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System for Preheating of Internal Combustion Engine Operating in Cold Weather Conditions

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Abstract: There are a lot of negative factors affecting the operation of Internal Combustion Engines (ICE) in the cold weather conditions, the first and main of which is a low temperature. In these conditions to ensure reliable start and operation of ICE the preheating is required. So, an additional source of thermal energy is needed. At the same time, during the operation of the ICE a significant amount of heat energy is dissipated and lost without usage. To provide reliable start and to increase durability of the ICE without additional energy sources are possible if accumulate and use ICE heat energy for preheating of ICE. Thus, we get a significant economic effect.

Key words: Internal combustion engine, cold weather conditions, low temperature, heat storage, durability

INTRODUCTION

Sometimes the start of Internal Combustion Engines (ICE) of automotive and specialty vehicles in cold weather conditions (−25°C and below) require significant additional energy and human resources.

Usually, the problem of cold ICE start is solved by implementing of different methods like additional ICE starts during long operation pauses, using of heaters and other preheating systems. The special place among the ICE preheating systems is taken by heat storage systems.

RELEVANCE

The heat balance of the diesel engine “RME-238” shows that 60% of combusted fuel energy is dissipated to the environment. These heat losses per year are >100 thousand MJ. Such heat energy would be enough for heating the 200 M2 house within 1 year. Thus, relevance of the ICE heat storage to ensure its start is obvious (Vashurkin, 2001).

A number of scientists including N.N. Karnaukhov, A.I. Tarkhov, A.I. Khorosh, S.V. Kaverzin, S.D. Gulin, V.F. Kramskoy, M.I. Samoylova and others are engaged in the solution of relevant problem.

Researchers proposed various designs of the heat storages for ICE (Karnaukhov *et al*., 2006; Vashurkin, 2001; Kaverzin *et al*., 1998). However, as a rule, proposed designs had disadvantages, a complicated design and manufacture or needed great modification of structural units and required additional power sources.

Based on analysis, researchers proposed a method of the ICE thermal regime control and a design of the heat storage. Proposed heat storage is capable to keep temperature of ICE not lower than -10°C and ensures the ICE start even after 8-10 h of operation pause at an ambient temperature -30 to -40°C. The proposed heat storage operates cyclically. The working cycle consists of six stages (Fig. 1).

CONSTRUCTION

The heat storage consists of several containers (sections) filled with a heat retaining material based on sodium acetate. The containers are tightly fixed on the surfaces of the ICE block and ICE sump. Each container is covered from outside with heat-saving covers consisting of two layers (Fig. 2).

The outer layer 8 is a heat storage case. The internal layer is fixed to the outer layer. The outer layer is made of a strong supporting synthetic net with polyester. The applied material allows reaching the necessary strength of the heat storage in all ICE operation conditions.

The layer 7 is a heat-saving layer. It consists of foam polyethylene covered with aluminum foil on one of its sides. The heat-saving layer reduces heat losses to the environment, thus, it maintains the ICE temperature effectively.

The layer 6 is a heat retaining substance. This layer works as the heat accumulator during the ICE operation and as the heat energy source during the ICE operational pauses.

The heat storage sections are made of polyurethane and have an operating temperature range -45 to +200°C. The heat retaining substance is the solution of sodium acetate. The heat storage principle is based on the feature of the substances to allocate and to receive heat energy in the process of transition from one state of aggregation

