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INFLUENCE OF HEAT TREATMENT ON THE α COEFFICIENT, THE PISTON – CYLINDER CLEARANCE WITH DACIA ENGINES

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ABSTRACT: The concerns related to the reduction of heat engines' noxious agents conditioned the study of the influence of alpax alloy states over the value of the heat transmission coefficient and based on this, over the piston-cylinder clearance. The tests performed through the dilatometrical [4] method proved that the cast alloy thermally untreated in order to obtain maximum mechanical attributes at room temperature, behaves better regarding the α coefficient [2] as it allows the possibility to obtain a piston-cylinder clearance of lower values which brings fuel consumption benefits and, thus, reduces noxious agents [1…7].

Key words: alloy, piston, heat treating, noxious

1. INTRODUCTION

The overwhelming importance and the influence of piston-based heat engines in the most various fields of activity (terrestrial, marine, aeronautic, etc) currently can no longer be challenged or questioned (Figure 1). A daily life without a "personal" car is almost unconceivable, not mentioning the other means of individual or mass transport.

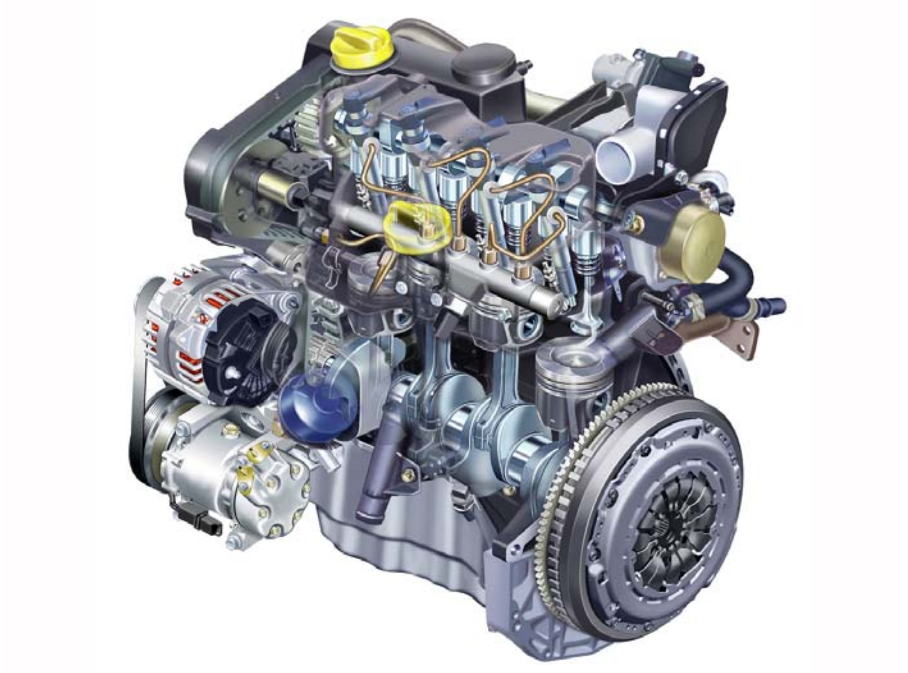

Fig.1 The Motor Dacia Logan Engine

The above mentioned major reasons crucially determined (obliged) all the experts (metallurgy experts, heat engine builders, etc.) to find the best technical solutions for the piston-cylinder couple (reasonably considered "the heart of the heat engine"), among which we can mention:

-determine the best nature of alloys that the piston-cylinder couple is made of;

- determine and establish the technologies to obtain the piston-cylinder couple;

- determine the "best" heat treatment (HT) regime of the piston-cylinder couple.

We must specify that with the materials of heat engine cylinders things are relatively clear – ferrous materials are used, especially cast iron.

However, with pistons, things are more complicated, because of the very high diversity of heat engines (marine, road, aeronautic, etc). even if we only refer to road heat engines it is enough for us to mention that in this case, also, a wide range of alloys is recommended. But significant is the fact that aluminium alloys, at least for light road vehicles, there have been considered as the most suitable alloys. Moreover, it has been concluded that such alloys provide a favorable priority complex in case of cast manufacture.

As for the chemical structure of alloys for pistons, two great categories are used: alloys containing a lot of solid solution α (alloys having as main addition agent Cu) and alloys from the alpax group (alloys containing as main addition agent Si).

The favorable technological, metallurgical and thermal properties [2] that alpax alloys cast into pistons are provided with, make that light cars (vehicles) generally be equipped with such pistons.

