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Design and Analysis of Mechanism for Dynamic Characterization of Power Transmission System

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Abstract : *Power transmission systems are being widely used for transmission of power between two members. Once a particular transmission system is realized it needs to be qualified before its course of application. As part of this intended torque of the transmission systems needs to be measured and tested. Conventional means of dynamic characterization of power transmission system has got the demerit of energy consumption to a greater extent. Because of this more effort is to be put in terms of power for the sake of testing the intended system. Great need exists for a system which consumes less or ideally no energy while performing test. This project aims at evolution of a novel technique for evaluating the torque transmitting capability of power transmission systems without consuming more energy. To start with all the subsystems of the proposed design will be identified and each of them will be designed for getting their dimensions. Then these dimensional models will be transformed to solid model of the assembled configuration using 3D CAD software. Functional load which will be experienced by this design will be assessed and structural analysis will be carried out against these loads using Finite Element Method (FEM) in commercial FEA software i.e. ANSYS.*
Keywords: *Power transmission, Mechanical link, Rotating shafts, FEM, CAD*

I. Introduction

Power transmission system is normally used to mechanically link two or more rotating shafts, most often parallel. These systems may be used as a source of motion, to transmit power efficiently, or to track relative movement as shown in Fig. 1.

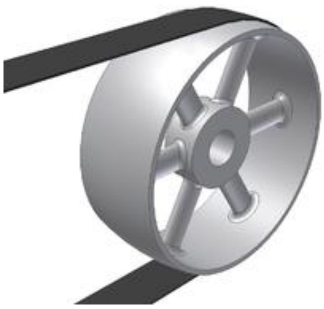


Fig. 1.Typical power transmission system.

The moment a transmission system is ready it needs to be qualified before put in normal use. This demands to measure and test intended torque of the transmission systems. Conventional means of dynamic characterization of power transmission system has got the demerit of energy consumption to a greater extent. Because of this more effort is to be put in terms of power for the sake of testing the intended system. Great need exists for a system which consumes less or ideally no energy while performing test. Hence it is decided to explore the availability of such system.

A model of dry friction tensioner in a belt-pulley system considering transverse belt vibration is developed, and the influence of the dry friction on the system dynamics is examined. The discretized formulation is divided into a linear subsystem including linear coordinates and a nonlinear subsystem addressing tensioner arm vibration, which reduces the dimension of the iteration matrices when employing the harmonic balance method [1]. A test bench for the evaluation of the energy efficiency of belt drives is presented. The construction and measurement procedure is discussed with respect to measurement accuracy and reproducibility. Also the impact of additional parameters such as belt tension and misalignment can be analyzed[2]. The paper work basically emphasis on the case pertaining to a belt drive, which is used for flour mill operation. The operation of a flour mill is explained as under. A high capacity flour mill demand power approximately 27 Hp for crushing the grain into required form of flour. A bag of grain wheat is poured into the hopper. The wheat grain continuously inserted through cavity to the crushing stone. Generally this crushing stone gets power through belt drive. Due to crushing action of the stone the wheat grain then converted into desired flour [3]. A comprehensive selection of belt type and construction from industrial and agricultural applications is extensively tested and compared for idling loss and power transmission efficiency. Data is documented for Vee, joined-V, V-ribbed, and synchronous belt types and for cogged, plain, and laminated V-belt constructions. The level of energy savings achieved by the replacement of plain-base wrapped V-belts with cogged V-belts is emphasized[4]. Belt drives are used in numerous applications to transmit power between various machine elements. Some common applications include transportation vehicles, household appliances such as vacuum cleaners and washing machines, and devices driven by electric motors such as power machine tools. Belt drives come in various types, such as: at belts, serpentine belt drives, v-belt drives and push belts for continuously variable transmissions [5]. The thesis presents the design and analysis of a Twin Tensioner for a Belt-driven Integrated Starter-generator (B-ISG) system. The B-ISG is an emerging hybrid transmission closely resembling conventional serpentine belt drives. Models of the B-ISG system's geometric properties and dynamic and static states are derived and simulated [6]. Belt drives have been serving the industry for a long period. Certain features of belt drives such as slippage, tension fluctuations, and sliding of the belt on the pulleys lead to highly nonlinear deformation, large rigid body motion, dynamical contact with sticking and slipping zones and cyclic tension. The performance of motion control for belt drives is important in many industrial fields and is affected by these factors [7]. As it was mentioned earlier, all the existing systems are useful for measuring tension alone and no system is available which can evaluate the torque transmitting capability. Further conventional means of dynamic characterization of power transmission system has got the demerit of energy consumption to a greater extent. Because of this more effort is to be put in terms of power for the sake of testing the intended system. Great need exists for a system which consumes less energy while performing test.

