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A REVIEW ON DESIGN, DEVELOPMENT, TESTING AND OPTIMIZATION OF THOMPSON CV JOINT WITH BRASS AND PHOSPHOR BRONZE AS TRUNNION MATERIAL

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ABSTRACT

In direct mechanical drive system, coupling of various driven elements is required. Majority of drive elements like gear reducers, lead screws and host of other components are driven by shaft that is supported by multiple bearings. Due to rigidity of coupling, slight misalignments will be there between a driving and driven shaft. The function of power transmission coupling is transmitting torque from driving shaft to drive shaft along with shaft misalignment. Misalignment in shaft may results into unwanted strains on shaft bearings causing to wear out. Few conventional solutions are available for misalignment problems like Oldham's coupling and universal joint which have several limitations. These limitations can be overcome with Thompson constant velocity (CV) coupling which offers features like minimizing side loads, higher misalignment capabilities, more operating speeds, improved efficiency of transmission and many more. This paper presents review on constant velocity joints/couplings design and optimization. In this paper the research work of various researchers related to transmission couplings and constant velocity joints is reviewed.

Keywords: Thompson constant velocity joint, Optimization & design, Constant velocity couplings, Transmission Coupling.

INTRODUCTION

The basic function of a power transmission coupling is to transmit torque from an input/driving shaft to an output/driven shaft at a specified shaft speed and, if required along with shaft misalignment also. Shaft misalignment is the result of many factors including installation errors and tolerance variations. Shaft misalignment can increase the axial and radial forces exerted on the coupling. In misaligned shaft applications, undesirable side loads are usually introduced by the coupling. These side loads result from dynamic coupling behavior, frictional loads and loads caused by flexing or compressing coupling components. The undesirable results include:

- Torsional or angular velocity vibrations which reduces system accuracy.
- Excessive forces and heat on system bearings which reduce machine life.
- Increased system vibration and noise which adversely affects equipment operation.

Conventional solutions for transmission coupling along misalignment like Oldham's coupling & Universal joints have several limitations in terms of maximum angular offset permissibility, efficiency of transmission, bearing life, operating speed etc.

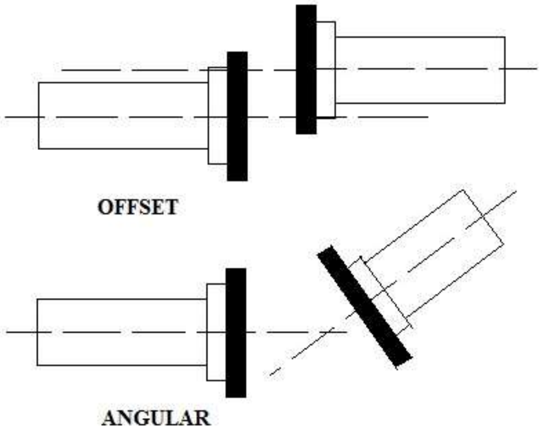

Figure1: Types of Misalignments

As performance of engines of automobile are enhancing, full proof power transmission coupling is required for which constant velocity joints can be used such as Thompson constant velocity joint. The main features of the Thompson CV coupling are; minimizing or even eliminating side loads, higher shaft misalignment capabilities and greater drive accuracy. The Thompson Constant velocity joint is an ideal solution to the power transmission between shafts at angle of 30 degree to 65 degrees, the only wearing parts being the parasitic bearing joints. The Thompson constant velocity joint ensures that no fluctuating loads are transmitted across to the output shaft. Constant velocity joints offers,

- True constant velocity high angle shaft coupling through all angles of rotation and articulation.
- Maximum working articulation angle of 15 degrees. Coupling does provide a stroke limiting device to prevent angle being exceeded.
- Nominal high torque rating.
- Maximum peak torque rating for short duration periods.
- Maximum speed of rotation 2,500 rpm.
- Generation and excitation of vibration forces is minimised through patented spherical dividing mechanism providing true constant velocity rotation.
- True point centricity enabling pivoting applications to be fully realized.
- High torsional and radial rigidity. Axial length compensation can be achieved by appropriate splined shaft connections or similar if required.
- High axial rigidity feature allows for axial load transfer. E.g. transfer of thrust loads.
- Combine two constant velocity couplings with a splined connecting shaft to provide axial and radial misalignment applications up to 15 degree angles.
- No requirement for phased or angular connecting flanges as with traditional UJ technology.
- Minimal heat generation from roller bearing components unlike traditional constant velocity joint technology thus providing highest efficiency and maximum service life at high speeds and full angle.

