Bulletin of the Transilvania University of Braşov • Vol. 2 (51) – 2009
Series I: Engineering

THE INFLUENCE OF THE AIR-SIDE FIN PITCH ON THE OVERALL PERFORMANCE OF RADIATORS FOR THE AUTOMOTIVE INDUSTRY

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Abstract: *This paper contains experimental research conducted for a large number of automotive radiators. The heat-exchangers were identical with the exception of the air-side fin pitch, which was varied. Focused on heat-rejection and pressure-drop variance, the study yielded design recommendations.*

Key words: *radiator, fin pitch, automotive, efficiency, heat rejection, pressure drop*

1. Introduction

On the matter of selecting the right heat exchanger from among several possible designs, the device of choice is the one that achieves the required heat rejection ($\dot{Q}$) with minimum energy consumption (P) for fluid circulation, while occupying the smallest space (V - volume). A certain device cannot fulfill all these requirements at the same time. A diminished heat exchanger volume can be obtained either by increasing the circulation speed of the two fluids (for an existing device), or by altering the heat transfer surfaces, i.e. decreasing the fin pitch. Nevertheless, both methods lead to higher energy consumption for fluid circulation.

2. Comparison Criteria

In order to conduct an accurate comparison of heat exchanger thermal and fluidodynamic performance, standard practice tends towards expressing the volumetric efficiency variance as a function of energy efficiency.

$$\varepsilon_v = f(\varepsilon_e) \tag{1}$$

- Volumetric efficiency, ε_v:

$$\varepsilon_v = \frac{\dot{Q}}{\Delta t_m V} = \frac{kA}{V} \ \text{[W/m}^3\text{K]} \tag{2}$$

- Energy efficiency, ε_e:

$$\varepsilon_e = \frac{\dot{Q}}{\Delta t_m \cdot P} = \frac{k \cdot A}{\dot{V}_1 \Delta p_1 + \dot{V}_2 \Delta p_2} \ \text{[W/WK]} \tag{3}$$

where: $\dot{V}_i$ and Δp_i (i=1,2) represent volumetric flow-rate and pressure drop of the two fluids.

Relevant conclusions can be drawn even though this last criterion can be accurately

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applied only for heat exchangers with the same thermal power $\dot{Q}/\Delta t_m$ at the imposed flow rates $\dot{V}_1$ and $\dot{V}_2$.

3. Experimental Research

In order to assess thermal and fluidodynamic performance, the engineers at RAAL Bistrita designed and manufactured several aluminum radiators with identical frontal dimensions (Fig.1.); the devices featured rectangular water ducts and air channels fitted with wavy fins (Fig.2.) of different pitch sizes: 3.5, 4, 5 and 6.5 mm. The thickness of the core is G=30 mm and the fin height is h=8 mm, both constant.

