UDC 536.2.083

M. Nosov,
postgraduate student
Zaporizhzhya State Engineering Academy,
Zaporizhzhya
e-mail: nosovmak@gmail.com

RESEARCH OF THE THERMAL CONDUCTIVITYIN METAL SAMPLES WITH DIFFERENT PERFORATION FORMS

Introduction

The porosity in metals has been perceived only as a negative factor for a long time, which reduces the mechanical properties and tightness of the material. For preventing and blocking the negative effects of porosity in metals were dedicated a lot of scientific works, some of them are used in present time [1-3].

Despite the negative impact of porosity, porous metal materials found their usage in various fields: in the aerospace industry, as titanium and aluminum sandwich panels; in medicine as implants in humans [4]; in shipbuilding as a body for passenger vessels; in the automotive industry as structural elements [5-7]. Prevalence of porous metallic materials is caused by their unique physical and mechanical characteristics, such as high stiffness in combination with a very low density (low specific gravity) and / or high gas permeability combined with a high / low thermal conductivity [8]. Such materials globally divided on three types: porous metals [9]; metallic foams [10, 11] and cellular metals [12]. Each category has its unique porosity parameters and methods of production.

In spite of the unique characteristics and prevalence, porous metal materials is still haven't unified theory of dependence of the effective thermal conductivity from the parameters of porosity (pores location, pores form, their size, etc.). The aim of this work is to investigate the influence of a combination of factors (form, size and position of pores) in the porous metal material on the thermal conductivity.

The main part of research

For research was chosen the computer modeling method. It is due to the fact that the manufacturing of metal samples with precise form and pores location is extremely difficult and can lead to significant errors of experimental results. Also computer method allows to fully elimination of the convective and radiation components.During the simulation of the thermal process, heat flow was routed from one side and was uniformly allocated on the surface. The heat flux was 0,1 W, the heating time was 1 second. Such period of time is simplifying the calculation process. The initial temperature of the samples was 20 °C. The heat transfer coefficient was 23 W/m^2·K, ambient temperature was 20 ° C. The convective surface was located opposite the heating surface. All other surface were adiabatic. Size of mesh was 0,0004 m. The number of elements was over 250000.

Thermal process which was modeled gave us temperature of heating surface and temperature of opposite surface in the last moment of time. Due to parameters which were taken from experiment, we can calculate coefficient of thermal conductivity using the following formula

$$\lambda = \frac{Q \cdot l}{\left(T_2 - T_1\right) \cdot S},$$

where $l - ¿$ sample length;

$Q - ¿$ heat flow which was routed;

T_1, T_2 – temperatures of heating and opposite surfaces;

S – cross sectional area of sample.

For investigation of influence of the perforation form on the thermal conductivity, were created samples with the holes of the following forms: circle, ellipse, square, equilateral triangle and hexagon.The holes sizes were selected in such way that their cross-sectional areas were the same and were equal $1{,}13094 \cdot 10^{-4}$ m^2. The material was the same as in previous experiment. The holes were located in-line and staggered, the distance between the centers of the holes are the same in all cases. Parameters of thermal process were identical to the previous. Figure 1 shows the temperature allocation in the samples.

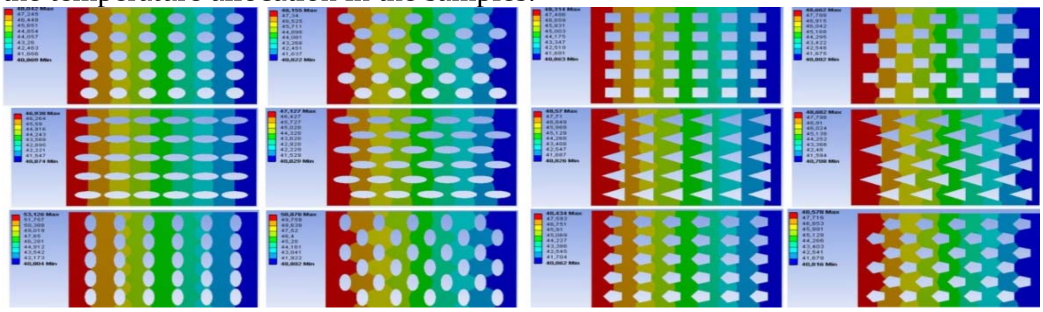

Figure 1 – Allocation of temperature in the samples

By results, which were obtained during the experiment under samples with different perforation forms, was built diagram of the thermal conductivity coefficients for the samples with different perforation forms (Fig. 2).

