A Review Paper on Design, Optimization and Testing of Special Purpose Worm and Worm Wheel Gearbox for Butterfly Valve Operation

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Abstract— The aim of this project is to design, manufacture and validate design of gearbox parts using both analytical and experimental techniques. Standard gearboxes are available in the market. But sometimes required output torque is in between standard output torque values. In this case higher standard output torque gearboxes are used which are uneconomical, heavy as well as large in size. Also quarter turn worm and worm wheel gearboxes for opening and closing of butterfly valves gives better performance, because butterfly valves rotate only in 90°. This paper represents design, optimization and testing of special purpose worm and worm wheel gearbox for butterfly valve operation.

Key words: Worm, Worm Wheel, Butterfly Valve, Torque, Finite Element Analysis, Optimization

I. INTRODUCTION

Power transmission devices use a gear arrangement in an enclosed housing to transfer energy, increase torque and reduce speed from one device to another. Gearboxes are used in many applications including machine tools, processing and other industrial equipments, conveyors, mixers, extruders, wind turbines, winches, cranes, pipelines, agricultural equipments and many other rotary motion power transmission applications that require changes to torque and speed requirements.

For operating medium and large size valves, gearboxes are used. Worm gears are cylindrical gears with a spiral thread that drive mating worm wheels in high speed reduction applications. They operate on non-intersecting perpendicular axes. Worm can rotate worm wheel but worm wheel cannot rotate worm. It means worm gear drives are single direction. Worm and worm wheel gearboxes are used for operating butterfly valves, plug valves etc.

II. LITERATURE REVIEW

F.L. Litvin et. al.[1] have proposed the solution to basic problems of design, generation and simulation of meshing and contact of hybrid worm and worm wheel gear box. Software is developed for simulation of meshing and contact of misaligned worm and worm wheel gear drive.

Faydor L. Litvin et. al.[2] have demonstrated an advanced design of the worm gear drive to obtain transmission errors as a parabolic one. The transmission errors of a gear drive are reduced due to elastic deformation of contacting tooth surfaces. Klingelnberg's worm gear drive is based on application of a disk that is provided by a surface of a circular cone. A computer program is developed to evaluate tooth contact analysis for testing of the bearing contact and transmission errors for unloaded and loaded gear drives.

B. Karpuschewski et. al.[3] have addressed power consumption of the manufacturing processes itself have to be further optimized. They analyzed processes like continuous generating gear grinding, discontinuous profile grinding and honing of tooth flanks performs better than conventional processes. They conclude final manufacturing step is steadily decreasing for the benefit of hard finishing by abrasive processes.

T.J. Yeh et. al.[4] have analyzed the mathematical model and a robust control of a worm gear drive. Also they proposed static and dynamic models of worm and worm wheel regarding coefficient of friction. They developed better model than PID controller.

C. Heinzel et. al.[5] have illustrated application of elastic bonded grinding wheels for surface finish operation of gears. A discontinuous profile grinding process has very high potential to develop a high surface finish with high shape accuracy. They studied impact of machining parameters as well as grinding wheel specifications on surface finishing of worm and worm wheel gearbox.

Padmanabhan et. al.[6] have presented analytical work on optimal solution of worm and worm wheel gear box design problem with ACO. In this mathematical calculations objective function of gearbox design is power, weight, efficiency and center distance. Constraints of the objective function are bending stress, compressive stress. They use Ant Colony Optimization to get highest efficiency of worm and worm wheel gear drive.

Y.K. Mogal et. al.[7] have developed reliable gear pair design with help of Genetic Algorithm. We can take minimization of volume, center distance between worm and worm wheel and deflection of worm etc as objective function of design. Gear ratio, face width, pitch circle diameters of worm and worm wheel are variables.

