Agricultural tractor performance levels. Comparison between hydraulic power test carried out according to OECD Codes and ISO 789 Part 10

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Abstract

Agricultural and forestry tractors are equipped with quick-action hydraulic couplers designed to operate rotary tools or drive apparatus with linear movements used on agricultural machinery pulled, pushed or carried by tractors. Higher available oil flow and the rising number of connections for fluid power present on modern agricultural and forestry tractors increase interest in evaluation methodology of hydraulic system performance.

As a results of the last review of ISO Standards some of the representatives of National Designated Authorities members of the OECD Standard Codes for the Official Testing of Agricultural and Forestry Tractors proposed to adopt ISO 789-10 test procedures in OECD Codes instead of the procedures stated in them, in order to improve harmonisation between Standards.

In order to verify the differences in measurements the Italian tractor testing station of Torino set up a test equipment able to verify the hydraulic system performance in accordance with OECD Codes and ISO 789-10 Standard.

The paper provides brief information on the instruments and components used to set up the testing apparatus and briefly explain the procedural differences between Standards. Using the equipment and the procedures described two comparative test were performed on two agricultural tractors. The results are shown and commented.

Introduction

Agricultural and forestry tractors are equipped of quick-action hydraulic couplers designed to operate different implements used for agricultural and forestry works. Power supplied by engine can be easy conveyed by high pressure fluid in pipes to rotary tools or to cylinders drive apparatus with linear movements on agricultural machinery pulled, pushed or carried by tractors.

Higher available oil flow and the rising number of connections for fluid power present on modern agricultural and forestry tractors increase interest in determination of the performance of their hydraulic system.

Hydraulic power provided by agricultural and forestry tractors can be evaluated using the methodology included in a specific section of OECD Code 1 and 2 or following the procedure contained in ISO 789-10.

As a results of the last review of ISO Standards some of the representatives of National Designated Authorities members of the OECD Standard Codes for the Official Testing of Agricultural and Forestry Tractors proposed to adopt ISO 789-10 test procedures in OECD Code 1 and 2, in order to improve harmonisation between Standards.

Being involved in tractor testing according to OECD Codes, the Institute for Agricultural Mechanisation has been appointed to make comparative tests using both type of measurements to point out differences in figures given, costs and time required for execution.

Method

The quantities to be measured when the hydraulic power test is carried out according to the OECD Codes and ISO 789-10 are shown in table 1.

The procedure to carry out measurements of hydraulic power according to OECD Codes and ISO 789-10 requires the use of the components listed in table 2.

The starting conditions of both two testing procedures required that hydraulic fluid is classified according to ISO 3448 and that fluid temperature in the hydraulic reservoir shall be 65°C±5°C.

The OECD Codes state that throttle or governor control lever must be adjusted to maximum power while the ISO 789-10 requires that the throttle or governor control lever shall be adjusted to maintain the rated engine speed.

The OECD Codes needs just one testing line to carried out all sampling. It is made up of a temperature transducer, a pressure gauge at the outlet of the tractor, a flow meter and an adjustable restrictor valve.

OECD Code 1 and 2	ISO 789 – Part 10
0. Temperature in the oil tank	
1. The pump delivery at the minimum pressure 2. The pressure sustained by the open relief valve 3. The hydraulic power available at the service coupling, at the flow corresponding to a hydraulic pressure equivalent to 90% of the actual relief valve pressure 4. The maximum hydraulic power available at the service coupling and the corresponding oil flow and hydraulic pressure	1. The minimum available steady state differential hydraulic pressure 2. The maximum steady state hydraulic pressure 3. The maximum loop return pressure 4. The maximum available hydraulic power 5. The maximum sump return pressure 6. The peak pressure

Table 1. quantities to be measured in accordance with the OECD Codes and ISO 789-10

OECD Code 1 and 2	ISO 789 – Part 10
1. a gauge to measure the temperature of the oil in the tank; 2. a gauge measuring the pressure of the oil exiting the tractor; 3. an adjustable restrictor valve to vary the flow rate; 4. a flow meter to measure the oil flow; 5. a recording system to sample data with plotter to draw the curve defined as flow rate versus pressure or if a continuous recording equipment is not used, a system to draw the curve after reading all data on display	1. a gauge to measure the temperature of the oil in the tank; 2. two gauges measuring respectively the pressure of the oil exiting and the oil reentering the tractor; 3. an adjustable restrictor valve to vary the flow rate; 4. a flow meter to measure the oil flow; 5. a double acting cylinder without a cushion 6. a continuous recording equipment is preferable to sample all data to be used to evaluate all quantities and to draw the curve defined as flow rate versus pressure

