Session 1547

Wheel Bearing Tester
Project: Machine Elements to Design Engineering

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Introduction

In order to be competitive in the job market engineering graduates are required to have understanding in fundamentals as well as training in the state of the art technology along with realistic design experience. This demand can be satisfied by introducing real world applications in design courses, where students can use theories as well as training in solving problems.

In this project students were presented with a problem of an axle manufacturing company who was experiencing accumulated repairs with a machine designed to test wheel bearings. This project involves designing a testing equipment that will overcome some of the shortcomings of the current tester and use standard hubs and shafts to mount the sample bearings. The bearing tester will use wheel assembly under conditions of actual use. The wheel speed and loads simulated by the tester is matched to highway conditions. By simulating the speed and forces until failure, the quality and reliability of the bearings are assured.

During the project students used the fundamentals they learned in statics, strength of materials, and introductory machine elements courses. This involved free body diagrams, load calculations, and reactions under highway conditions. The test fixture shaft sizing involved bending and torsional moment diagrams, shaft deflection, stress concentration, and combined stress calculation. In designing the testing equipment students were involved in the calculations and parts selections of bearings, belts, and pulleys. Two cylinders are used to simulate load under road conditions. In designing the hydraulic system students had the opportunity to use their background in hydraulics including pumps, actuators, valves, and controls that they learned in a basic fluid power course.

The bearing tester consists of a number of control elements such as vibration analyzer, load cells, temperature and pressure sensors. Based on their calculations and catalog search required parts were selected. In the selection process students contacted vendors and discussed parts specification and costs. The project ends with instructions and operational procedure of the testing device.

Design

The wheel bearing tester (fig. 1) involve the design of a fixture shaft for mounting test specimens and a hydraulic system for simulating radial and axial loads. The system instrumentation include feedback and control of temperature and pressure, monitoring of the generated heat and a vibration analyzer. The design is based on the defined test parameters identical to road conditions. The heaviest axle to be tested is rated at 10,000 pounds radial loads and 7,000 pounds side load. The side load could be in either direction. The average highway speed is assumed to be 70 mph. Simply by changing the pulleys or installing a DC drive motor the tester can be adopted for a variety of speeds. The tester life is expected to be 10 years.

Test Fixture

The test fixture consist of a large diameter shaft with a hub mounted on one end and a pulley on the other. The fixture is provided with a special bearing hub and spindle assembly, because the production drum is not designed to withstand the continued testing forces for the desired life of the testing equipment. With the given load capacities in mind a shaft size is assumed and a free body diagram is developed for the first trial calculation. Based on load calculation a set of spherical roller bearing is specified for the fixture shaft. The shaft is mounted on pillow blocks with a set of spherical roller bearings designed for heavy radial as well as axial loads. The fixture shaft is belt driven by a motor mounted under the test bench. This involve calculation for the required horsepower and selection of electric motors, belts and pulleys. The life of the fixture shaft bearings are calculated with the given loads and road conditions.

Load Application

Two hydraulic cylinders mounted under the test bench are used to provide the required radial and axial load. This load is transmitted through an arm that is designed to carry a 10,000 pounds radial and a 7,000 pounds axial load. Finite element analysis is done with several arm dimensions. Accordingly the inside arm radius is determined. The finite element analysis shows a maximum of 37,250 psi with a life expectancy of 10 million cycles. According to the cyclic loading curve the material selected is SAE 4130 normalized and annealed steel. Load cells are installed in line with the cylinders for the feedback of the bearing forces to the controller. The tester is programmed to test for a variety of load capacities.

Hydraulic System

The design requires a background in hydraulics including engineering calculation and parts selection of pumps, cylinders, valves, fittings etc. Thus students get a first hand knowledge in catalogs search, item selection and specification, and costs involved. Due to the magnitude of the axial and radial loads the cylinder and rod sizes need extra attention. Rods need to be checked for column buckling which involves Eulers’s equation. Based on calculation two three and half inch cylinders with one inch rod diameter was specified. The selected system pack is Vickers RPP3-DO3 model DGMRI-3-PP-FW-40. The system includes a 1.5 gpm pump with a pressure rating of 1,000 psi driven by a 2 hp, 115/230 V, 3600 rpm motor.