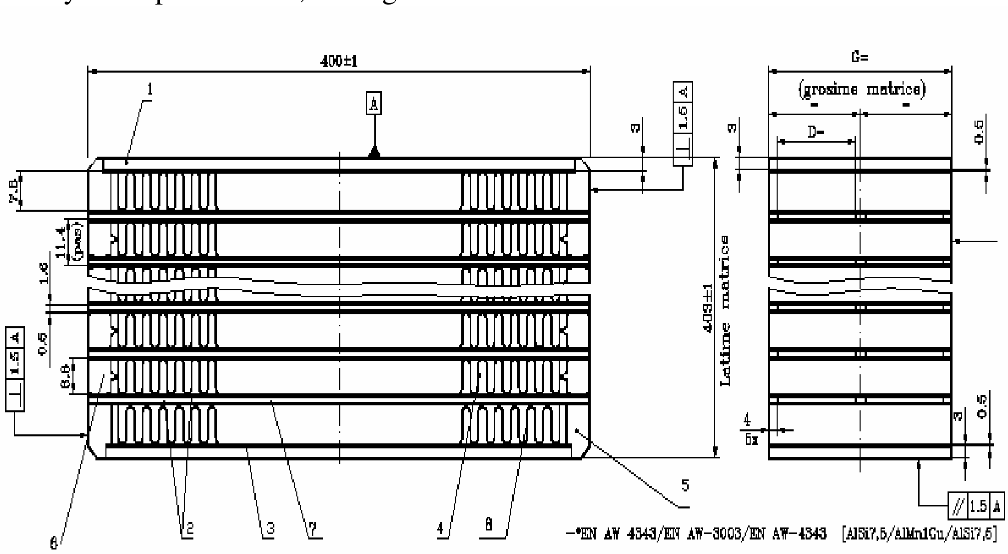

Fig.1. *Coolers for testing*
Legend:1,-lateral wall ,2,3-separator plates, 4-fin, 5 –spacer, 6-air spacer, 7-water spacer

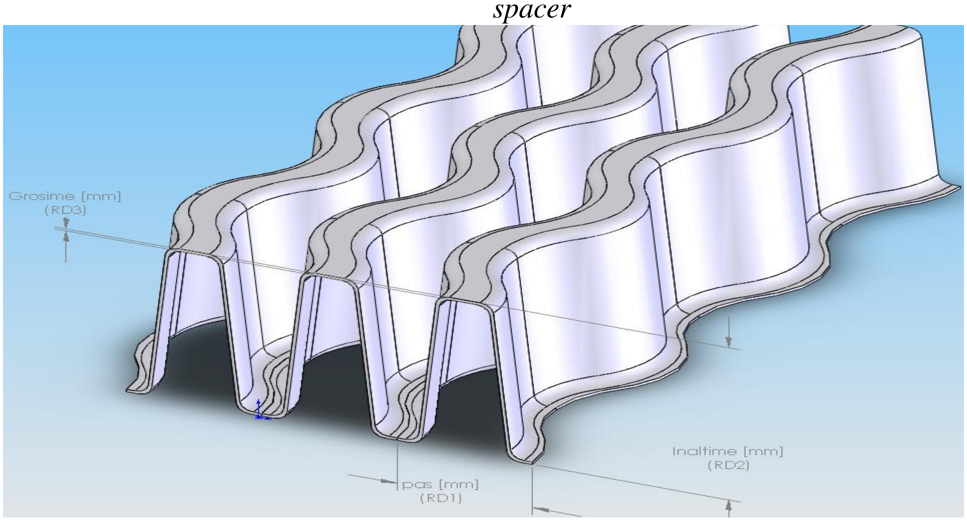

Fig.2. *Wavy fin featured on the radiators tested*

This is how four heat exchangers with different thermal transfer surfaces were obtained. The tests were performed on

RAAL's own testing rig, designed and fitted with top quality European-standard equipment.4. Processing the Raw Data

With the gathered data the following curves were plotted:

- the respective heat rejections plotted as a function of air flow-rate through the four tested radiators (Fig.3.);
- air-side pressure drops plotted as a function of air flow-rate (Fig.4.)
- volumetric efficiency variance plotted as a function of energy efficiency (Fig.5.)

In an actual situation, for different kinds of heat exchangers which are all able to achieve the target heat rejection at certain fluid flow-rates, the best solution from an economical point of view is spotted immediately: the device that provides the highest energy efficiency while maintaining the same volumetric efficiency.