This work aims at evolution of a technique for evaluating torque transmitting capability of power transmission systems without consuming more energy by adopting novel means.

II. Design Philosophy

Proposed design will enable the designer to recover part of energy required to test the transmission system. Proposed design with all subsystems is shown in Fig. 2.

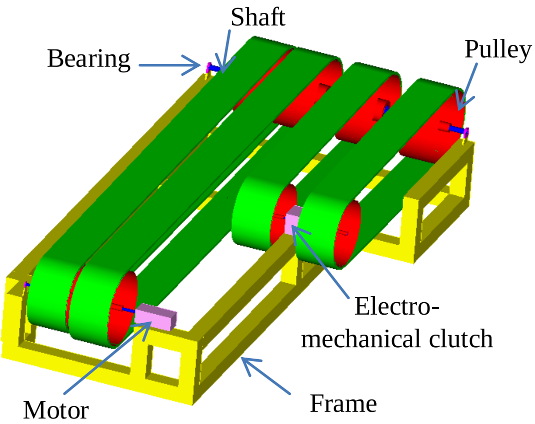


Fig. 2. Proposed design

Two pulleys which are of different size will be mounted on common shaft which will be attached to motor shaft. Other set of pulleys will be mounted on another common shaft. It is to be noted that as two pulleys are of different size, two drives will have differential speed and the same speed will be conveyed to either side of electro-mechanical clutch. With no electrical excitation to the clutch, the input shaft & output shaft freely rotate. With electrical excitation, the input shaft becomes coupled to the output shaft. Motor feeds the specified torque to drive which will be fed to magnetic clutch as input wile the load torque is less than the output torque, the clutch drives without slip. Load torque will be increased gradually and when it crosses output torque, the clutch will slip smoothly at the torque level set by the coil input current as input torque and load torque values are known, value of load torque at which clutch slips will be taken as output torque. This output torque will be compared with input torque to evaluate the torque transmitting ability of the power transmission system.

From the above figure the following components are identified for which detailed design is carried out.

- Electro-mechanical clutch
- Pulley
- Motor
- Shaft
- Bearing
- Frame

III. Design Configuration

Following design inputs are considered.

- Type of power transmission: Flat drive
- Allowable stress = 100 MPa

Outcome of design is summarized in Table 1.

Table 1: Design parameters

Sl. No.	Design Parameter	Value
Electro-mechanical clutch		
1.	Torque range	6 to 400 N-m
2.	Maximum rpm	1800
Pulley		
1.	Diameter	1.4 m
2.	Width	750 mm
3.	Number of arms	6
Motor		
1.	Torque	400 N-m
2.	Rpm	1800
Shaft		
1.	Diameter	100 mm
2.	Length	5 m
Bearing		
1.	Outer diameter	180 mm
2.	Width	34 mm
3.	Designation	6220-2Z

IV. Structural Analysis

Structural analysis of trailer system is carried out using Finite Element Method (FEM) in ANSYS software in order to assess the design adequacy against the self-weight with 1g acceleration. Maximum Von Misses stress thus obtained is compared with allowable stress and obtained the available factor of safety.

Criteria

Static analysis

- Minimum available factor of safety should be more than the desired factor of safety (1.5).

Modal analysis

- System should not have any frequency at 27 Hz and 30 Hz associated with operating speeds of engine i.e. 1607 rpm and 1800 rpm.