Table 2. Components necessary to carry out measurements in accordance with OECD Codes and ISO 789-10

The ISO 789-10 requires two different lines to carry out the complete test. First line used to perform the available hydraulic pressure test and maximum available hydraulic power test is the same of the OECD test line previously described with the addiction of a pressure gauge at the inlet of the tractor.
For the available hydraulic pressure test it is necessary to place the hose test assembly with male couplers at the female couplers of the tractor, which provides the hydraulic supply of the tractor implements. Measurement of maximum steady hydraulic pressure, maximum pressure at the male coupler returning flow to the hydraulic system and minimum available steady differential hydraulic pressure should be carried out. The male coupler that controls the oil reentering the tractor has to be taken off and to be connected with the port where the oil flow return directly to the reservoir. Measurement of maximum pressure at the male coupler and at the port returning flow to the reservoir should be carried out.
ISO 789-10 maximum available hydraulic power test has a similar procedure to the one used in OECD Codes but the calculation of the power should be done using the differential pressure coming from the two pressure gauges.
ISO 789-10 requires the measurement of the peak pressure. A second testing line with a double acting cylinder and 2 pressure gauges placed on the outlet and inlet of the tractor coupler should be used. A total of 15 complete cycles where it is fully extended and retracted should be performed, measuring the maximum pressure.
All above-mentioned components are connected, by a conditioning system, to a computer equipped with an acquisition data board and running a software for test-station management developed in a graphical programming language (called G) typical of the LabVIEW environment. It is essentially consisting of two sections. First section, the initialization one, in which the operator can personalize the standard settings of the test (acquisition frequency, acceptable tolerances in system stabilization, etc.) and can also select characteristic parameters of the tractor under test (category, type and viscosity index of hydraulic fluid, engine speed, etc.). A second operating section in which test-station regulations and data acquisition procedures are actually executed.
Both sections are designed to give remarkable importance to the graphical user interface behind which all technological and algorithmical aspects are hidden. These measures are carried out by a digital acquisition card (National Instruments AT-MIO16H) which has sixteen analog input and two analog output channels with sixteen bit resolution in range [-10V, +10V] and two counter - timer inputs. The input/output operations are performed at a frequency of 10 Hz on the basis of measurements obtained filtering and decimating samples acquired at 1 kHz. The operational conditions are reached by digital control loops that carry out pressure or flow rate stabilization driving the adjustable restrictor valve. These loops are designed to work with different kinds of tractors. The operator can always monitor all those not directly controlled variables that must remain stable

within tolerances like requested by standards. At the end of test session, measurements are suitably processed and a report is automatically produced.
The additional equipment necessary to carry out test in accordance with ISO 789-10 results in an increase of about 2500 $ of the cost of a the testing rig built to perform OECD Codes test only.
Using the equipment and the procedures described previously comparative tests on agricultural tractor hydraulic system were performed on two tractors with the characteristics shown in table 3.

	Tractor 1	Tractor 2
Tractor		
Rated engine speed	2300 rpm	2500 rpm
High idle engine speed	2500 rpm	2700 rpm
Pto power at rated engine speed	47.5 kW	50.5 kW
Category (as specified in ISO 730-1)	1	2
Hydraulic system		
System	Open center	Open center
Pump type	gear	gear
Flow, as stated by the tractor manufacturer	63.8 l/min	60 l/min
Pressure relief valve, as stated by the tractor manufacturer	19.0 MPa	19.0 MPa
Numbers of couple pairs	2	2
Hydraulic oil		
Viscosity	11.50 cST	11.50 cST
Classification	API GL 4	API GL 4
Temperature during test in the reservoir	60-70 °C	60-70 °C

Table 3. Tractors used in comparative tests

Results
The figures resulting from comparative tests on hydraulic system are contained in table 4 and 5.
The differences in comparable figures obtained in hydraulic power test with oil routed through 1 couple pair performed according OECD Codes and ISO 789-10 standard are summarized in table 6.