Control System

The control system considered for the bearing tester center around a programmable logic controller. PLC monitors the shaft speed, once the desired speed is achieved the loading process begins. A vibration sensor on the spindle is used to determine the bearing failure. Calibration of this sensor need to be made for each type of hub assembly tested to accurately account for any background noise. A temperature sensor can be used to detect the bearing failure caused by excessive heat generation.

Engineering Calculations

Major machine elements used in this design are a fixture shaft, fixture shaft bearings, belts, pulleys, hydraulic cylinders for load simulation, and load arm to transmit axial and radial loads on specimen bearings. Typical calculations were made for these parts followed by catalog search and parts specification.

Fixture Shaft:

Combined torsional and bending stresses were considered for the shaft calculation. First equivalent torque and equivalent bending moment was obtained and the diameter was determined once with the equivalent torque and once with the equivalent bending moment. The larger of the two values was used for the final design.

Belts and Pulleys:

Among other considerations the horsepower requirement include start up torque, friction losses and bearing losses. A service factor of 1.3 was considered for the final power calculation and a 5 hp. motor was specified. Belt calculation involved speed ratio, center distance, friction angle, histogram, power correction factor, and belt tension. A 3VX belt from Gates was specified.

Operating Procedure

A schematic drawing of the wheel bearing tester is shown in figure 1 including a listing of the major elements and specifications. Test parameters normally include speed, radial and axial forces, cornering force, cooling requirements, and lubrication. Test engineer is responsible for the selection of specimen bearings and appropriate production spindles, axles, and drums or in the case of prototype testing, custom fixturing for the machine. Prior to each test the characteristics for bearing failure such as maximum temperature, vibration limits, size of spalling areas, etc. are defined.

Following is the basic operating procedure for the bearing tester:

- Assemble the bearings in the drum
- Insert the spindle assembly into the drum with bearings and specified lubrication
- Select a drum adapter if necessary
- Mount the drum and spindle assembly on the face of the bearing tester shaft and insert bolts through the back of the drum to secure it.
- Clamp the load arm to the spindle assembly and slide it in or out to align the lower hydraulic cylinder.
- Check the set-up. Make certain that all bolts are tight and the bearings spin freely.
- Hook up the sensors and limit switches.
- Start motor slowly checking that the drum is true and the bearings run smoothly.
- If everything is running smoothly, apply required force.
- After machine has warmed up for a few minutes, fine tune the adjustments if necessary.
- After the bearing has failed all required data are recorded. Then the drum and spindle assembly is removed from the machine and disassembled for inspection.

Conclusion

This type of design project with hands on training is a very effective art of teaching. This has its foundation in the class room materials. The routine type of problem solving lacks in motivation. Students get the feeling of accomplishment when they see the finished project and more so with the final product. The author will be glad to share his experience and information with engineering instructors interested in this type of project.

References

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2. M. F. Spotts, "Design of Machine Elements", Prentice Hall
3. SKF Product Service Guide, 190-710
4. Gates V-Belt Drive Design Manual 14995-A
5. Grainger Catalog #387
6. Schrader Bellows Catalog
7. Hydraulics plus Electronics Systems and Components-Vickers Catalog #400
8. Sensotec Catalog

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Professor Kundu received Dipl. Ing. degree from Technical University, W. Berlin, Germany and MS degree from University of California, Berkeley both in Mechanical Engineering. Currently, he is an Associate Professor in the Department of Mechanical Engineering Technology of Purdue University in Elkhart, Indiana. Mr. Kundu has worked over ten years in the industry mostly in research and development.