LITERATURE REVIEW

[1] Ian Watson, B. Gangadhara Prusty and John Olsen have stated in research paper titled “Conceptual design optimization of a constant-velocity coupling” that The Thompson Coupling operates using the robust double Cardan mechanism. Constant velocity and determinate linkage kinematics are maintained by a spherical pantograph. This mechanism forms an extra loop attached to the intermediate shaft in the double Cardan linkage, and consequently constrains this shaft to bisect the axis of input and output. Closed-form expressions for its motion and the rotation of the double Cardan joint are derived by consideration of spherical linkage kinematics. These expressions are then used to drive basic conceptual design optimization, whose goal is to reduce induced driveline vibration. The findings of this optimization are discussed with respect to the current design of the Thompson joint. Improvements in induced driveline vibration are possible, subject to the satisfaction of other coupling design criteria.

[2] Chul-Hee Lee and Andreas A. Polycarpou has proposed in their research paper titled “A phenomenological friction model of tripod constant velocity (CV) joints” that constant velocity (CV) joints have been favored for automotive applications, compared to universal joints, due to their superiority of constant velocity torque transfer and plunging capability. High speed and sport utility vehicles with large joint articulation angles, demand lower plunging friction inside their CV joints to meet noise and vibration requirements, thus requiring a more thorough understanding of their internal friction characteristics. A phenomenological CV joint friction model was developed to model the friction behavior of tripod CV joints by using an instrumented CV joint friction apparatus with tripod-type joint assemblies. Experiments were conducted under different operating conditions of oscillatory speeds, CV joint articulation angles, lubrication, and torque. The experimental data and physical parameters were used to develop a physics-based phenomenological CV joint dynamic friction model. It was found that the proposed friction model captures the experimental data well, and the model was used to predict the external generated axial force, which is the main source of force that causes vehicle vibration problems.

[3] Majid Yaghoubi, Seyed Saeid Mohtasebi, Ali Jafary and Hamid Khaleghi in their research work titled “Design, manufacture and evaluation of a new and simple mechanism for transmission of power between intersecting shafts up to 135 degrees (Persian Joint)” has introduced a new mechanism which is designed for the transmission of power between two intersecting shafts. The mechanism consists of one drive shaft and one driven shaft, six guide arms, and three connecting arms. The intersecting angle between the input shaft and the output shaft can be varied up to 135° while the velocity ratio between the two shafts remains constant. The research also includes a kinematic analysis and a simulation using Visual NASTRAN, Autodesk Inventor Dynamic and COSMOS Motion. The software showed that this mechanism can transmit constant velocity ratios at all angles between two shafts. By comparing the graphs of analytical analysis and simulation analysis, validity of equations was proved.

[4] Katsumi Watanabe and Takashi Matsuura in their research paper titled “Kinematic Analyses of Rzeppa Constant Velocity Joint by Means of Bilaterally Symmetrical Circular-Arc-Bar Joint” has proposed that mechanism whose elements are bilaterally symmetrical with respect to the bisecting plane of driving and driven rotational axes is able to use as the constant velocity joint. The constant velocity joint that is composed of input and output shafts, two circular-arc elements and the frame is a most elementary joint. The closed loop equation of the circular-arc-bar joint whose kinematic constants are any values is deduced in the form of the quadratic equation of the output angle. The Rzeppa constant velocity joint is composed of several sets of the ball and two circular-arc grooves. A relative motion of the ball to two circular-arc grooves is analyzed and the output angle error in a practical use which contains sinusoidal fluctuations with periods 2π, $2\pi/3$, and $2\pi/6$ is simulated by the circular-arc-bar constant velocity joint.

[5] Tae-Wan Ku, Lee-Ho Kim and Beom-Soo Kang in their research work titled “Multi-stage cold forging and experimental investigation for the outer race of constant velocity joints” has explored that as an important load-supporting automobile part that transmits torque between the transmission and the driven wheel, the outer race of CV (constant velocity) joints with six inner ball grooves has been conventionally produced by the multi-stage warm forging processes, which involves several operations including forward extrusion, upsetting, backward extrusions, sizing and necking, as well as additional machining. There is still no choice but to produce the complex shaped components other than by this warm forging process. As an alternative, multi-stage cold forging process is presented to replace these traditional warm forging. The multi-stage cold forging procedure is first considered through a process assessment regarding the traditional multi-stage warm forging one. Then, the process is simplified and redesigned as one operation to produce the forged outer race and the backward extrusions of the traditional process, and the sizing and necking are also combined into a single sizing-necking process.

