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Tractor hydraulic power data acquisition system

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ABSTRACT

Tractor hydraulic power is used on a wide range of agricultural implements; however, the availability of operational hydraulic data at points other than full engine throttle position is limited. Operators could utilize this hydraulic data to maximize field efficiency and minimize machinery costs when determining suitable machinery for field operations. A field usable hydraulic test apparatus capable of measuring tractor hydraulic pressure and flow rate data was developed. The goal of this study was to determine if a hydraulic flow and pressure measurement device could be installed on the rear of a tractor to provide implement hydraulic power consumption at different hydraulic hose orientations. The measurement system installed allowed hydraulic lines from the tractor hydraulic remote ports to be attached to the flowmeter and pressure sensors at multiple angles of 0°, 45°, and 90° in different configuration layouts. Tests were performed at different flows and pressures for each hose configuration. The pressures were compared across configurations to a base line reading from a hydraulic pressure and flow rate measurement apparatus used by the Nebraska Tractor Test Laboratory (NTTL). Pressure deviations from the base line were small and ranged between 10.56 kPa and 32.2 kPa. Flow rate differences (<167 mL min^{-1}) were determined to be negligible (<0.5%). Calculated power differences (<33 W) were less than 1% full scale power measured. This small power loss suggested that using the hydraulic measurement apparatus developed as part of this study would enable accurate measurements of tractor hydraulic power provided to implements regardless of hydraulic hose bend angles.

1. Introduction

The Organization for Economic Co-Operation and Development (OECD) Code 2 (OECD, 2016) test requirements for tractor hydraulic power only stipulate flow and pressure to be recorded at maximum engine speed. However, operators utilize hydraulic power at various engine speeds, from low idle to maximum speed, necessitating the determination of hydraulic power usage over a range of engine speeds. When instrumenting an agricultural tractor to obtain actual operational data from the hydraulic system, mounting locations and space requirements are the most important design aspects of the system. Tractor hydraulic systems must endure the stress of intermittent use and frequent on/off cycling and are widely used for powering implements where mechanical systems are too complex or electrical components are cumbersome for the necessary power requirement. Manufacturers install the entire hydraulic system in a relatively small space due to the power take-off shaft (PTO), drawbar, and 3-point hitch in the same area at the rear of the tractor (Fig. 1).

Determining hydraulic power available for agricultural implements require few sensors. Implement hydraulic power consumption can be determined by measuring the pressure and the flow rate of the fluid delivered to the implement. Researchers have the option of installing a flowmeter between the main hydraulic pump and the hydraulic remote ports, or as an extension between the remote ports and the connected implement. A recommendation by the flow meter manufacturer (Flo-tech Activa F6206-AVB-NN, Racine Federated Inc., Racine, Wisc.) states that a minimum upstream conductor length of 10 times the flowmeter port diameter and a minimum downstream conductor length of 5 times the flowmeter port diameter is required (Flo-Tech, 2015). This is typically done to create laminar fluid flow in the measurement region to maximize the accuracy of flow rate readings. In a case where space is the limiting factor, having the recommended lengths of straight tubing in line with the flowmeter can be difficult. Unable to create a straight-lined hydraulic measurement apparatus on the rear of a tractor would introduce tubing bends on the apparatus. Tubing bends are similar to fittings and valves in that they create local energy losses (Larock et al., 2000). A previous study on agricultural tractor performance used a Hydrotecknik RE6 flow turbine installed in the main pump line

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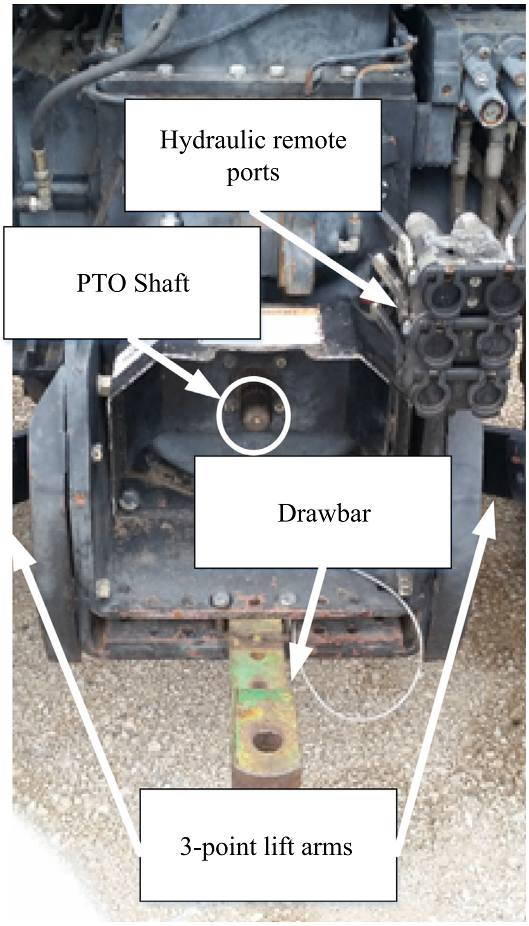

Fig. 1. Typical locations at the rear of an agricultural tractor for delivery of power to implements.

upstream of the hydraulic remote block at the rear of the tractor (Burgun et al., 2013). This approach limited the hydraulic implement power measurement accuracy by inducing the hydraulic systems efficiencies into the measured data. The author's approach also modified a tractor part which would require that the modification be undone after the project has ceased, to ensure the tractor hydraulic system functions to manufacturer specifications after the tractor returned to normal use.