To begin with geometric model of the intended design is built in 3D CAD software from its dimensions. However load bearing members are only considered for analysis. Then geometric model is converted into FE model by discretizing shafts and frame with beam (BEAM4) elements and all other subsystems like pulley, motor, clutch, etc with mass (MASS21) elements as all subsystems are made of steel its material properties are considered for the analysis Nodes corresponding to base of the frame constrained for all DOF.

FE model with boundary conditions is shown in Fig. 3.

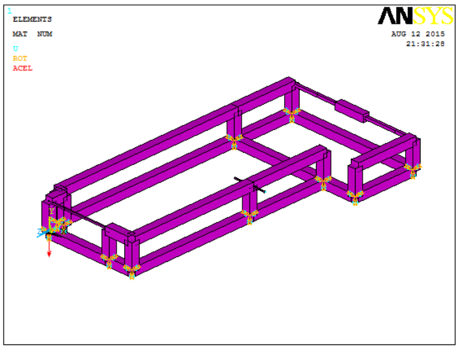


Fig. 3: FE model

Static analysis was carried out and the correspondingVon Misses stress plot is shown in Fig. 4.

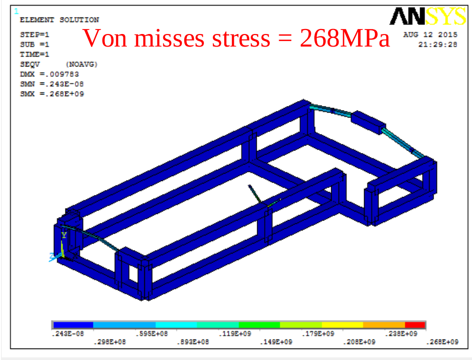
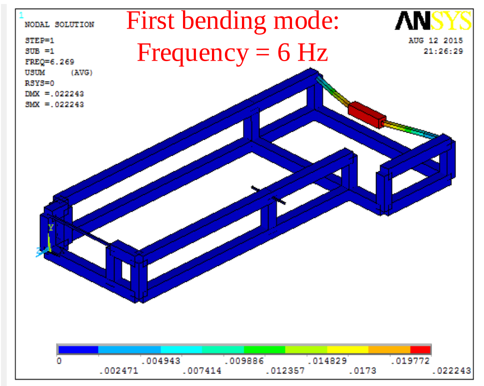


Fig.4. Stress plot

Then dynamic (Modal) analysis was also carried out. Modal analysis is the study of the dynamic properties of structures under vibration excitation. In structural engineering, modal analysis uses a structure's overall mass and stiffness to find the various periods that it will naturally resonate at. A modal analysis calculates the undamped natural modes of a system. These modes are given in decreasing order of period and are numbered starting from 1. Mode shape plot corresponding to first natural frequency is shown in Fig. 5.



V. Results And Discussion

Outcome of analyses is summarized in Table 2.

Table 2: Analyses results

Sl. No.	Result	Maximum Value	Allowable value	Factor of safety
Static				
1.	Von Misses stress	268 M Pa	660MPa	2.46
Modal				
2.	Natural frequencies	6,10,17,25,39,44 Hz	27 Hz & 30 Hz (Critical)	--

- Maximum Von Misses stress is observed to be 268MPa.
- Available factor of safety is observed to be 2.46 which is more than minimum desired factor of safety (1.5). Hence the design is safe.
- Test system does not have any frequency at 27 Hz and 30 Hz associated with operating speeds of engine i.e. 1607 rpm and 1800 rpm.
- Hence system doesn't experience resonance.

VI. Conclusion

This work aimed at evolution of a technique for evaluating torque transmitting capability of power transmission systems without consuming more energy by adopting novel means. Proposed design will enable the designer to recover part of energy required to test the transmission system. Available factor of safety is observed to be (2.46) by comparing the maximum stress with that of allowable stress (Yield) of steel material i.e. 660 MPa. As the available factor of safety (2.46) is more than minimum desired factor of safety (1.5) the design is safe. Test system does not have any frequency at 27 Hz and 30 Hz associated with operating speeds of engine i.e. 1607 rpm and 1800 rpm.

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