Claudiu-Ioan Boanta et al.[8] have presented results on performance of the same type gear reducer mounted the same but the combination of hardened steel materials (worm) - steel heat treatment improvements (worm wheel).They analyzed thermal limit of the reducers equipped with worm face gear with asymmetric flanks is about 50% higher than the worm face gear with cylindrical worm symmetrical flanks. Also thermal limit for driving on the convex side for both couples is more favorable material situation.

Sagar B Ghodake et. al.[9] have illustrated Wear debris analysis, Vibration Analysis, Acoustic Emission Analysis, and Temperature analysis techniques for fault detection in worm and worm wheel gearbox. To detect fault in Worm gearbox, they gives detailed study of Wear Debris analysis. This paper aims to give insight on various diagnosis methods to detect the presence of naturally developed faults within worm gearboxes.

III. CONCLUDING REMARKS OF LITERATURE REVIEW

Concluding remarks regarding literature review are as follows-

1) Literature review helps to get knowledge of how to design and optimize butterfly valve actuation using worm and worm wheel gearbox.
2) With the help of literature review detailed study of working of worm and worm wheel gearbox can be done.
3) New techniques are to be studied which are found in analytical work of worm and worm wheel gearbox.

IV. PROBLEM DEFINITION

It is decided to design, optimize, manufacture and test special purpose worm and worm wheel gear box for butterfly valve operation.

V. PROPOSED WORK

A. Objectives

1) To study literature review.
2) To design and optimize gear pair.
3) To design remaining parts of gearbox.
4) To manufacture gearbox components and assemble the gearbox.
5) To test the gearbox performance for required torque.

B. Scope of work

For effective operation of butterfly valve of required torque, generated through designed worm and worm wheel gearbox is the aim of project work. It may be suitable for few butterfly valves of different sizes.

Gearbox is designed according to design data books. Worm and worm wheel gearbox has constant ratio of disc speed of butterfly valve to input shaft rotation. Constant output torque is obtained through entire movement of butterfly valve disc.

C. Methodology

Methodologies with respect to objectives given above are as follows-

1) To design and optimize gear pair-

Worm and worm wheel of the gearbox will be designed according to the procedure mentioned in design data books. In this section, Study of Optimization of worm and worm wheel (components of gearbox) is given. Software available for analysis of worm and worm wheel is Finite Element Analysis. Also various optimization methods are to be used to check whether proposed design will function or not.

2) To design remaining parts of gearbox-

Remaining components of the worm and worm wheel gearbox will be designed according to the procedure mentioned in design data books. Design and analysis of gearbox enclosure will be done with the help of available CAD and 3D software's. Other bought out items will be directly purchased from market.

3) To manufacture gearbox components and assemble the gearbox-

As per above individually designed parts, gearbox will be manufactured. All the gearbox parts will be assembled with fool proofing.

4) To test gearbox performance for required torque –

Actual testing will be carried out on valve. In this test, gearbox will be mounted on valve. The valve will be subjected to its rated pressure. Operation of butterfly valve will takes place. The torque supplied by the gearbox will be measured. Then the gearbox will be disassembled as well as checked for any cracks or failure. Experimental setup of worm gearbox is as shown in figure1.

a) Fluid flow

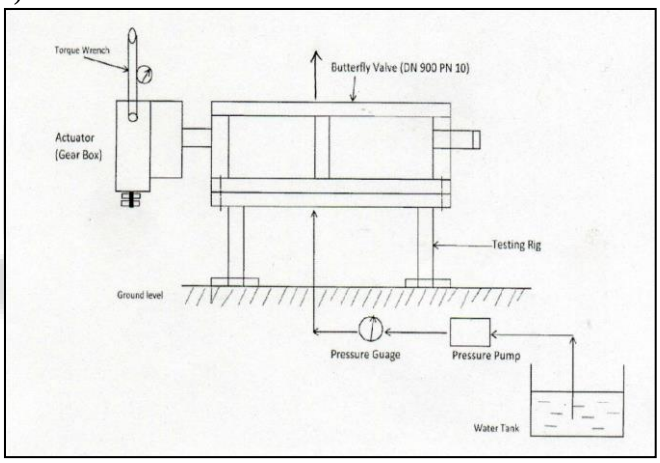

Fig. 1: Proposed Experimental Setup

Open and closed position butterfly valves when a fluid flow through it is as shown in figure 2. Front view and top view of butterfly valve with gearbox is as shown in figure2. in both conditions- when valve is in closed position and also when valve is in open position as shown in figure2.