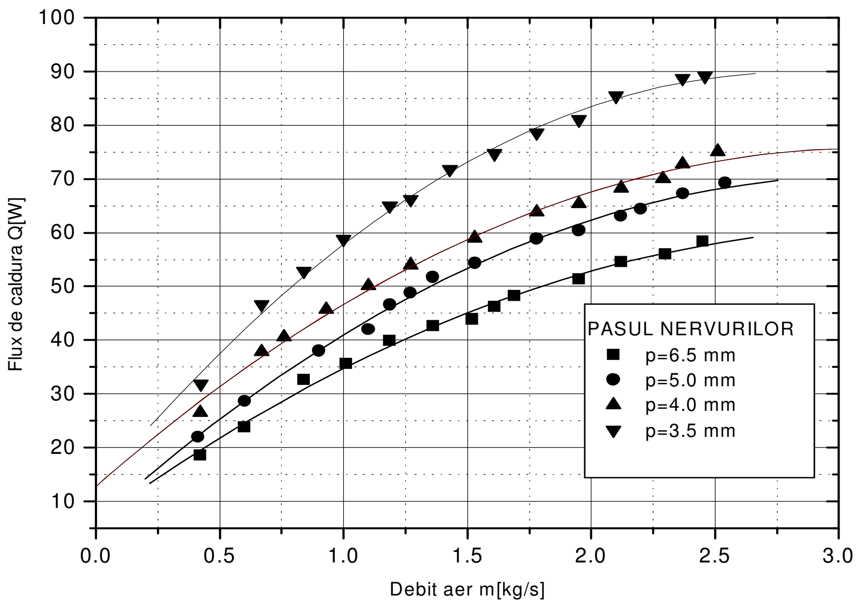

Fig.3. *Heat rejection variance as a function of air flow-rate*

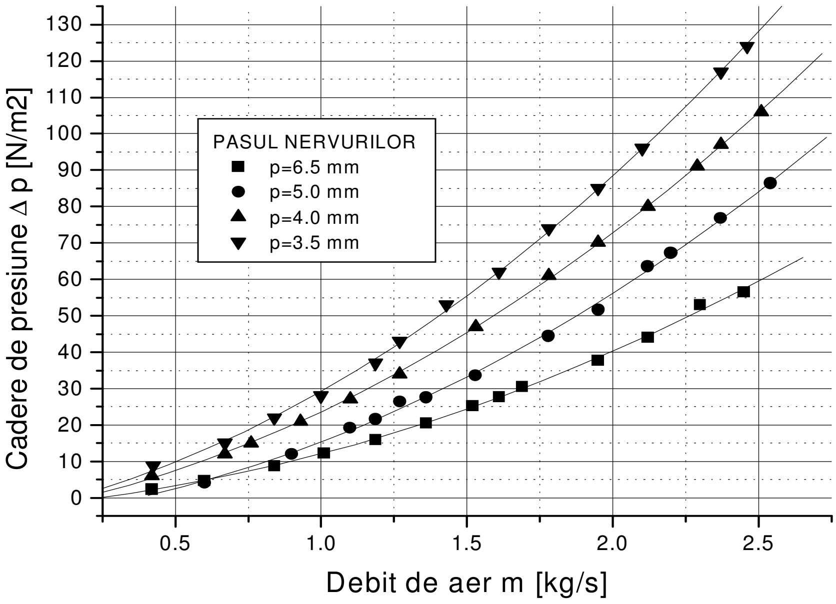

Fig.4. *Air-side pressure drop as a function of air flow-rate*

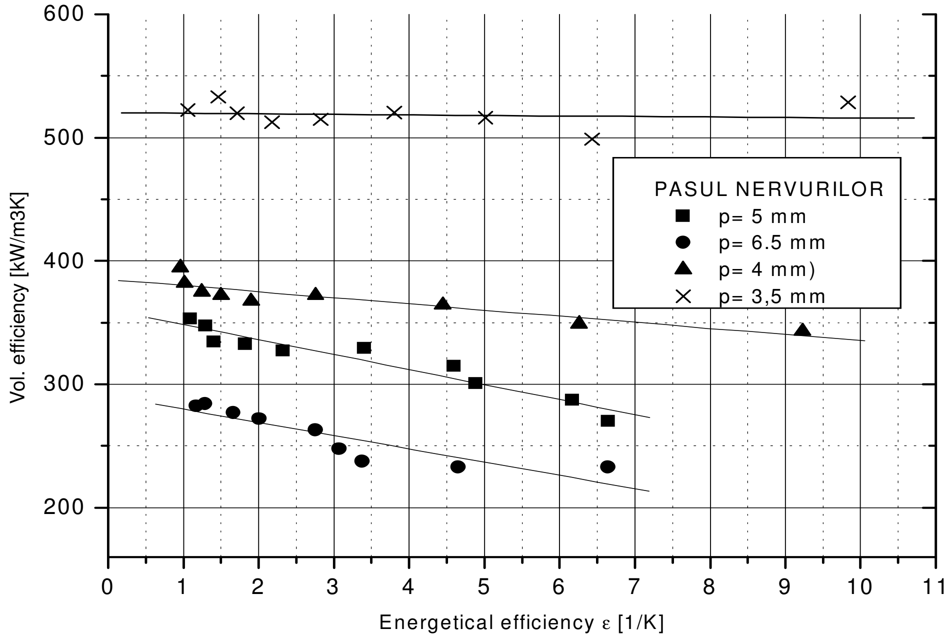

Fig.5. *Volumetric efficiency variance as a function of energy efficiency*

5. Conclusions

An analysis of the data presented above yielded the following conclusions:

- the heat rejection parameter rose while the air fin pitch was decreased, which was to be expected due to the increase in thermal exchange surface (denser fin area)
- the pressure drop parameter increased proportionally while decreasing the fin pitch, because the flow area diminished consequently.

In our case, from an economical point of view, the best solution was the thermal transfer surface featuring a fin pitch p=3.5 mm, because at the same energy efficiency value the volumetric efficiency parameter was higher. However, the designer is usually bound to take into consideration the pressure drop factor [5,6], an important characteristic that is sometimes critical for choosing the suitable constructive solution. Fan noise is also another factor that lately has to be taken into consideration more and more [7].

The research led to the conclusion that the results presented in the industry established works can be applied strictly to those types of fins depicted by the authors and with the specified dimensions. Each actual case requires thorough research and study, both theoretical and experimental, like the one presented above, and still taking into account the boundaries set by the customer.

