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EFFECTS OF TENSILE FORCES ON THE ACOUSTIC EMISSIONS OF ELECTRIC MOTORS

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1. INTRODUCTION

This study describes an analysis of the effects of variation in tensile forces on the noise emission of a belt driven system. Belt tensile forces have static and dynamic components . The static component is relevant during steady power transmission. The dynamic component is dependent on several factors: the eccentriciy of the pulleys, nonuniformity of the belt and pulley surfaces, and dynamic loading.

2.BELT MECHANICS

Belt drives are widely used in engineering industry. Home appliance manufacturers are one of largest users, in clothes washers and dryers and the office machinery. Belts for power transmission have been developed, having a flexible member made of high tensile fibres or steel cords, enclosed in an envelope, made of some resilient material such as rubber (1). The envelope is firmly bonded to the tension member, provides the belt with necessary frictional and shock absorbing qualities and transmits load from pulley surface to tension member.

3. TENSIONING FORCES

Tensile forces act on the belt and, together with noise, affect the efficiency and quality of power transmission (2). The static and dynamic components of the tensile forces cause transverse and flexural vibrations. Static tensile forces are dependent on initial tensioning which is related to power transmission forces and belt speed. When a belt vibrates transversely, the length of vibrating span changes at two times frequency of the belt vibration. Two factors that can drive a belt into transverse vibration are pulley run out or irregulatiry and the tension itself. Irregularities on belt surface can cause periodic changes in tension (3). Pulley faults (Eccentric rim or groove), variations in belt profile, or non-homogenous belt material can change the effective diameter of the pulley. Any variation in the effective radius of the belt changes belt tension and belt velocity. These changes cause variations in bearing load and rototational velocity of the pulley .

Important parameters when the belt is not moving include the fundamental frequency of belt, velocity of the transverse wave on the belt , length of the belt span between pulleys, and velocity of the vibrating belt span. Axially moving belt tension changes both static and dynamic components and causes flexural vibrations (4). The variations in static tensile forces and sporadic changes that cause the sidebands of the fundamental frequencies are considered in an analytical model. Inertia of pulley and bending stiffness of the belt are not included in the model.

4.NOISE SOURCES

Belt drives may lead to both torsional and rectilinear forced vibrations. Any change in belt radius causes variations in belt tension and belt velocity that can change bearing load and the rotational velocity of the pulley. When the belt drive system is started, the tensile forces deviate and fluctuations appear that are dependent on the features of mechanical system. Vibration spectra show that the origins of the peak frequencies are related to natural frequency of the belt span and rotational frequencies of the pulley. Sidebands in the spectrum depend on variatoin in tensile forces around the static values. Table -1 illustrate all the causes of noise that effect noise emissions of electrical motor when the case of clothes washer is considered.

Inital tensioning	$2\times f_f$ Hz
Variation of dynamic loading	$2\times f_f$ Hz
Irregularities on the belt and pulley surfaces	$2\times f_f$ Hz
Eccentricity	$2\times f_f$ Hz
Transfer ratio	$2\times f_f$ Hz
External and centrifugal forces	$2\times f_f$ Hz
Damping, low modulus, fluctuating tensile forces	$2\times f_f$ Hz
Variation of tension and belt velocity	$2\times f_f$ Hz
Change of effective pulley diameter and pulley velocity	$2\times f_f$ Hz
Belt stiffness	$2\times f_f$ Hz
Power transmission	$2\times f_f$ Hz
Drive motor suspension	$2\times f_f$ Hz

Table-1, Causes that effect the noise emissions of electrical motor in clothes washer. f_f is the belt fundamental frequency of the belt span.

The modes of transverse vibration of a running belt are closely associated with the modes of vibrating string. However, their frequency and form differ because the vibrating medium is moving longitudinally. The transverse vibration belts can usually be excited by the pulley run out, which changes the tension and by belt joints.

