COMPOSITE ALLOY WITH VERY LOW DIMENSIONAL HYSTERESIS DURING HEATING AND COOLING FOR COMBUSTION ENGINE PISTON

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Introduction

The most loaded parts of internal combustion engines are pistons, which must to fulfill growing functional and durability demands. By the object of article is the working out of material with the high durability and functional properties principally basing on lowering of difference in thermal expansion during the piston warming and cooling. The lowering of difference of thermal expansion increases the resistance of piston structure on fatigue damages and increases piston resistance on thermal shocks. During heating period the intermetal phases occurring in the microstructure succumb partial dissolution in the solid solution α, but in the cooling process they are giving off again. The partial plastic deformation of the piston occurs, which results in gradual growth of difference between its expansion during the heating and contraction in the cooling processes (so-called hysteresis). The developed composite material with the minimal difference of thermal expansion during the warming and cooling will permit to increase the piston resistance on fatigue damages and on thermal shocks, but moreover it will enable the application of engine designs with the smaller working clearances.

Experimental

Materials

The alloy chemical composition is presented in Table 1 below.

Table 1 Chemical composition of novel alloy.

No.	Chemical Composition, %					
	Si	Mg	Cu	Ni	Cr	Mo
Standard Alloy	12.5	0.37	5.0	4.15	-	-
Novel Alloy	12.25	0.22	3.5	0.015	0.03	0.22

Investigated alloy microstructure is presented on Fig. 1.

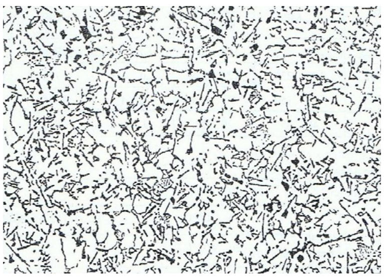


Fig. 1 Exemplary microstructure of investigated alloy.

Apparatus and Procedures

Investigations were performed with use of a precise dilatometer, which permits on the registration of the changes in specimen dimensions in the function of temperature and time.
The measurements in the straight and differential coordinate system are possible. The tests of investigated and reference materials take place in the same conditions, and measurements in differential coordinate system are performed in the same equipment. Heating and cooling takes place in the special equipment, which realizes temperature program of specimen heating and cooling. The dimension changes are measured with the inductive transducer. Temperature is measured with the Pt-PtRh thermocouple. The advantage of the used method is the continuous measurement of change in absolute or relative elongation as a function of time and temperature, as a function of temperature depending on the straight or differential measurement application. The schematics and the view of research stand are presented on Fig. 2 and Fig.3, respectively.

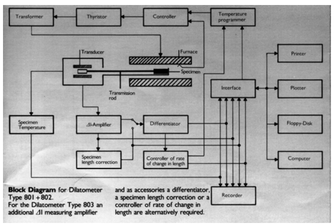


Fig. 2 Schematics of research stand.

Fig. 3 The view of the research stand.

Results and Discussion

Fig. 4 presents the course of the relative elongation in the function of time during ageing of alloy material in the temperature of 200°C.
The aim of investigation was the elimination of characteristic hump presented on Fig. 5. After receiving the course illustrated on Fig. 6, the minimized differences in the value of the thermal expansion coefficient during heating and cooling were obtained, as is shown on Fig.7.
The investigation results show a significant impact of alloy additions and heat treatment to ensure the small hysteresis of thermal expansion coefficient α.
The use of alloy additives alone does not provide a small hysteresis of thermal expansion coefficient α, as in the heating and cooling process the redevelopment of the inter-metallic phases in material occurs.

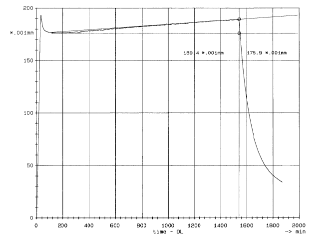


Fig. 4 Course of relative elongation of the piston sample, as a function of time for the aging at a temperature of 200°C.

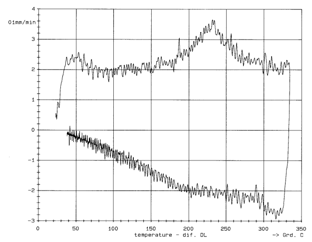


Fig 5 The course of derivative of specimen dimension increase to the time as a function of temperature (T) during heating and cooling (phase transition in 170°C-300°C temperature range.

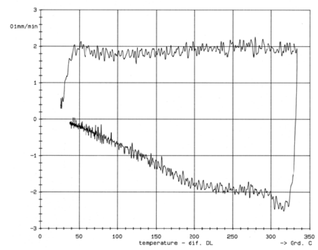
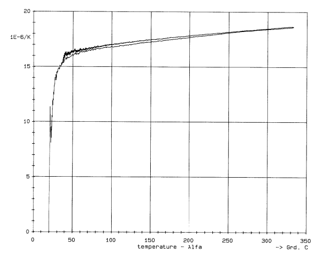


Fig. 6 Course of derivative of specimen dimension increase to the time as a function of temperature (T) during heating and cooling without phase transition.

Only performing a multistage heat treatment may interrupt this process, stabilize the phases, which is reflected in the minimization of uncontrolled changes in thermal expansion coefficient α



Fig, 7 The linear course of the coefficient of linear expansion α as a function of temperature (T) during heating and cooling with a minimum difference of coefficient at the same temperature.

Conclusion

Changes in thermal expansion coefficient at the time of heating and cooling may be very large, as well as during subsequent cycles of heating and cooling of an internal combustion engine piston with respect to standard Siluminum alloys used for pistons of internal combustion engines.

The best mechanical properties and dimensional stability, low hysteresis in thermal expansion coefficient α, was obtained by the introduction of several elements to the alloy material, which synergistic effect is far greater than separate effect of any single alloy element.

During the heating of the engine piston the alloy elements are partially dissolving in the solid solution α, and in the cooling process they are giving off again.

Consequently, there is a partial plastic deformation of the piston, resulting in a gradual increase in the difference between the expansion during heating and shrinkage in the cooling processes (so-called hysteresis).

However, the presence of pre-eutectic phases in Siluminum microstructure reduced the difference in coefficient of thermal expansion during heating and cooling.

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