2. STUDIES ON THE ATSI$_{12}$CuMn ALLOY CAST INTO THE PISTONS OF DACIA

From the multitude of theoretical and experimental studies carried on both in our country and abroad [1…5] is was found the fact that the ATSi$_{12}$CuMn alloy is best suitable for casting heat engine pistons m.a.s. because it is provided with a good fluidity, it can be cast into a casting mould (shell) fitted on cold chamber casting machines, it has the suitable hardness and mechanical resistance, it has a refractoriness relevant for the operating temperature of pistons (around 300°C), it has a low thermal extension coefficient and a good dimensional stability on varying operating engine regimes, etc (Figure 2).

Fig.2 The Tractor Piston

2.1. Influence of heat treatment (HT) on α extension coefficients and on the magnitude of the piston-cylinder clearance

As demonstrated, [1][2] the HT hardening and annealing state is a metastable state and because of that within the piston alloy structure occur phase changes with consequences over the variation of the thermal extension coefficient values. Therefore, α_i initial and α_f final thermal extension coefficients appear.

As the values of such coefficients decrease during the preservation at 325°C, test simulating the real conditions of the piston head during operation, there will be reached a value of the final thermal extension coefficient (α_f) which, actually, represents the real size of this parameter. Between the two values of the linear thermal extension coefficients the following general relations are valid:

$$\alpha_f < \alpha_i \tag{1}$$

when:

$$\alpha_i = \alpha_f + c \tag{2}$$

where:

$$c = \alpha_i - \alpha_f$$

After the execution by fitting of the piston – cylinder nozzle, based on its calculation with an unstable operating clearance (j_{eI}), resulted from a α_i linear thermal extension coefficient, another stable operating clearance (j_{eII}) is created, relevant for the α_f linear thermal extension coefficient.

As $\alpha_f < \alpha_i$, it results that $j_{eII} > j_{eI}$ (3)

Fig.3. shows the scheme explaining the regulation (after the preservation at 325°C or after engine's operation) of the operating clearance at its final value, specific for the nozzle operation.

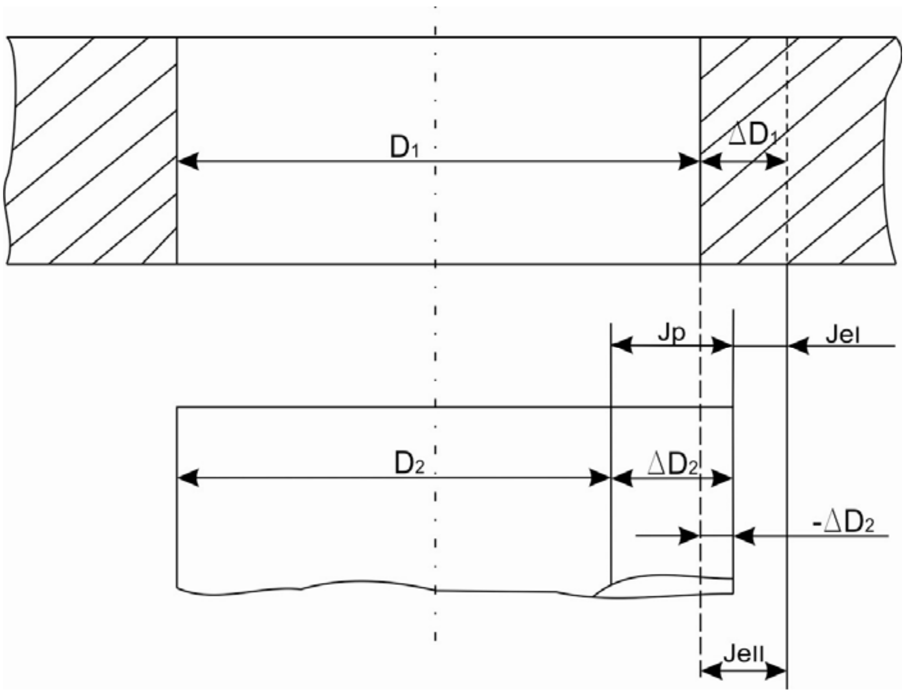

Fig.3 Scheme of the operating thermal clearance regulation at the piston-cylinder nozzle

Considering the nozzle formed between cylinder 1 (with the D_1 diameter) and piston 2 (with the D_2 diameter), for the standardized reference temperature T_0=20°C, upon the design of the assemblage, the design clearance (j_p) is developed. We will have the following relations:

$D_1/D_2 > 1$ (4)

as D1>D2, we will obtain:
$j_p=D_1-D_2$ (for $T_0=20°C$) (5)

At cylinder operating conditions, at the operating temperature T_c, the D_1 cylinder diameter will increase by the value ΔD_1. The operating temperature of the T_p piston will determine the increase of the piston diameter by ΔD_2. For such increases we will submit the nozzle to another value of the contact dimensions ratio, based on which a new value of the thermal clearance (j_{eI}) is created, operating clearance. We will have the following relations:

$(D_1+ \Delta D_1)/(D_2+ \Delta D_2) > 1$ (6)

As $D_1+ \Delta D_1> D_2+ \Delta D_2$

We obtain:

$j_{eI} = (D_1+ \Delta D_1)-(D_2+ \Delta D_2)$ (7)

On the other side:

$\Delta D_1 = D_1 \cdot \alpha_{1c}(T_c-T_0); \Delta D_2 = D_2 \cdot \alpha_{2p}(T_p-T_0)$ (8)

Where: α_{1c}-the cylinder material linear thermal extension coefficient;
α_{2p} –the piston material linear thermal extension coefficient;

For such values the designer determines the design clearance (see Fig.1) according to the formula:

$J_{pI}+\Delta D_1= J_{eI}+\Delta D_2$ (9)

where:

$J_{pI} = J_{eI}+\Delta D_2- \Delta D_1= J_{eI} + D_2 \cdot \alpha_{2p}(T_p-T_0) - D_1 \cdot \alpha_{1c}(T_c-T_0)$

The literature gives values of the admissible dispersion field, for the good performance of the internal combustion engine, for the operating clearance of the piston upper part like:

$J_{eImax}=0{,}003 \times D$ [mm]

$J_{eImin}=0{,}002 \times D$ [mm] (10)

In our case, considering D=100mm, we will have:

$J_{eImax}=0{,}03$ [mm]

$J_{eImin}=0{,}02$ [mm]

Where clearance allowance activity:

$T_{jeI}= J_{eImax}- J_{eImin}\cdot 0,01$ [mm] (11)

If in the above mentioned formula, given for the design clearance, we consider the following values:

$D_1=D_2=100$[mm]-nominal level of the bore and shaft making the cylinder-piston nozzle;

$\alpha_{1c} =10\cdot 10^{-6}$l/°C-the cylinder material linear thermal extension coefficient [2]

T_{2p}=325°C-the temperature considered for the piston head;

T_{1c}=180°C-the operating temperature of the cylinder [2];

And also the linear thermal extension coefficients determined, at samples' heating, through dilatometrical analysis [2],[4]

$\alpha_{12T} =23.08\cdot 10^{-6}$l/°C (for the treated);

$\alpha_{12N} =22.78\cdot 10^{-6}$l/°C (for the not treated);

We can proceed to the calculation of the design clearance values for the 2 states of the alloy (tab.1)

Tab.1 Values of the piston-cylinder nozzle design clearances calculated with α initial (α_i)

Nozzle type	State	Maximum design clearance J_{pImax}[mm]	Minimum design clearance J_{pImin}[mm]	TJ_{pI}
$ATSi_{12}CuMn$	treated	0,574	0,564	0,01
	not treated	0,564	0,554	0,01

In reality, the piston preserved at 325°C, or during operation inside the engine (long term) "regains" its dimensions based on another value of the linear thermal extension coefficients, noted α_f according to the alloy and heat treatment.

$\alpha_{f2T} =22.25\cdot 10^{-6}$l/°C (for the treated)

$\alpha_{f2N} =22.55\cdot 10^{-6}$l/°C (for the not treated)

And for which the values of the J_{pII} resettled design clearances are being calculated, values given in table 2.

Tab.2 Values of the piston-cylinder nozzle design clearances calculated with α final (α_f)

Nozzle type	State	Maximum design clearance J_{pImax}[mm]	Minimum design clearance J_{pImin}[mm]	TJ_{pI}
$ATSi_{12}CuMn$	treated	0,548	0,538	0,01
	not treated	0,557	0,547	0,01

Comparing the data obtained through calculation with α_i (tab.1) to those from (tab.2) obtained through α_f, the differences of the design clearance values come out (tab.3).

Tab.3 Values the differences of the design clearance values come out [mm]

Nozzle type	state	$J_{pImax} - J_{pIImax}$ [mm]	$J_{pImin} - J_{pIImin}$ [mm]
$ATSi_{12}CuMn$	treated	0,026	0,026
	not treated	0,007	0,007

3. Conclusions:

Based on the analysis of the data from Table 3 the following conclusions result:

The clearances calculated at cold using the stabilized thermal extension coefficients α_f allow the execution of tighter nozzles (clearances at cold with lower values) because ($\alpha_f < \alpha_i$) have lower values than α_i with over 0.001mm.

As a consequence of point 1, it is mandatory that the pistons will be submitted to stabilization annealing HT (which, let us admit, is already done in engineering works, only that the regime is not the most favorably chosen, as heating at 225°C is recommended with preservation of 10 hours). In this case we can appreciate that the most favorable conditions for the completion of total dissolution (separation) processes of basic addition formations (F_{Ea}) or of inter-metallic compounds (I.C.) are not achieved.

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