Chapter		Measured trait	ISO versus OECD data	
OECD	ISO 798-10		Tractor 1	Tractor 2
2.2.2.2.1	6.1.2.1	Maximum pressure (MPa)	99.5%	99.3%
2.2.2.2.2	7.2.1	Maximum flow (l/min)	94.9%	97.9%
2.2.2.2.4	7.2.1	Maximum power (kW)	93.3%	92.5%

Table 6. Tractors used in comparative tests

Poorer results in maximum flow available through 1 couple pair in ISO 789-10 test are mainly caused by the adoption and maintaining the rated engine speed during tests, instead of throttle control lever set to maximum power engine speed in OECD Codes. For this reason and because of the use of differential pressure, as the difference of pressure leaving the tractor couple pair and pressure re-entering to the tractor, the maximum power is lower than that calculated with the OECD method. In the OECD hydraulic power test pressure at the oil tractor outlet is used to determine maximum hydraulic power.
The necessity of keeping the rated engine speed during tests makes ISO 789-10 maximum power test more difficult to execute when tractor are not equipped with automatic engine speed regulator.
ISO 789-10 requires a compulsory hydraulic power test to be carried out using all tractor hydraulic outlets. Differences in results of hydraulic power test performed with oil routed through 1 couple pair and all (2, in tested tractor) couple pairs are shown in table 7.

ISO 798-10 Chapter		Measured trait	ISO 789-10 Power test 2 couple pairs versus 1 couple pairs	
1 couple pair	2 couple pair		Tractor 1	Tractor 2
7.2.1	7.2.2	Maximum flow (l/min)	100.4%	102.3%
7.2.1	7.2.2	Maximum power (kW)	99.4%	95.7%

Table 7. ISO hydraulic power test figures with 2 coupler as percentage of hydraulic power figures with 1 coupler

HYDRAULIC SYSTEM PERFORMANCE THROUGH ONE COUPLE PAIR

Chapter	OECD Codes: Hydraulic power test	Values	Values	ISO 789-10: Hydraulic power at tractor/implement interface	Chapter
2.2.2.2.1	Pressure sustained by the open relief valve (MPa)	22.34	22.25	Maximum pressure (MPa)	6.1.2.1
2.2.2.2.2	Pump delivery rate at minimum pressure (l/min))	63.81	60.59	Maximum available flow from one couple pair (l/min)	7.2.1
2.2.2.2.3	**Hydraulic power at 90% of the actual relief valve pressure setting**				
	Hydraulic power (kW)	9.47			
	Flow rate (l/min)	28.28			
	Pressure (MPa)	20.11			
2.2.2.2.4	**Maximum hydraulic power**			**Maximum available hydraulic power test**	7.2.1
	Maximum power kW)	14.06	13.12	Maximum available hydraulic power (kW)	
	Flow rate (l/min)	51.95	47.87	Flow (l/min)	
	Pressure (MPa)	16.24	16.44	Differential pressure (MPa)	
				Available hydraulic pressure test	6
			30	Standard flow (l/min)	6.1.2.1
			18.19	Maximum differential pressure (MPa)	
			0.07	Maximum loop return pressure (MPa)	
			0.07	Maximum sump return pressure with coupler (MPa)	6.1.2.2
			0.07	Maximum sump return pressure without coupler (MPa)	6.1.2.3
			21.84	Peak pressure (MPa)	6.2

HYDRAULIC SYSTEM PERFORMANCE THROUGH ALL COUPLE PAIRS (2)

Values	ISO 789-10	Chapter
	Maximum available hydraulic power through simultaneous use of all coupler pairs	7.2.2
60.86	Maximum available flow from all couple pairs (l/min)	
13.04	Maximum available hydraulic power (kW)	
47.28	Flow (l/min)	
16.55	Differential pressure (MPa)	

Table 4. Comparative performances on hydraulic system of tractor 1 (category 1)