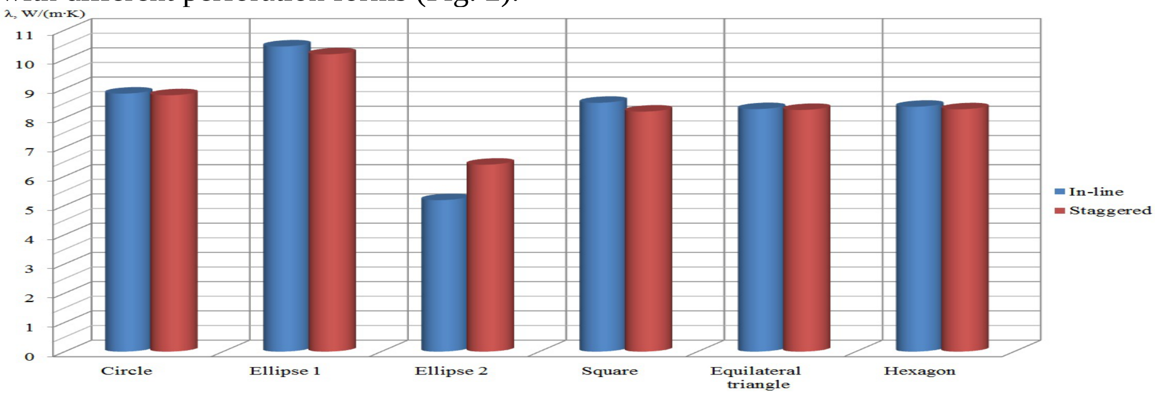

Figure 2 – Thermal conductivity coefficients for the samples with different perforation forms

Conclusions

The results which was found in this research give the opportunity to make next conclusions:

1. On the thermal conductivity (without radiation and convective component) has a greater effect holes form, rather than their location (at the same porosity).
2. When we used holes form of ellipse with staggered location, perpendicular and parallel to the heat flow, difference of thermal conductivity was 59%.
3. When we replaced holes form of circle to ellipse located perpendicular to the heat flow, thermal conductivity reduced by 27%.
4. The difference between staggered and In-line location of circular holes was 0.66%.
5. The best for thermal insulation materials are holes form of an ellipse which located perpendicular to the heat flow. In this case, if the holes have in-line location, thermal conductivity will be smaller. This result is explained by the smallest distance between the holes, which leads to a bigger dispersal of heat energy.
6. Thermal conductivity in the samples with perforation forms of a square, equilateral triangle and hexagon very closed to each other and smaller than at form of circle on 3,56-6%.
7. Since the impact of holes location on the thermal conductivity is very small, follows the conclusion that it’s necessary to focus on the study of influence of the pores form and porosity as a whole.

REFERENCES

1. *Gunasegaram D. R., Farnsworth D. J., Nguyen T. T. Identification of critical factors affecting shrinkage porosity in permanent mold casting using numerical simulations based on design of experiments // Materials Processing Technology. 2009. Vol. 209. P. 1209-1219.*
2. *William van Grunsven Porous metal implants for enhanced bone ingrowth and stability / Thesis submitted to the University of Sheffield for the degree of Doctor of Philosophy.Department of Materials Science and Engineering.September 2014.*
3. *Aluminium foams as a filler for leading edges: Improvements in the mechanical behavior under bird strike impact tests / J. A. Reglero, M. A. Rodriguez-Perez, E. Solorzano, J. A. de Saia // Materials and design. 2011. Vol. 32. № 2. P. 907-910.*
4. *Lepeshkin I. A., Ershov M. Ju. Vspenennyjaljuminij v avtomobilestroenii // Avtomobil'najapromyshlennost'. 2010. № 10. P. 36-39.*
5. *KrupinJu. A., Avdeenko A. M. Sil'noporistyestruktury – novyjklasskonstrukcionnyhmaterialov // Tjazheloemashinostroenie. 2008. № 7. P. 18-21.*
6. *Tehnologicheskieprocessy i materialy. 2012. – P. 181-184.*
7. *Fractal dimension of pore-structure of porous metal materials made by stainless steel powder / H. P. Tang [et al.] // Powder Technology. 2012. Vol. 217. P. 383-387.*