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EXPERIMENTAL RESULTS OF TEMPERATURE VARIATION IN TORQUE CONVERTERS OPERATING WITH TWO-PHASE FLOW

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Hydrodynamic transmissions are usually provided with a cooling circuit which assures an optimum (a convenient) oil temperature.

In this paper are investigated the influence of closing the cooling circuit on the operation of CHC-350 torque converter by partial degree of filling with oil, namely with two-phase flow. The facility used as testing rig is presented. Also is calculated the energetic balance of the torque converter, from thermal point of view.

Experimentally are determined the temperature rise in time by different degrees of filling of the torus and by various resistant torques.

Keywords: torque converter, two-phase flow, experimental results.

1. Introduction

Hydrodynamic transmission found a large area of applications in automotive industry by cars, busses and heavy civil engineering machines, in mining, for ships and railway engines (locomotives) etc. The running of torque converters is with good performances in optimum temperatures domain 70…90^{o}C.

It is important to establish what happens when a blocking (closing) of the cooling circuit occurs. The running time until the optimum temperature is touched varies with the degree of filling. In the following pages, we analyze the temperature variation with the degree of filling in the CHC-350 torque converter.

2. Testing rig for hydrodynamic transmissions

In the Laboratory for Hydraulic Machines of the "Politehnica" University of Timisoara, Romania, it is an experimental facility for hydraulic transmissions. The testing rig consists from: cooling system, electric motor, hydrodynamic torque converter CHC-350, braking electric machines regenerative type, apparatus

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for torque and speed of rotation of the hydrodynamic torque converter's shafts, pressure and temperature gauges of the oil inside the transmission, electric frequency conversion equipment, data acquisition system and all are computer controlled.

The hydrodynamic torque converter is provided with transparent walls for visualizing the flow. We will film with a video recorder the start and stop of the torque converter, namely a transient regime.

The parameters of the system are: degree of filling with oil of the torque converter; constant resistant torque; initial oil temperature and pressure. The flow structure is monitorised by different speeds of rotation read in revolution per minute.

2.1. Lisholm-Smith torque converter testing rig

The facility consists from o testing rig as it is shown in Fig. 1, with following components: 1-torque converter Lysholm – Smith; 2-multiple speed induction motor; 3-dynamo for load; 4-Ward – Leonard system for power regeneration; 5-additional electric aggregate for excitation; 6-closed circuit for coupling brake circuit; 7-gear pump; 8-radiator; 9-starter equipment; 10-gauge for torque; 11-data acquisition system: FC – frequency converter, DA – data acquisition equipment, and computer.

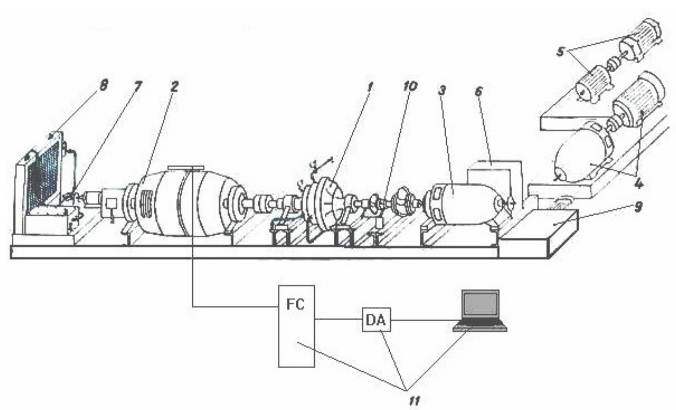

Fig. 1. The testing rig for hydrodynamic torque converters.

2.2. Temperature measurement

For temperature determination in the two-phase fluid existing in the hydrodynamic transmission was used Chromel – Alumel type K probe and digital sensor type DS 1820 (see Table 1). The Chromel – Alumel probe has 1,5mm diameter. The advantages of measurements with thermocouples are: ready for connection to the measuring instrument, not sensible at shock and vibration, resistant to extreme pressures, corrosion resistant. The thermocouple TC output is an electrical signal obtained in mV, by voltmeter, and temperature value is obtained by calibration curve. For DS 1820 sensor, the measured temperature is read by electronic screen. The schemes of two gauges for temperature measurement are presented in Fig. 2 and Fig. 3.

