ASSESSMENT METHODOLOGY OF A NON-CONVENTIONAL COOLING SYSTEM

HLAVŇA Vladimír, Prof., Ing., PhD
SOJČÁK Dušan, Ing.
University of Žilina
e-mail: vladimir.hlavna@fstroj.utc.sk
e-mail: dusan.sojcak@fstroj.utc.sk

Abstract

During experiments focused on cooperation of a non-conventional combustion engine featuring basic elements of absorptive cooling equipment that constitutes its non-conventional cooling circuit it is necessary to define methodology of assessment. The methodology of assessment comes out of the physical principal of cooling equipment and from the need to take away energy from the cooling system of the combustion engine. The methodology was prepared on the basis of the performance number – COP (Coefficient of Performance) of the system. The coefficient of performance defines quality of reconstruction and pressure-temperature relations necessary for a physical process to take place. The paper contains a description of determining the performance number for the particular test stand and experiment. Some results of assessment according to the specified methodology are also presented in the paper.

1. Introduction

At a theoretical solution of construction of a non-conventional cooling system of the combustion engine its fundamental elements and non-conventional coolant were designed. These elements constitute parts of one-stage absorptive equipment. In a practical solution the influence of fundamental elements was tested on a test stand, Fig. 2. It was found out that the combustion engine can be put into operation for the purpose of experiments. After the basic experiments and after the verification of the physical principal of evaporation in atmospheric conditions, which is being used in an absorptive cooling system, it is necessary to define the methodology of assessment of a non-conventional cooling system. The assessment methodology is based on the assessment of energetic systems efficiency [1].

Energetic or thermodynamic efficiency of energetic equipment can be generally defined as a ratio of energetic flows $\sum E_u$ assessed as the gain from the given equipment to energetic flows $\sum E_v$ exerted to obtain useful energetic flows. For energetic efficiency then holds the following:

$$EF = \frac{\sum E_u}{\sum E_v}\,, \tag{1}$$

for energetic balance of the equipment where generally processes of transfer and transformation of different flows of energy take place then holds:

$$\sum E_v = \sum E_u + \Delta E\,, \tag{2}$$

where ΔE are energetic flows which are not efficiently used in the given energetic equipment and are released into the ambient environment.
Energetic efficiency expressed according to relation 1 determines a quantitative value of the acquired useful energetic flows from the equipment needed for delivery of unit of power energy exerted to obtain the energetic flows. To express such an energetic efficiency we can use the notion of the coefficient of performance (COP) or a degree of use of primary energy (PER). The cooperation of the combustion engine and absorptive cooling equipment will be assessed by means of the coefficient of performance.

2. A theoretical performance number COP_{red}

The COP expresses attainable useful work. The higher COP value the given system achieves, the less primary energy needed for output energetic flows the system consumes. The COP can be used only for mutual comparison of similar equipment with similar types of energetic flows in application (from the point of view of heat or mechanical energy), e.g. of combustion engines.
On the test stand we use the energy accumulated in the cooling system and energy corresponding to the effective output. As we do not use the energy bound in exhaust gases we cannot assess the system by means of the complex COP. That is why the COP_{red} [3] is determined.

$$COP_{red} = \frac{Q_e + Q_{ch}}{Q_p} \ . \tag{3}$$

Q_e – energy corresponding to the effective output, Q_{ch} – energy accumulated in the cooling system, Q_p – energy bound in fuel.
By means of relation 3 it is possible to define a theoretical value of the reduced output number but under the condition that Q_{ch} will be equal to the cooling output of the absorptive unit Qabj. Such a situation would be very advantageous and Qe will be fully transformed e.g. to electric output.

3. A real performance number COP_{red}

The determination of a real coefficient of performance for the test stand can be carried out from two criteria:

A. a real coefficient of performance determining the quality of realization of the evaporation physical principal. It determines how much energy contained in the coolant will be transformed into other so called evaporation energy – heat. The mass flow of coolant and cooling output for an absorptive unit corresponds to the value of evaporation heat at the defined evaporation efficiently,

B. a real coefficient of performance defining the cooling output achieved by the cooling unit. This assessment can be carried out only when the test stand is able to work at the maximum possible evaporation efficiency so that the operational ability and long life of the combustion engine is sustained.

$$\textbf{A:}\ COP_{red} = \frac{Q_e}{Q_p}\eta_{el} + \frac{Q_{ch}}{Q_p}U_{v\acute{y}p}\ , \tag{4}$$