Major parts and specifications:

1) Fixture Shaft - 1045 cold rolled steel
2) Bearing -pulley side - SKF # 24044 CCK3O/W33
3) Bearings - wheel side - SKF #24044 CCK3O/W33
4) Hub and bearing assembly to be tested
5) Production axle used for testing
6) Arm Cap
7) Arm
8) Motor Pulley - 3V Super HC Type QD 6.9”dia.
9) Belt - Gates 3VX 600
10) Shaft Pulley - 3V Super HC Type QD 8.0” dia.
11) Horizontal Cylinder - Schrader Bellows #SB0106 PL-2 Series
12) Vertical Cylinder - Schrader Bellows # SBOlO6 PL-2 Series
13) Load Cell - Sensotec Model 41 rated at 30,000 lbs.
14) Motor - GE 3-Phase 5hp 1155 rpm NEMA 215T frame

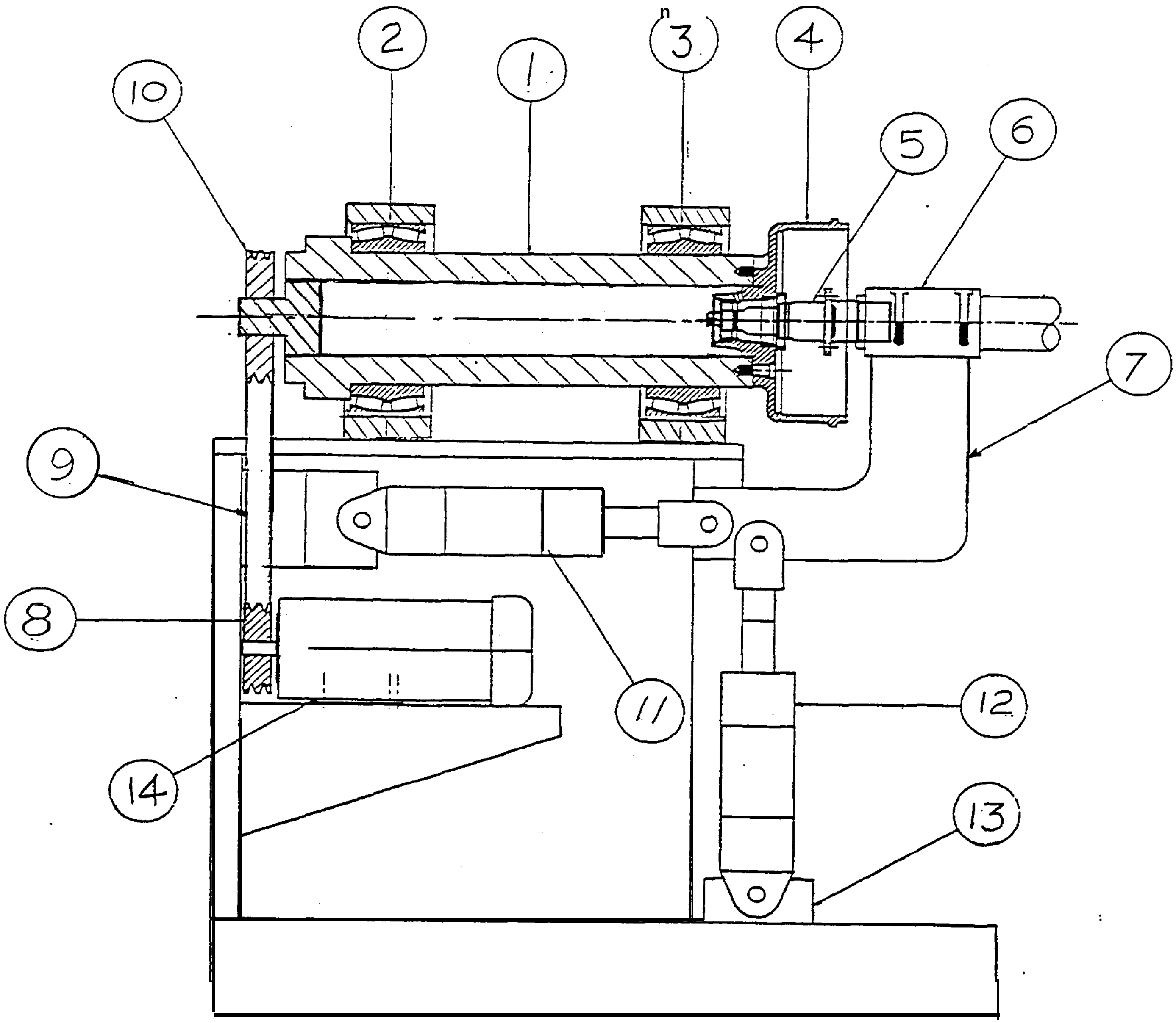

FIG. I