Table 1

Temperature range

Temperature probe	Temperature range	Accuracy
Chromel-Alumel type K	$0 \div 1000\ ^0C$	$\pm$ 0,75%.
Sensor DS 1820	$-55 \div +125^0C$	$0{,}5^0C$

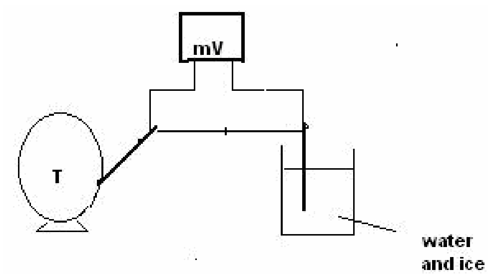

Fig. 2. Measurement scheme for thermocouple type K

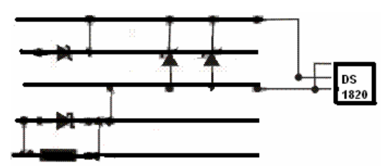

Fig. 3. Measurement scheme for DS 1820 sensor

For comparison the measured temperature by above mentioned two methods, in Fig. 4. is presented the results obtained for 97,5 % degree of filling.

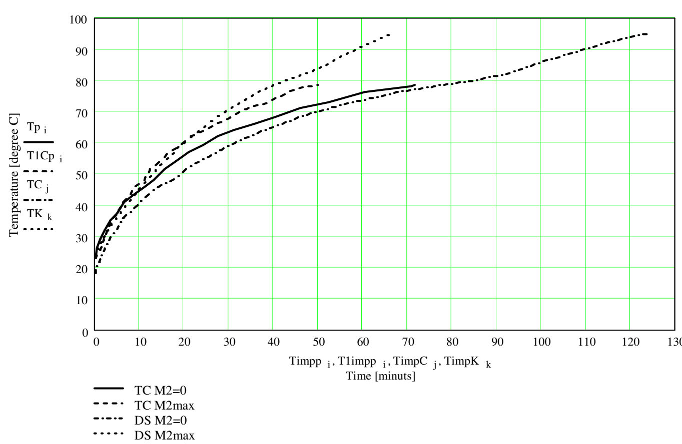

Fig. 4. Comparison measured temperature by two methods for 97,5 % degree of filling.

2.3. Torque converter heating

Thermal power balance of the torque converter is:

$$P_{dis} = P_{tme} + P_{lic} \tag{1}$$

where:

- the power dissipated through the operation of the torque converter is

$$P_{dis} = (1 - \eta_{tc}) \cdot P_1 \tag{2}$$

- the power transited to environment is

$$P_{tme} = \sum \lambda_i \cdot A_i \cdot \Delta\theta_i \tag{3}$$

- the thermal power transported by cooling liquid is

$$P_{lic} = \rho_0 \cdot Q_a \cdot c_u \cdot \Delta\theta \tag{4}$$

We consider the data of the CHC - 350 Lysholm – Smith type investigated torque converter given in Table 2.

Table 2

Data of the CHC - 350 Lysholm – Smith type torque converter

Type	CHC - 350
Max efficiency	$\eta_{tc} = 66\%$
Rated nominal power entrance	$P_1 = 2$ kW
Thermal conductivity coefficient	$\lambda_i = 6 \ldots 10$ W/m^{2}K
Torque converter area	$A_i = 0{,}5$ m^2
Temperature difference torque converter-air	$\Delta\theta_i = 226 \ldots 136^0$C
Temperature difference oil - air	$\Delta\theta = 60^0$C
Specific heat of the oil	$c_u = 2000$ J/m^{2}K
Oil density	$\rho_0 = 890$ kg/m^3
Cooling rate of flow	$Q_a = 0$ m^3/ s

Maximum temperatures difference which may be obtained, without cooling circuit is given in Table 3. The values are higher than the technical allowed temperature. So without cooling the hydrodynamic torque converter may operate only a limited time.