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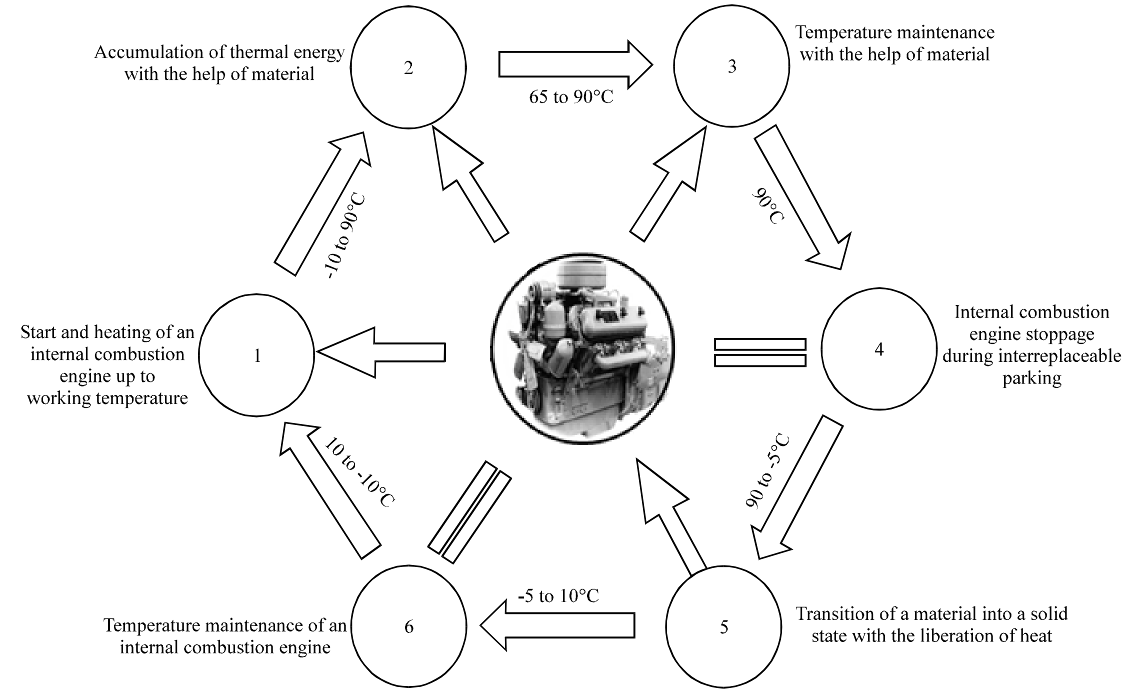

