Analysis and simulation of the oscillations in a Pulley-Ribbed Belt System.

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July 23, 2019

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Abstract— This paper presents the analysis and computer simulation of the rotational and transverse oscillations present in a circular motion transmission system through the relationship of pulley-ribbed belt, widely used in the industrial robots. The studied system is a pulley-ribbed belt coupled with rigid pulleys. The analysis is based in the mathematical model proposed by Randall S. Beikmann. The analytical methods considers: (i) the geometric characteristics, (ii) the behavior in permanent status and (iii) the dynamical response of the system. Dynamic analysis of this system is complex because: (i) it has coupled rotational and transverse vibration modes in a non-linear form, and (ii) includes a circular motion transmission system acceleration-deceleration profile. The proposed analysis allows to determine a priori the frequency, the phase shift and the oscillation amplitude of a section of the ribbed belt excited by any forced velocity profile.

Keywords: Pulley-Ribbed Belt System, transverse modes, rotational modes, Dynamic analysis of a Pulley-Ribbed Belt System.

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Introduction— The rotational motion transmission system based on pulley-ribbed belt coupling, is a flexible coupling mechanical system with sliding elements, used widely in industrial robotics, because of the advantages with respect to other types of mechanical couplings. Although it has been used since more than forty years to transmit mechanical energy through a circular movement, this system still presents important challenges in: (i) formal mathematical analysis, (ii) computer aided design and (iii) new applications not yet studied.

Circular motion transmission systems must operate reliably with minimal noise and vibration. The problems that normally arise are the resonance, the noise and fatigue [1]. Since 1969 the belts in "v" have been replaced by ribbed belt and tensioners in transmissions systems. These systems use multichannel ribbed belts, to reduce flexion and damper stiffness. Ribbed type transmissions are reliable, reduce the tension of the belt and the generation of friction heat when operating near the constant tension of the belt [2].

The use of pulley-ribbed belt system reduces noise and vibration levels. There is a great interest in the full understanding of the dynamic and static behavior of this nonlinear mechanical system. Effective tools for the model have been developed over several years and predict its response. In all belt with fixed pulleys of transmission systems, rotational and vibration transverse modes occur [3].

In rotational modes accessories rotate on their axes and belt sections act as axial springs. In the transverse modes sections of belt vibrate transversally, similar to a stretched rope.

Both degrade the performance of the system. Rotational modes of sheaves induce dynamic tension in the belt, fatigue in components, dynamic reactions, fatigue in the elements and noise in the structure. The transverse vibrations also induce dynamic tensions and can radiate directly noise.

Rotational modes in a ribbed belt have been studied during the last twenty five years. In [4] rotational modes are studied as a stationary system including the support and the belt damping. In [9] a dynamic tensioner coupled with a transmission system is studied. In [5] is presented the study of a ribbed belt with a dynamic tensor under the rapid acceleration of the machine. Finally, in [6] the transient response of a similar system [5] is examined with rapid acceleration of the engine, to predict the sliding of the belt. However, all these studies ignore the transverse dynamics of the belt.

In this work an appropriated mathematical model is proposed. This model must be at the same time: (i) as simple as possible and (ii) reflect accurately the static and dynamic behavior of the system. The document is organized as follows: in section number one the mathematical model is proposed. The computational method used in the static analysis is described in section two. Results and the respective analysis are presented in section three. Finally some conclusions are presented.

References

[1] Doyle, E., and Hornung, K. G., 1969. Lateral Vibration of V-Belts. ASME Paper No. 69-VIBR-24.

[2] Casidy R. L., Fan, S. K. MacDonald R. S., and Samson, W. F., 1979. Serpentine-Extended Life Accesory Drive. SAE Paper No. 790699.

[3] Houser, D. R., and Oliver, L., 1975. Vibration of V- Belt Drives Excited by Lateral and Torsional Inputs. Proc. Fourth World Congress on the Theory of Mechanisms, Vol. 4, Newcastle Upon Tyne-England, Sep. 8-13.

[4] Gaspar, R. G. S., and Hawker, L. E., 1989, Resonance Frequency Prediction of Automotive Serpentine Belt Drive Systems By Computer Modeling. Proc. ASME Conf. Mechanical Vibration and Noise, DE Vol. 18-12, pp. 13-16.

[5] Barker, C. R., Oliver, L. R., and Breig, W. F., 1991. Dynamic Analisys of Belt Drive Tension Forces During Rapid Engine Acceleration. SAE Paper No. 910687

[6] Hwang, S. J., Perkins, N. C., Ulsoy, A. G., and Meckstroth, R., 1994. Rotational Response and Slip Prediction of Serpentine Belt Drive Systems. ASME Journal of Vibration and Acoustics. Vol. 116, No. 1, pp. 71-78.

[7] Beikmann, R. S., 1992. Static and Dynamic Behavior of Serpentine Belt Drive Systems: Theory and Experiment. Ph. D. Dissertation, The University of Michigan, Ann Arbor, MI.

[8] Wickert, J. A., and Mote, C. D. Jr., 1998. Current Research on the Vibration and Stability of Axially-Moving Materials. Shock and Vibration Digest, Vol. 20, No. 5, May, pp. 3-13.

[9] Hawker, L. E., 1991. A Vibration Analysis of Automotive Serpentine Accessory Drive Systems. Ph. D. dissertation, University of Windsor, Ontario, Canada.

[10] Li, Xiao-jun, Chen, Li-qun, 2008. Modal Analysis of Coupled Vibration of Belt Drive Systems. Applied Mathematics and Mechanics, 29(1), 9-13.

[11] Beikmann, R.S., Perkins, N. C., and Ulsoy, A.G., 1991. Equilibrium and Analysis of Automotive Serpentine Belt Drive Systems Under Steady State Operating Conditions. Proccedings of the ASME Midwestern Mechanics Conference, Rolla, MO, October 6-8, pp. 533-534.