Table 3

Maximum temperatures difference

λ_i	6	7	8	9	10
$\Delta\theta_i$	226	194	170	151	136

3. Experimental results

The functional performances of the torque converters can be influenced by the variation of the entrance speed, n_1, the modification of the geometry of pump impeller and turbine runner blades and the modification of the degree of filling χ_u respectively through using a two-phase working fluid (liquid-gas) [1, 2].

In this issue, there are presented a part of the experimental results obtained, considering the thermal regime in a Lysholm-Smith torque converter, operating with two-phase fluid type mineral oil-air.

Thus, the experimental researches, put in evidence that temperature variation in time in two-phase fluid mineral oil-air, is strongly influenced by the working regime of the torque converter (CHC - 350), through the turbine load. Therefore the tests were organized in accord to transmission loading, minimal loading, idle regime, (M_2=0) and maximal loading/braking of the turbine for different degrees of filling using constant input speed n_1=1000 rev/min. The experimental results obtained are presented in Fig. 5.

The analysis of the experimental curves presented in Fig. 5 shows that the warming of the two-phase flow is produced faster in the case of maximum loading of the turbine and generally the warming process is strongly influenced by the hydrodynamic transmission degree of filling, respectively trough the balance of each constituent, mineral oil or air, in the two-phase flow.

It can be observed that the warming is stronger at higher degree of filling. The cause of this warming could be the physical different properties of the mineral oil and of the air and in other words that the maximum loading/braking of the turbine is followed by irreversible heat transfer of one additional part from kinetic energy of two-phase flow, which because of the braking are transformed in heat and pressure potential energy.

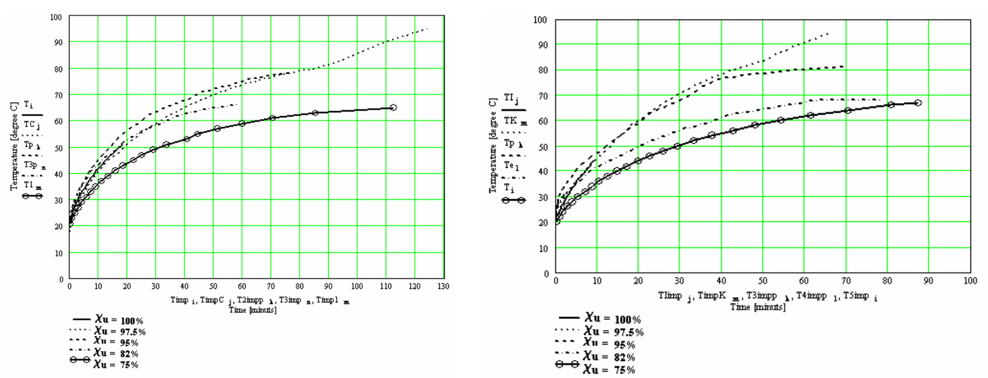

Fig. 5. Temperature variation in time in idle regime (M_2=0) and with maximum load regime (M_2= M_{2max}=70…270 Nm) for different degrees of filling.

The maximum rise of temperature by a transient starting regime occurs by a degree of filling of χ_{uM} = 95 % by idle regime and χ_{uM} = 97, 5 % by maximum loading of the torque converter. The global effect of the two-phase working fluid warming, respectively of the parametric modification of the degree of filling can be better appreciated trough mechanical parameters from turbine outlet, respectively mechanical torque M_2 and outlet speed of rotation n_2.