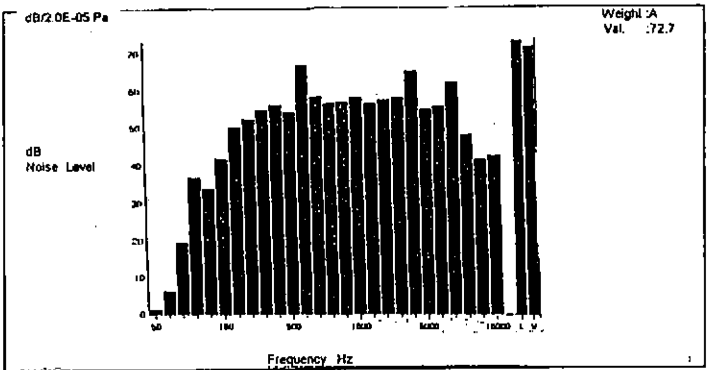

Figure- 1-Overall A weighted sound power level when the static tension of the belt is adjusted to 80 Hz

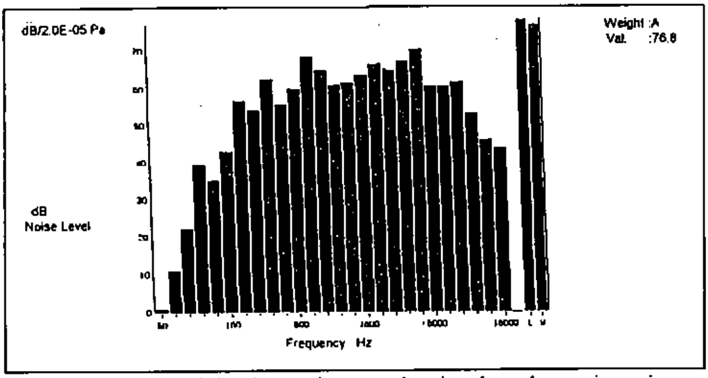

Figure-2-Overall A weighted sound power level when the static tenison of the belt is adjusted to 100 Hz

5.MEASUREMENTS

Figures 3 and 4 illustrate the noise radiation on the surface of hemispere when the clothes washer was lotated to the midst of the field. In order to figure out the effects tension forces on the noise emissions, belt tensioning was adjusted to 80 Hz and 100 Hz respectively. Figures 6 and 7 illustrate the vibration spectrums obtained on the front bearing housing of electrical motor at the same conditions.

The tension of the belts are measured by using a hand held tension tester. This tester apart from contact type mechanical sensors that assses tension by pressing on the belt, measure natural frequency of first mode of free transverse vibration of the belt.

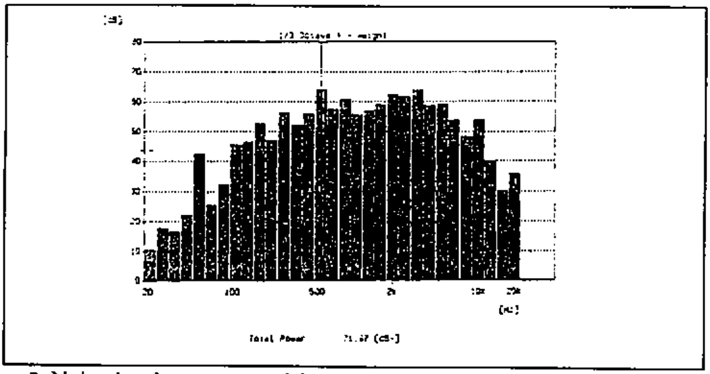

Figure-3 Noise level spectrum . Measurement is performed by using the sound intensity when the belt tensioning is adjusted to 80 Hz.

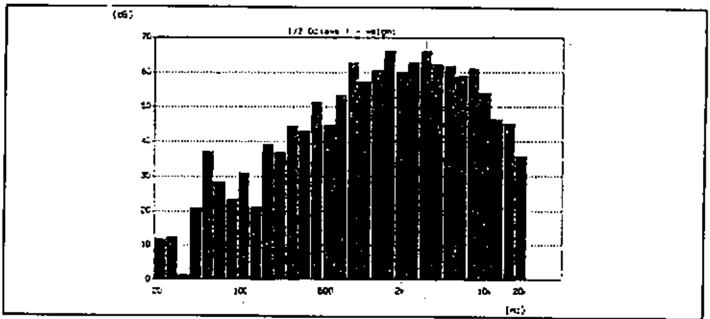

Figure-4 Noise level spectrum. Measurement is performed by using the sound intensity when the belt tensioning is adjusted to 100 Hz.

