NFPA Gift Project Progress Report

Performance Analysis of Hydraulic System Components for a Fluid Power Curriculum and Capstone Design Project

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Whenever feasible most design practices recommend use of standard components that meet established product and process performance criteria. If characteristics of a component at specified operating conditions are not available, use of such a component in a new design or a new application would require experimental definition of those characteristics prior to component selection. With the assistance of NFPA Gift Fund, a laboratory setup was developed to study performance of hydraulic pumps and motors for senior design projects. Selection of pump and motor based on the study resulted in significant improvement in performance of hydraulic systems being designed.

A modular test bench consisting of a Power module, Circuit module, Application module, Conditioning module and proper instrumentation for measurement of characteristics data was designed and built for use in student projects and demonstrations in a fluid mechanics class. The Power module allows measurement of pressure and flow rate of a pump at different pump speed and input power. The Application module can be used along with the Power module to vary hydraulic motor load. The two modules were assembled in a test bench and used to study performance characteristics of a set of hydraulic pumps and motors under consideration in two design projects. The goal of the projects was to design a hydraulic system to transfer a rider's manual power from a bicycle pedal to the bicycle wheel in the most efficient manner. The test bench utilized a battery-powered DC electric motor driving the pump by a synchronous belt and pulley system. The pump speed is controlled by using a variable speed DC motor controller. A friction clutch was developed to control the hydraulic motor load by varying applied torque on the motor shaft, thus simulating operation of a bike in a level track as well as hilly terrain. The torque is applied by using weights in a lever arm which pushes the friction clutch against an aluminum drum connected to the motor shaft. The frictional force of the clutch and leverage ratio of the arm determines the torque applied to the motor shaft.

In the design projects, selected pump and motor were installed in the test bench and desired load is applied to the hydraulic motor through the friction clutch. At different operating conditions, the pump input power is determined by using voltage, current and rated efficiency of the electric motor, while the output power is calculated from the pressure and flow rate. At the same time corresponding friction torque and hydraulic motor velocity (rpm) provides output power of the motor. The efficiency characteristics of each set of hydraulic pump and motor, at various loading conditions, were further used for analysis of system performance. Each hydraulic motor and pump was rated in terms of their efficiency at the operating conditions encountered in the bicycle's hydraulic systems thus providing the rationale for selection of specific pump and motor. Since design and fabrication of special pump and motor for this project was not realistic, without such testing, students would need to go through a prolonged trial-and-error process in order to select the most suitable pump and motor set. Selection of pump and motor through such lab test allowed the design team to focus on the other crucial aspects of the design. The testing system is now available to other student design teams.

Currently, in collaboration with a local fluid power company, a larger system is being developed for further study of performance characteristics of other hydraulic system components. The Power and Application modules will be integrated with a new Circuit module and Conditioning module to create a more complete hydraulic test system and study its performance characteristics. The overall system will be used in a junior level fluid power class and in other student projects, starting in Fall 2010 semester.