References:

1. Hewitt, C.F.: *Heat Exchanger Design Handbook*. New York. Begell House Inc, ,1998
2. Ilies, P., Nagi, M.,. Martian, V. *New compact systems for optimising the cooling groups used in industrial machines.* In: Bulletin IPIasi, Tomul L(LIV), Fasc.6C, S. Const. De . Mas. 2004. p. 3-12.
3. *** *Herstelle von Kuhlern und Warmeaustauschern weltweit*, AKG, catalog, 2004*.
4. Ilies, P., Nagi, M,. Martian, V.: *Trends of more compact cooling systems for vehicles and self driven cars equipped with diesel engines.* In: The 10th International.Congres Conat 2004, Brasov, 2004.
5. Nagi, M., Ilies, P., Martian, V.: *Critical considerations regarding the generalization of the results that were obtained at the oil-air coolers testing*. In: Bulletin IPIasi, Tomul L(LIV), Fasc.6C, S. Constructii De . Masini 2004. p. 133-138.
6. Nagi, M., Ilies, P., Martian, V.: *Cercetări experimentale privind performanțele răcitoarelor combinate tip shell,* Constanta, 2005.
7. Ilies, P., Nagi, M,. Martian, V.: *New constructive solutions for noise attenuation on cooling systems for industrial machines.* In: Conferinta Stability Pact cu participare internationala, Timisoara, Vol 2,. 2005 p.121-124
8. Nagi, M, Iorga, D, et al: *Schimbatoare de caldura*, Vol I, Timisoara,. Mirton, 2006
9. Nagi, N, Laza, I, Mihon, L: *Schimbatoare de caldura*, Vol II, Timisoara . Mirton, 2007