Fig. 1: Working cycle of the heat storage

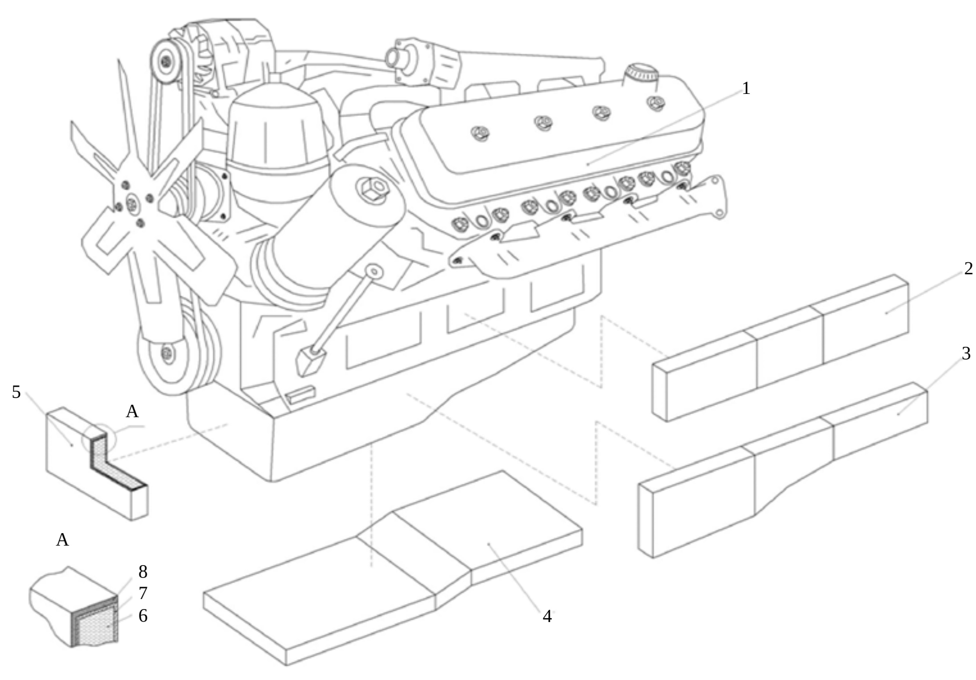

Fig. 2: Heat storage construction. 1: Internal Combustion Engine (ICE); 2: block sections; 3-5: sump sections; 6: heat-retaining substance; 7: heat-saving layer; 8: heat storage case

to others. The detailed description of selection and research of the sodium acetate heat-retaining material properties is provided in by Yarkin and Pustovalov.

The design of the heat storage allows avoiding emergence of thermal stresses in the ICE because the heat storage maintains the temperature of the ICE without

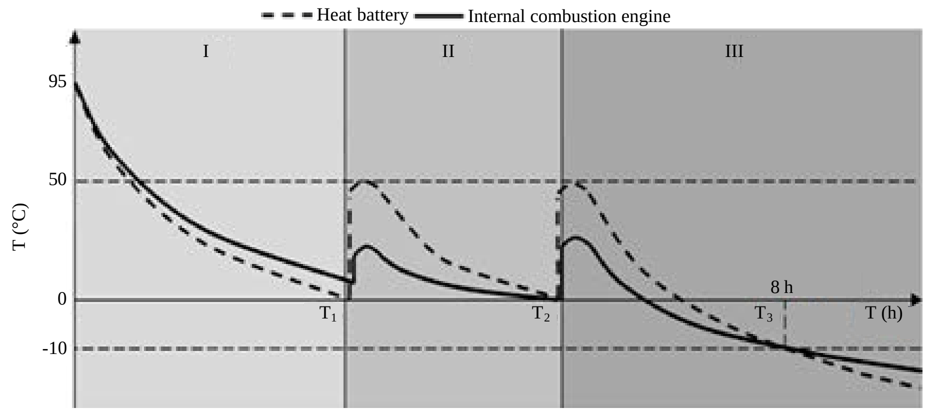

Fig. 3: Characteristics of the heat storage and ICE temperatures versus the duration of operational pause

abrupt changes. The previously proposed heat storages heated the cold ICE with big temperature gradient, so this could lead to sudden destruction of separate structural elements due to the occurrence of critical temperature deformations.

Theoretical and experimental research: The characteristics of the heat storage and ICE temperatures versus the duration of operational pause are presented in Fig. 3. The heat energy of the operating heat storage can be calculated using the Fourier's law. The detailed mathematical models are presented by Karnaukhov *et al*. (2010) published by researchers earlier. The mathematical model of the cooling down of the ICE with the heat storage has the final form:

$$\Delta T_{M\eta} = T_B + \left(\frac{C_M \cdot m_M \cdot (T_{M1} - T_B) - \left(5.67 \cdot \varepsilon \cdot F_P \cdot \left((T_B/100)^4 - (\Delta T_{M\eta\text{-}1}/100)^4\right)\right)}{C_M \cdot m_M} \right) \quad (1)$$

Mathematical model of heating up and cooling down of oil of the ICE with the sodium acetate heat storage:

$$\Delta T_{M\eta} = T_B + \left(\frac{(C_M \cdot m_M \cdot (T_{M1} - T_B) + Q_{Na}) - \left(5.67 \cdot \varepsilon \cdot F_P \cdot \left((T_B/100)^4 - (\Delta T_{M\eta\text{-}1}/100)^4\right)\right)}{C_M \cdot m_M} \right) \quad (2)$$

The mathematical models 1, 2 allow to observe the dependencies among the ICE oil temperature, ambient temperature, quantity and properties of a heat-retaining material.

To verify theoretical calculations the heat storage experimental models were made and series of laboratory and field experiments were carried out.