MATERIALS AND METHODS

Design and Analysis:

With reference to literature available, an optimization study can be done of Thompson constant velocity joint with brass and phosphor bronze as trunnion material. The study involves design of Thompson CV joint which includes following steps,

- Kinematic design of linkage set to deliver power transmission for angular offset (30 to 65 degree angular offset on either side of input shaft).
- System Design and geometrical derivations of the control linkage for position of coupling to achieve vibration free angular offset to the desired output in angular direction of input shaft.
- Selection and design of central link, linkage geometry for minimum space occupation and minimum inertia to make drive compact, light weight and precise.
- Selection of motor drive transmission.
- Mechanical design: This part includes the design and development of linkages, section dimensions for strength criterion. The linkage section dimension will be calculated using theoretical derivation using appropriate theories of failure and the dimensions thus arrived to, will be checked and validated using ANSYS.
- The following components of the drive will be designed using ANSYS.
  - Input hub
  - Central link
  - GE (spherical bearing bush) for central link
  - Intermittent angular offset linkage set.

Manufacturing:

Suitable manufacturing methods will be employed to fabricate the components and then assemble the test set–up. The fabrication will be carried out as per layout shown in figure 1.

Experimental analysis & Testing:

Experimental analysis and testing of drive will include

- Testing of drive to derive performance characteristics.
- To check the validity of experimental results with theoretical results.
- To carry out comparative study of experimental and analytical results to decide the optimization of number of rollers and cam profile.
- Interpretation of results will be done to suggest the modifications to improve the design of central link profile, angular link geometry, number of angular links for desired speed ratio outputs.

Experimental Validation:

The following figure shows the layout and design of test rig for Thompson constant velocity joint.

The test rig includes following mail components as:

- Thompson constant velocity joint
- Variable speed motor
- Reduction pulley
- Bearing housing
- Brake dynamometer pulley

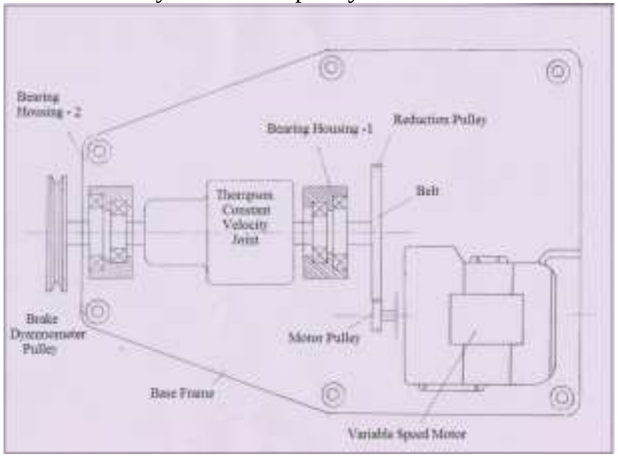

Figure 2: Layout & Design of Thompson CV joint test rig

Thompson CV joint test rig will be constructed for experimental analysis as follows:

- Testing of drive to derive performance characteristics
  - ➢ Torque Vs Speed
  - ➢ Power Vs Speed
  - ➢ Efficiency Vs Speed
  - ➢ Maximum angular offset and performance at maximum angular offset.
- To check the validity of experimental results with theoretical results.
- To carry out comparative study of experimental and analytical results to decide the optimization of number of rollers and cam profile.
- Interpretation of results will be done to suggest the modifications to improve the design of central link profile, angular link geometry, number of angular links for desired speed ratio outputs.

SUMMARY

As transmission is very important part of any mechanical drive system, efficiency of the system is based on the efficiency of the transmission system. A transmission coupling is most important component which defines efficiency of transmission system & hence detail study of transmission coupling is required to get coupling with no losses. Thompson constant velocity joint is considered as solution to the limitations of conventional solutions for transmission along misaligned shafts. Apart from Thompson constant velocity joint, there are several constant velocity joints. Optimization of Thompson constant velocity coupling will certainly give the results which can be used for further studies in the field of transmission. Also optimization study of TCVJ will provide guidelines for further research and applicability of the constant velocity joints.

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