instantaneous coefficient of friction, the system structural damping or the local normal pressure to compute more precisely the point when the bifurcation occurs that is to say when the negative damping appears.

Stick-Slip Motion and Instability linked with the transition Static Contact -Dynamic Contact
A typical phase plot have been drawn from the measurements of the vibratory displacement and velocity of the belt. The curve shows a typical flat upper side when the vibratory velocity of the belt matches the velocity of the pulley. That suggests that a stick phase occur during squeal. This hypothesis is confirmed with the enrichment of the sound spectrum during squeal. However if the previous results is systematic for one type of coating, it is not the case for all other belts with different coatings also when squeal occured? Further investigations have tried to link the occurence of stick-slip motion with the measure of the static coefficient of friction and an estimation of the critical velocity for the appearance of stick-slip for each of the tested coatings.

Conclusions

The presented work shows an application for friction-induced instabilities. The squeal phenomenon of v-ribbed belt has been reproduced on an equipped test rig. The instability of the belt appears after a threshold level is reached by both the sliding velocity and the tension in the belt spans. Neither the decrease in coefficient of friction nor the stick-lip motion are sufficient to explain the occurence of the wet belt squeal noise.