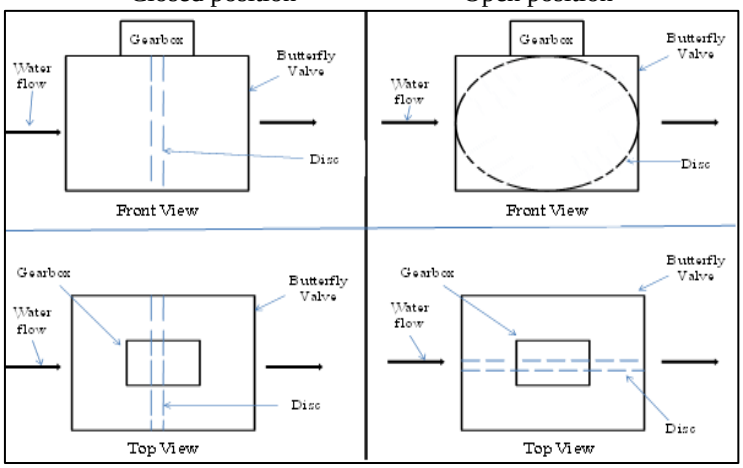

Fig. 2: Closed and open position butterfly valve

5) To validate analytical and experimental results-
Analytical and experimental results will be compared. Hence conclusion will be the brief description of detailed study of analytical and experimental work.

a) Flow Chart of Methodology

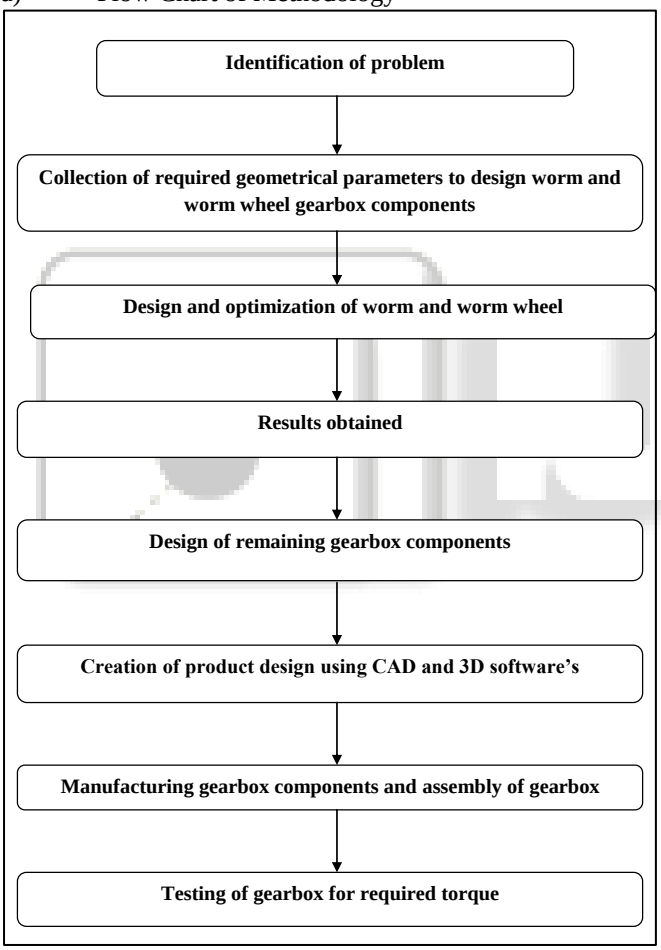

Fig. 4: Flow chart of methodology.

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