This research presents a different approach for determining the hydraulic power delivered to an implement by a tractor. The goal of this new approach was to minimize modifications to the tractor hydraulic system and allow the hydraulic power test system to mount on any tractor using standard ISO 5675 hydraulic couplers. Guidelines outlined in OECD Code 2 were used for temperature and measurement tolerances. Installing a straight-line flow meter system on the rear of the tractor will be a challenge as the hydraulic test apparatus needed to allow the 3-point lift arms and the PTO shaft to function unobstructed, without adding excessive length to implement hydraulic hoses (Fig. 2).

2. Objectives

The goal of this project was to develop a portable hydraulic pressure and flow measurement system. This system would attach to the remote hydraulic ports at the rear of the tractor with minimal modifications to determine the hydraulic power delivered to an attached implement. Specific objectives of the current research work were to:

- Determine which of the six tubing configurations used with a portable hydraulic pressure and flow measurement system could be mounted without modification to a tractor and provide adjusted pressure and flow rate measurements with differences less than 2% and 0.5%, respectively.
- Determine whether the hydraulic power obtained using the portable hydraulic pressure and flow measurement system had differences less than 1% of full scale hydraulic measurement bench power measurement.

3. Materials and methods

A system to test the effect of tube bend configurations on pressure and flow rate measurement accuracy was established. This system was comprised of an agricultural tractor connected with an in-line Device Under Test (DUT) and a bench hydraulic pressure and flow rate measurement test apparatus.

3.1. Measuring devices

Sensors with analog voltage signal output were selected to allow the most flexibility and compatibility with data acquisition system (DAQ) hardware, and ease of expansion into a higher order system. Following this guideline, a turbine style flowmeter (Flo-tech Activa F6206-AVB-NN, Racine Federated Inc., Racine, Wisc.) which had the capability of measuring 15–303 L min^{-1} within ±1.0% of the flow reading with an analog output of 0 V DC to 5 V DC was selected to work with the higher flow capacities of hydraulic systems on newer agricultural tractors. The turbine flowmeter measures the flow rate and hence only one sensor was required in the system loop. Additional benefits of the sensor design were: supplementary internal flow straighteners on both sides of the turbine and the availability of ports for installation of temperature and pressure sensors (Flo-Tech, 2015). Analog pressure sensors are widely available in a variety of pressure ranges. The selected pressure sensor (Omega Px309, Omega Engineering Inc.) was capable of measuring 0–34.5 MPa (0–5000 psi) with an analog voltage output range of 0 V DC to 5 V DC (Omega, 2014). The data acquisition interface between the sensor assembly and the data acquisition computer was a National Instruments (NI) myDAQ (National Instruments Corporation, Austin, Texas). NI myDAQ was a portable DAQ with multiple analog/digital inputs and outputs. A single 16-bit analog-to-digital converter was used to sample both analog channels with voltages of 0–5 V DC and sampling rates of 50 Hz per channel. Both analog channels were utilized as differential voltages, one channel for the pressure sensor and the other for the flowmeter on the DUT.

The flow meter ports (25.4 mm diameter) with SAE 16 threads, were connected to a series of reducers and adapters decreasing the dimensions from SAE 16 to 19 mm National Pipe Thread (NPT), and to 19 mm (¾ in.) medium pressure hydraulic hose (NRP-Jones Hydra-Lite II, 21.4 MPa maximum pressure rating) with ISO 5675 quick-couplers. The sensors and hoses were mounted to a plywood board using U-bolts as illustrated in Fig. 3a and b. The hose ends were able to be mounted with the hose in a straight-line configuration (0°), 45°, 90°, or any combination of these bends (Fig. 3a and b) using the plywood board and U-bolts; however, not all combinations were used for testing. The six tubing configurations selected were: 0-0, 45-0, 45-45, 90-0, 90-45, and 90-90. The reciprocal tubing configurations: 0-45, 0-90, 45-90 were assumed unnecessary due to symmetry. When organizing the tubing configurations as the main treatments, an orientation was selected in which the inlet and outlet were parallel but have opposite direction. For example, the male inlet coupler of the DUT would insert into the rear-facing tractor remote port and the female outlet coupler of the DUT would have the same rear-facing direction as the