It has been observed that at the same constant input speed n_1, indifferently which is the degree of filling and the loading level of the torque converter loading, the pressure in the transmission gets higher with the growing of the working fluid temperature. The outlet speed n_2 grows with the growing of the two-phase fluid temperature, by high degrees of filling. At smaller degrees of filling, the outlet speed n_2 decrease with the growing of temperature (Fig. 6).

Considering the running of the torque converters, seeing that, at higher degrees of filling, with the growing of the two-phase flow temperature grows the outlet mechanical torque M_2 and the speed n_2, appears a contradiction (probably accountable through the extremely complex thermo-hydrodynamic behavior of the two-phase liquid-gas components, generally) if we take into account the working characteristics of the torque converters obtained with the cooling equipment in operation.

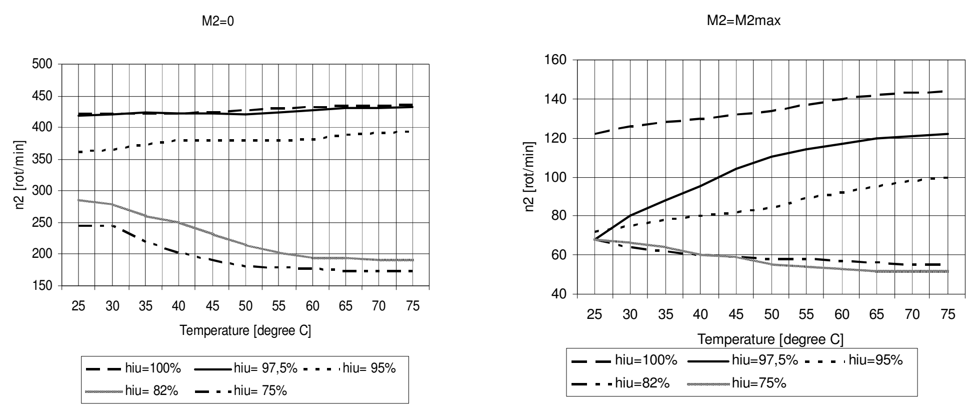

Fig. 6. Speed of rotation in function of temperature for different degrees of filling, without the torque converter load and with maximum load.

From Fig. 6, results that, for different degrees of filling χ_u =const. and for the same speed of rotation n_1 = *const.* the speed of rotation n_2 has different variations, monotonous, increasing or decreasing, with the temperature increase of the two-phase working fluid. Hence, results that, there exists a degree of filling χ_{uo} =const. at which, the speed of rotation remains constant, indifferently from temperature variation in time. Thus, if a gradient is defined as follows,

$$grad\ \Pi = \frac{\Delta n_2}{\Delta \theta}\left[\frac{\text{rev/min}}{^\circ C}\right] \quad (5)$$

then, $grad\ \Pi = 0$, for the degree of filling $\chi_{uo} \cong 85$ %, for maximum loading, and $\chi_{uo}^{*} \cong 91\%$, for minimal loading, and $grad\ \Pi > 0$, for different degrees of filling $\chi_u > \chi_{uo}$ or $\chi_u > \chi_{uo}^{*}$ and $grad\ \Pi < 0$, for different degrees of filling $\chi_u < \chi_{uo}$ or $\chi_u < \chi_{uo}^{*}$, respectively (Fig. 7).

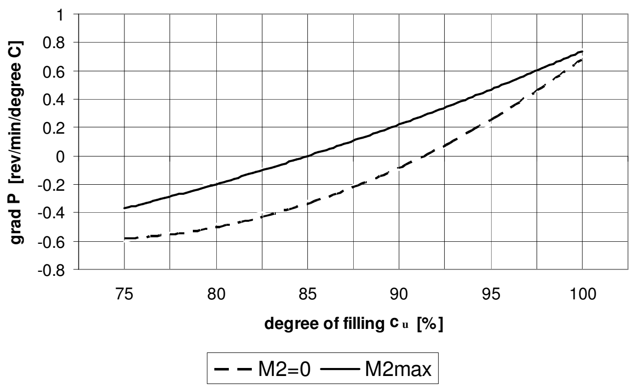

Fig. 7. Gradient of the speed of rotation with temperature in function of degree of filling, for idle regime and maximum load regime of the torque converter. The entrance speed of rotation is constant, n_1 = 1000 rev/min.