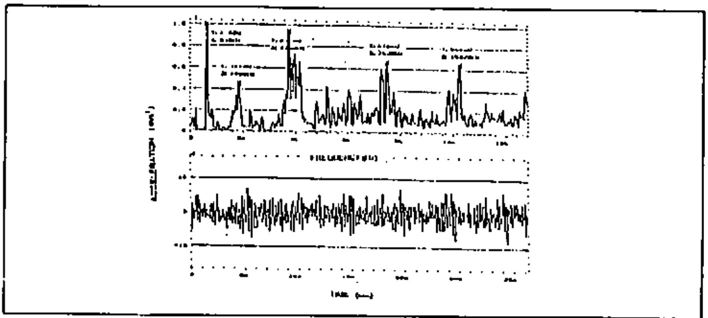

Figure-5 Change of vibration signal both in time and frequency domain on the stator when the static tension is adjusted to 80 Hz

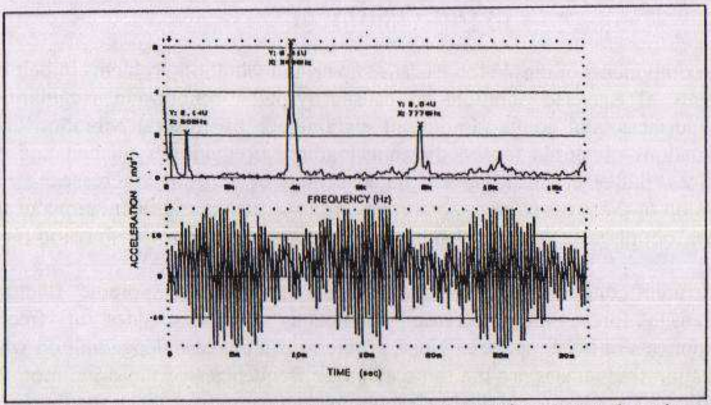

Figure-6, Change of vibration signal both in time and frequency domain on the stator when the static tension is adjusted to 100 Hz

There are two other ways to measure small amplitude of vibration. First by using microphone output that can be located within the nearfield of the belt driven system. Microphone output, then can be fed to frequency analyzer in order to have frequency of vibration, when the belt is excited with gentle tap of screw. Tapping the belt excites all modes of vibration, but higher modes can decay faster than fundamental, leaving a clean sinusodial output. The second method is to sense small amplitudes of vibration by proximity transducer. The amplitude of vibrations stay around 0.1 mm and can not effect value of belt tension.

6.EFFECTS OF TENSION FORCES

The tensile forces that act on the belt driven system include both static and dynamic components (5). Static components, include tension before operation, steady state power transmission, and belt speed. Dynamic components include irregularities on the surfaces of the belt and pulley eccentricity and runout, and dynamic loading on the mechanical system (6). Forces vary as a periodic function of pulley rotation and can be represented in Fourier series. The fundamental frequency of the fluctuating tension and the magnitude of the dynamic tensile forces are considered. When the transverse vibrations of the belt couple with axial deformation, dynamic tensile forces fluctuate.

The complete equation of motion of a transversely vibrating belt span includes inertia, damping, coriolis forces, centrifugal forces, restoring forces, and external forces per unit length of span (7). In this study, the inertia of the pulley and bending stiffness are neglected. The revised equation of motion of the belt span depends on the sporadic changes in tension (8). The components of the peak frequencies due to natural frequencies, harmonics of the pulley, rotating frequency and sidebands were the most important considerations (9).

7.CONCLUSION

The components of tensile forces cause noise and vibration problems in belt driven systems. Transverse vibrations are caused by pulley runout and irregularities on belt surfaces and joints. Important parameters of flexural vibration include fluctuations of tensile forces, dynamic loading, irregularities on belt and pulley surfaces, pulley eccentricity, and initial setting of tension. Increases in noise emission of the drive motor also correspond to variation and fluctuations of tensile forces, out of balance forces, length of belt span, and power transmission ratios.

The studies conducted on the clothes washer indicated that sporadic fluctuations in tensile forces may increase significantly the amplitudes of frequency components of noise spectra. Noise problems can increase depending on whether excitation frequencies are the same as mode frequencies of the drive motors and machines. Transverse and flexural vibrations can increase at twice the fundamental frequency.

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