η_{el} - efficiency of transformation of Q_e e.g. into electric output, $U_{v\acute{y}p}$ – evaporation efficiency.

$$U_{v\acute{y}p} = \frac{Q_{v\acute{y}p}}{Q_{ch}} = 1 - \frac{Q_{och}}{Q_{ch}} = 1 - \frac{(T_{vch} - T_{vych})}{(T_{vm} - T_{vym})} = 1 - \frac{dT_{ch}}{dT_M} \; , \tag{5}$$

$Q_{v\acute{y}p}$ – evaporation heat – energy, Q_{och} – heat taken away by means of the cooler, T – temperatures are described in the figure, dT_{ch} - temperature gradient on the combustion engine cooler, dT_M - temperature gradient of the combustion engine. The attainment of maximum evaporation efficiency emerges from pressure conditions in which the absorptive cooling unit is to be operated. It is the case of low pressure conditions. So far we have assessed the cooperation in atmospheric conditions only. After the COP_{red} had been defined from the point of view of evaporation efficiency it is possible to define places for measurement.

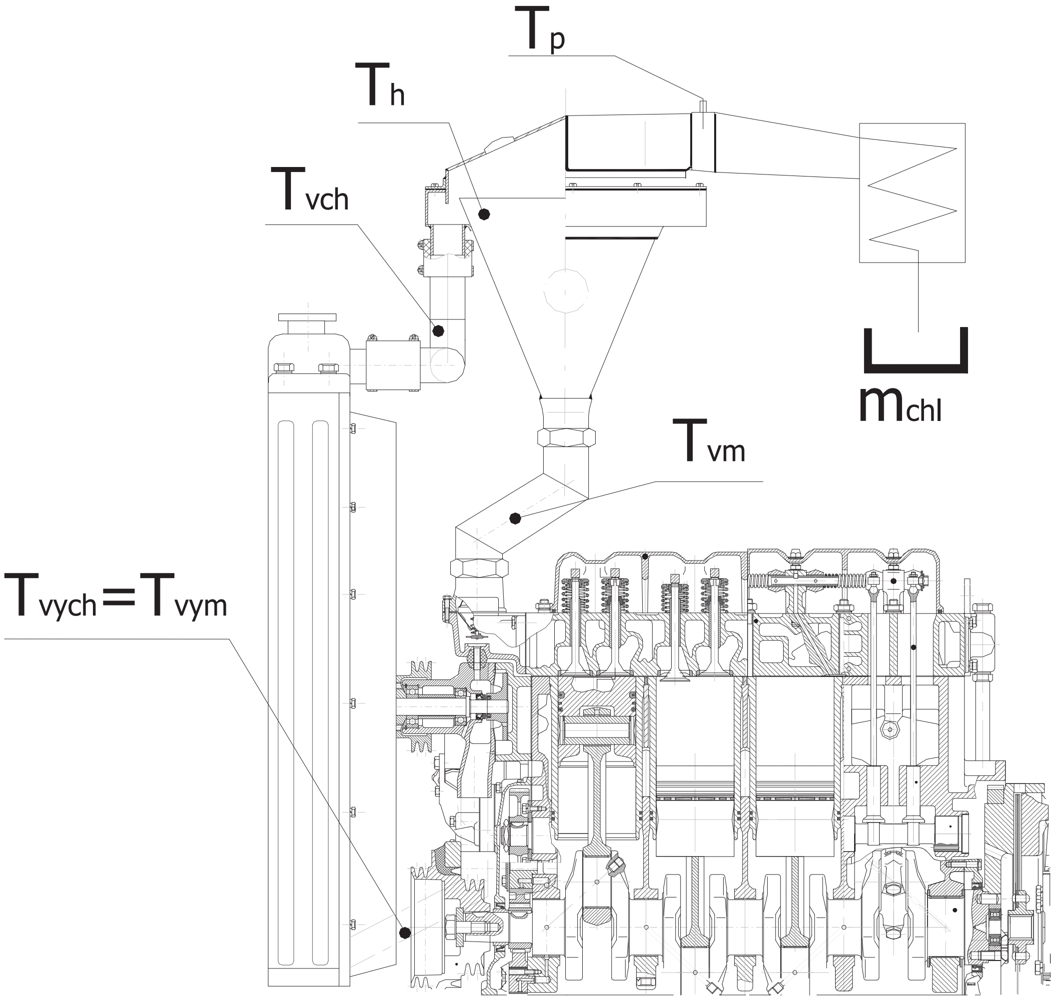


Fig. 1. m_{chl} – mass flow of coolant, T_{vm} – temperature at the combustion engine exit, T_p – temperature of vapor, T_h – temperature of surface in the evaporation vessel, T_{vch} – temperature of lean solution leaving the evaporation vessel and entering the cooler, T_{vych} and T_{vym} – temperatures entering the combustion engine [2]