HYDRAULIC SYSTEM PERFORMANCE THROUGH ONE COUPLE PAIR

Chapter	OECD Codes: Hydraulic power test	Values	Values	ISO 789-10: Hydraulic power at tractor/implement interface	Chapter
2.2.2.2.1	Pressure sustained by the open relief valve (MPa)	21.14	21.00	Maximum pressure (MPa)	6.1.2.1
2.2.2.2.2	Pump delivery rate at minimum pressure (l/min)	56.04	54.86	Maximum available flow from one couple pair (l/min)	7.2.1
2.2.2.2.3	**Hydraulic power at 90% of the actual relief valve pressure setting**				
	Hydraulic power (kW)	9.46			
	Flow rate (l/min)	29.86			
	Pressure (MPa)	19.02			
2.2.2.2.4	**Maximum hydraulic power**			**Maximum available hydraulic power test**	7.2.1
	Maximum power (kW)	11.68	10.81	Maximum available hydraulic power (kW)	
	Flow rate (l/min)	40.25	40.04	Flow (l/min)	
	Pressure (MPa)	17.42	16.20	Differential pressure (MPa)	
				Available hydraulic pressure test	6
			50	Standard flow (l/min)	6.1.2.1
			7.23	Maximum differential pressure (MPa)	
			0.24	Maximum loop return pressure (MPa)	
			0.06	Maximum sump return pressure with coupler (MPa)	6.1.2.2
			0.06	Maximum sump return pressure without coupler (MPa)	6.1.2.3
			21.35	Peak pressure (MPa)	6.2

HYDRAULIC SYSTEM PERFORMANCE THROUGH ALL COUPLE PAIRS (2)

Values	ISO 789-10	Chapter
	Maximum available hydraulic power through simultaneous use of all coupler pairs	7.2.2
56.14	Maximum available flow from all couple pairs (l/min)	
10.35	Maximum available hydraulic power (kW)	
37.41	Flow (l/min)	
16.60	Differential pressure (MPa)	

Table 5. Comparative performances on hydraulic system of tractor 2 (category 2)

In tested tractors there is a slight higher maximum flow with oil passing through 2 couple pairs, with a lower maximum power, than with oil passing through only 1 couple pair.
In ISO 789-10 the available hydraulic pressure test in steady state test is necessary to maintain a standard flow depending on tractor pto power. During the tests described in this document the standard flow was reached and maintained acting on an adjustable restrictor valve, driven by the software running on the computer.
Tested tractors have a PTO power more or less equal and are equipped with a gear pumps with a near maximum flow rate, but they belong to different categories. In the available hydraulic pressure test their behavior is, for this reason, very different.
In maximum available hydraulic pressure test category 1 tractor standard oil flow is 30 l/min, far from maximum available flow rate. For this tractor the maximum loop return pressure is the same as the maximum sump return pressure, with and without coupler.
For category 2 tractor the standard flow to be maintained during the test is 50 l/min, very near to the maximum flow. In this case the maximum loop pressure is higher than maximum sump return pressure, with and without coupler.
For both tractors the presence or absence of the coupler in test with oil reentering directly to the oil reservoir does not cause any difference between maximum sump return pressure with and without coupler. It is plausible to imagine that the difference between the 2 tractors in their maximum loop return pressure is related to the different tractor's standard oil flow rate adopted for available hydraulic pressure test in steady state.
In the ISO 789-10 pressure test maintaining the rated engine speed manually is easier than what happens in ISO 789-10 hydraulic power test described previously. For both tractor, the peak pressure recorded during ISO 789-10 pressure test are lower than maximum pressure.

Conclusion

ISO 789-10 hydraulic power test give lower figures than OECD Codes tests. Moreover maintaining the rated engine speed stable through the test is difficult without automatic speed regulation.
ISO 789-10 hydraulic power test procedure becomes interesting for tractors equipped with hydraulic oil pump able to give a flow rate at minimum pressure grater than 80-100 l/min. These tractors are equipped with more than one couple pair. In this case ISO 789-10 maximum available hydraulic power through all coupler pairs test gives complementary information about tractor performance that OECD Codes do not offer. Unfortunately until now it was not possible to carry out comparative tests on such big tractors to shed light on their hydraulic power behavior under both ISO 789-10 and OECD Codes tests.
ISO 789-10 available hydraulic pressure test in steady state provides information on the efficacy of tractor hydraulic system components. Figures found out in this test seem to be more interesting for hydraulic equipment manufactures rather than for agricultural tractor users.
Comparative tests show that tests on agricultural tractor system according ISO 789-10 result in an increase of cost, time and equipment, and support the impression that it does not reflect a clear and simple test for users, even if the information given in its test report is in-deph and extensive.

References

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