The graphic results of research of heat storage model for the "EO-5126" excavator at ambient temperature -27 to 32°C are presented in Fig. 4.

Heat exchange process in •ICE- heat storage• System during the operational pause can be divided into five stages.

The first stage is the ICE oil cooling down from +85 to +4°C within 3 h of operational pause. After 3-3.5 h of ICE cooling down the heat storage substance self-crystallization process is began in ICE block sections at -1 to -7°C. The sodium acetate solution temperature is increased to +50°C within the self-crystallization process.

The second stage is the ICE oil heating up from +4 to +10°C within 60-80 min by the released heat due to sodium acetate self-crystallization process in the heat storage sections installed on the ICE block.

The third stage is the ICE oil cooling down from +10 to 0°C within 40-50 min. Low rate of ICE oil cooling down is caused by sodium acetate heat-retaining properties and the presence of thermal insulation layer. The temperature of the heat storage sections installed on the ICE sump does not decrease below 2°C.

The fourth stage is the ICE oil heating up from -7 to 0°C to +10 to +13°C within 80-60 min by the released heat due sodium acetate self-crystallization process in the heat storage sections installed on the ICE sump. The fifth stage is the ICE oil cooling down from +10 to +13°C to -7 to -10°C within 1.5-2 h.

Thus, the temperature of ICE does not decrease below -10°C during 7-8 h of operational pause at ambient temperature -27 to -32°C. It provides reliable start of ICE. The deviations of experimental data from theoretical calculations do not exceed 7%.

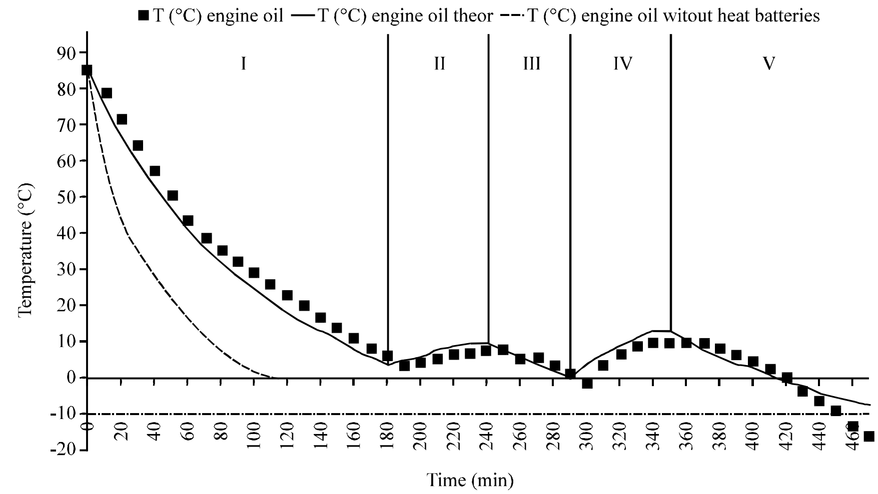

Fig. 4: Characteristics of ICE oil temperature versus operational pause time

CONCLUSION

The design of the heat storage for the car ICE operating in cold weather conditions was offered. The mathematical model of the heat energy transfer between the sodium acetate heat storage and the ICE was offered in various operating modes (charging, storage and heat transfer). This model allowed assessing of the time of the keeping sufficient temperature to start ICE reliably.

Theoretical results of calculations were verified during experimental research which included the preliminary experiment in the laboratory freezer and the field experiment in cold weather conditions. The deviation of experimental data from theoretical calculations did not exceed 7%.

The method of calculation of sodium acetate heat storage was developed. This method allowed calculating of the sufficient temperature keeping time for reliably ICE start in field operational conditions (ambient temperature, operation time, operation pauses, etc).

On the basis of the conducted researches a test heat storage for the "EO-5126" excavator ICE was made. To improve the test heat storage design the researches are conducted in the field operation conditions (a sandy pit).

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