B. $$COP_{red} = \frac{Q_e}{Q_p}\eta_{el} + \frac{Q_{ch}}{Q_p}\eta_{nch} \; , \tag{6}$$

$$\eta_{nch} = \frac{Q_{abj}}{Q_{ch}}, \tag{7}$$

η_{nch} - efficiency of the non-conventional cooling circuit of the combustion engine. If the absorptive cooling unit achieves a higher cooling performance than the heat flow to the cooling system, the value of efficiency can be higher than 1.

4. A real coefficient of performance COP_{red} in atmospheric conditions

The real coefficient of performance for the atmospheric system was determined on the real test stand, Fig. 2.

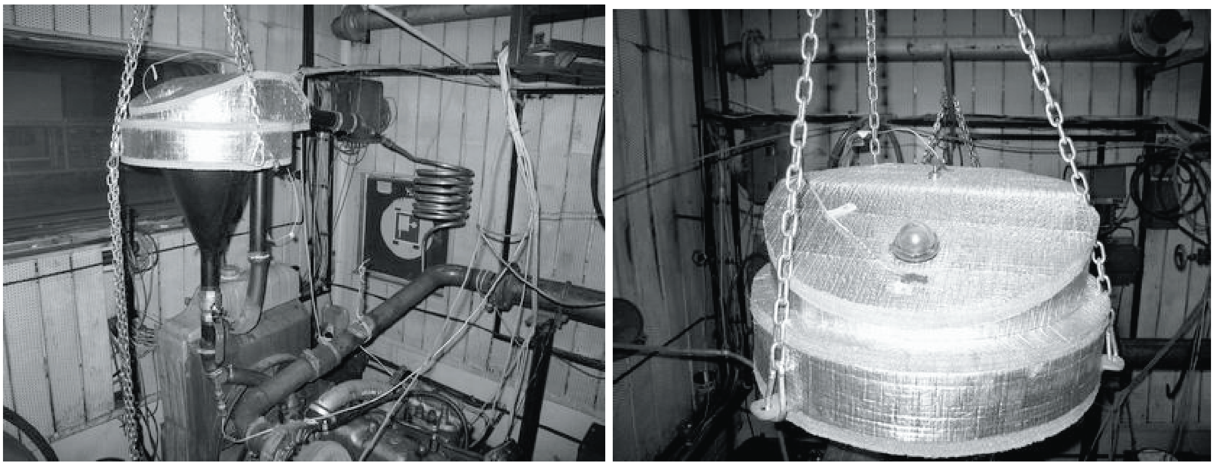


Fig. 2. Test stand and view of sensors

The course of measurement is characterized by means of the recording illustrated in graph 1.

Part I. – the combustion engine is heated approximately to the mild boiling point. **Part II.** – a compressor the support vapor dynamics and search into the influence of compressor on other temperature illustrated in graph 1. **Part III. –** course of measurement without a compressor, arbitrary transition of vapors into a copper spiral, Fig. 2. Fluctuation of temperatures taken at the exit from the evaporation vessel and from the surface in the evaporation vessel is caused by a fluctuating preservation of temperatures at the combustion engine exit. To maintain this temperature constant requires a skilled handling with the cover over the cooler. In this part of measurement we evaluate the evaporation efficiency and mass flow of the condensate – coolant. This parameter enables to determine an expected cooling performance and thus define the cooling potential of the non-conventional cooling circuit of the combustion engine in atmospheric conditions. **Part IV** – course of measurement with a compressor. In this part of measurement we again evaluate the evaporation efficiency and mass flow of the condensate – coolant.