The unique thermo-hydrodynamic case, when $grad\ \Pi = 0$, or when the speed of rotation $n_2 = const.$, respectively, it is thought that is the result of different response of the mineral oil and air from the two-phase flow, with the temperature increase.

The degree of filling, $\chi_{uo} \cong 85\%$ or the gradient $grad\ \Pi = 0$, respectively, $(or, n_2 = const.)$, offers outstanding assignments concerning the two-phase components mineral oil-air, respectively, as for the influence of temperature about of the physical properties of two-phase flow. On the other way, with the two-phase components, mineral oil-air, we can maintain the normal speed n_2 constant, indifferently of the temperature variation in time of the hydraulic transmission. If the degree of filling has the values, $\chi_{uo} \cong 85\%$, ($\chi^{*}{}_{uo} \cong 91\%$), respectively, the volumes of structural constituents of the two-phase medium mineral oil-air are $\upsilon_{oil} \cong 85\%$; $\upsilon^{*}{}_{oil} \cong 91\%$ and respectively $\upsilon_{oil} \cong 15\%$; $\upsilon^{*}{}_{oil} \cong 85\%$.

In conclusion, the degree of filling $\chi_{uo} \cong 85\%$, respectively, $\chi^{*}{}_{uo} \cong 91\%$, corresponding to entrance speed of rotation $n_1 = 1000$ rev/min, ensures a stationary regime of hydrodynamic transmission.

On the other hand, the degree of filling $\chi_{uo} \cong 85\%$ achieves only a steady-state conditions / operating duty of working from the thermodynamic standpoint, without to ensure and the best operating conditions from the power standpoint, that corresponds to best degree of filling $\chi_u \in (95\%,...,99\%)$.

4. Conclusions

The experimental results, that were obtained, permit the wording of some outstanding conclusions concerning the two-phase flow and the thermo-hydrodynamic properties of the fluids:

- the maximum rise of temperature by a transient starting regime occurs by a degree of filling of $\chi_{uo} \cong 95$ % by idle regime and $\chi_{uo} \cong 97$, 5 % by maximum loading of the torque converter;
- the heating of the two-component fluid, mineral oil-air, becomes more strongly with the increase of loading of the hydraulic transmission / hydraulic turbine, to the same entrance speed of rotation;
- the heating of the two-phase flow, in transient starting regime, rise more quickly with the increase of degree of filling of the torus and with the increase of entrance speed of rotation;
- there is certain a unique degree of filling at which the outlet speed of rotation of the transmission remains constant by different temperatures. This unique values are $\chi_{uo} \cong 91$ % for idle regime, $M_2 = 0$, and $\chi_{uo} \cong 85$ % to full load regime, M_{2max}, both at same entrance speed of rotation $n_1 = 1000$ rev/min;
- at last, the knowledge of the unique degree of filling $\chi_{uo} \cong$ const for different entrance speeds of rotation $n_1 = const.$, permits the establishment of working stationary regimes of hydrodynamic transmission from the thermodynamic standpoint.

REFERENCES

[1]. *M. Bărglăzan, C. Velescu*, Cuplaje, transformatoare şi frâne hidrodinamice, Ed. Politehnica, Timişoara, 2006.

[2]. *M. Bărglăzan*, Turbine hidraulice şi transmisii hidrodinamice, Ed. Politehnica, Timişoara, 2001.

[3]. *N. Peligrad*, Cuplaje hidraulice şi convertizoare hidraulice de cuplu. Ed.Tehnică, Bucureşti, 1985.

[4]. *C. Brennen, P. Cooper and P. W. Runstadler jr.*, “Polyphase Flow in Turbomachinery”, in ASME, San Francisco, 1978.