Part of graph III. *- evaporation efficiency according to relation 5:*

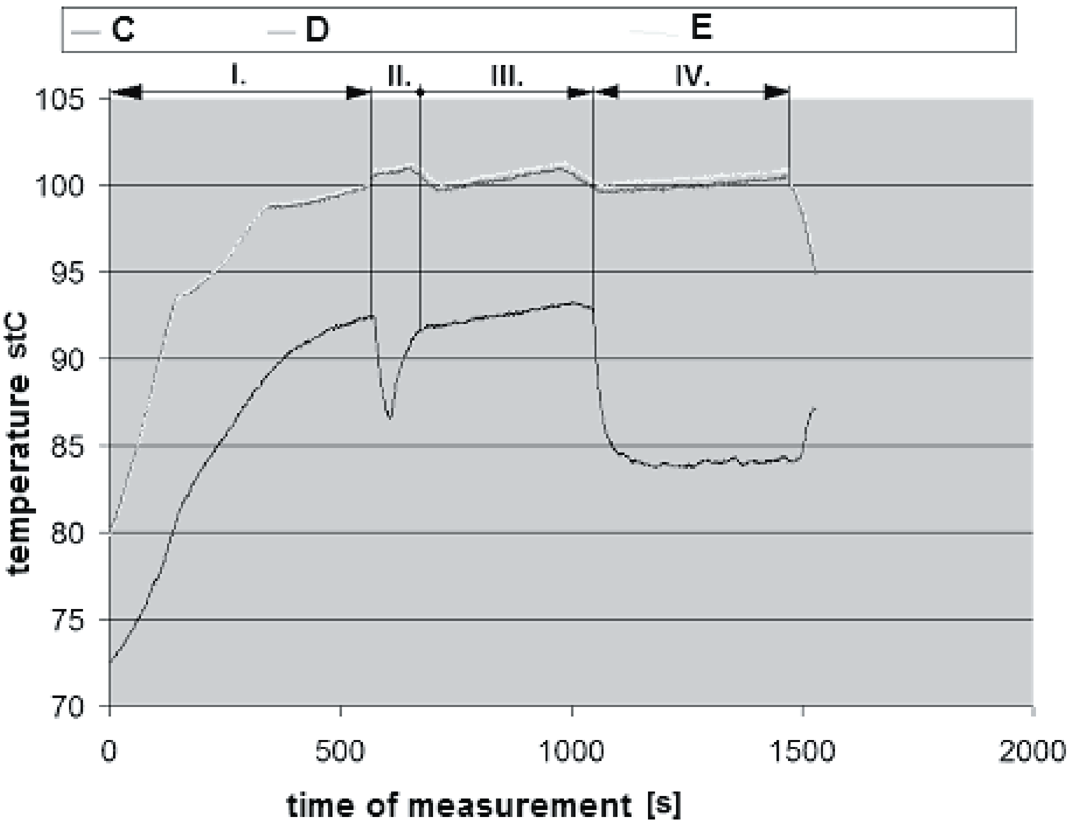
$$U_{tk} = 1 - \frac{10.43}{12.19} = 0.14 = \mathbf{14\%}, \tag{8}$$

at the caught flow of condensate of 0.015 kg/5min, which represents 0.5.10^{-4} **kg.s^{-1}**.

Part of graph IV. variant A-D - *evaporation efficiency:*

$$U_{tk} = 1 - \frac{10.43}{12.19} = 0.14 = \mathbf{14\%}, \quad (8)$$

at the caught flow of the condensate of 0.359 kg/5min, which represents **0.12.10^{-2}** kg.s^{-1}.



Graph 1. C – temperature of vapors, D – temperature at the exit from the evaporation vessel, E – temperature of the surface in the evaporation vessel

From the carried out measurements it is possible to define the coefficient of performance according to relation 4 and thus define the efficiency of the cooperation of the combustion engine and absorptive cooling equipment in atmospheric conditions and at the use of an alternative coolant featuring specific physical characteristics.

$$COP_{red} = 0.35 + 0.05 = 0.4.100 = 40\% . \quad (10)$$

5. Conclusion

The article describes a possible creation of a non-conventional energetic equipment on the combustion engine basis. Actually, it is a cooperation of the combustion engine with a one-stage absorptive cooling equipment. Such equipment constitutes a non-conventional cooling circuit of the combustion engine.

Part of the research is the determination of methodology for assessment of cooperation of the combustion engine with basic elements of the absorptive cooling equipment.

The first step is to define a cooling potential of the circuit in atmospheric conditions. The definition of a significant efficiency is not expected, but first experiments are aimed at outlining trends of observed parameters. In the circuit illustrated in Fig. 1 and 2 we are able to make use of 5% of energy accumulated in the coolant at the coolant condensate $0.12.10^{-2}$ $kg.s^{-1}$. In future research it will be necessary to rebuilt the cooling system into low-pressure conditions and use suitable coolant. Subsequently, a significant increase of the coefficient of performance and mass flow of the coolant can be anticipated. In the conditions defined in this way it is necessary to maintain the operational ability of the combustion engine.

References

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