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Temperature distributions in a copper and aluminium layered base of a CrNi-steel saucepan

Tahir Ayata *

Department of Mechanical Engineering, Kırıkkale University, 71451 Yahşihan/Kırıkkale, Turkey

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Abstract

The local temperature-distribution influences the amount of heat moving into or out of a body. In order to get the benefits of a multilayered structure when a constant temperature is required on one side of a metal plate with the other side heated irregularly, a variation between the thicknesses of the layered structure is needed. In the case of kitchenware products, where one side of the saucepan is heated irregularly, however, a constant temperature distribution is required on the other side.

In this study, the main objective is to find a numerical solution to the problem of non-regular distribution of temperature on the "non-heated" side of an irregularly-heated plate by means of placing two layers of Cu/CrNi and Al/CrNi of varying thicknesses in a combined structure. For this aim, the Finite-Element Method program package ANSYS has been used. The Al/CrNi laminated plate has a low temperature-gradient distribution on its upper (or "non-heated") surface due to its low heat conductivity compared with that of the Cu/CrNi steel.

Keywords: Anisotropy; Heat conduction; Layered plate; Temperature distribution

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* Tel.: +90 3183573571x1083; fax: +90 3183572459.
E-mail address: tahirayata@hotmail.com (T. Ayata).

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Nomenclature

F	layer thickness ratio, m/m
k_1	thermal conductivity of material 1, W/mK
k_2	thermal conductivity of material 2, W/mK
K_{I}	thermal conductivity in x direction, W/mK
K_{II}	thermal conductivity in y direction, W/mK
t_1	thickness of material 1, m
t_2	thickness of material 2, m
T	temperature, °C
x, y, z	rectangular coordinates, m

1. Introduction

A saucepan made from a single material when heated by an open flame, develops hot spots that can locally burn its contents. That is because the saucepan is thin, and heat is transmitted through the thickness more quickly than it can be spread transversely to bring the entire inner pan-surface to a uniform temperature [1]. It is also desirable to have accurate predictions of the surface temperature of food products during cooking. In order to get the benefits of a multi-layered structure when a constant temperature-distribution is required on one side of a metal plate with the other side heated irregularly, variations of the thicknesses of the layered structure are needed.

The metals of which saucepans are usually made – cast iron, duralumin or copper – have isotropic thermal conductivities whereas what we clearly want is a thermal conductivity that is higher in the transverse direction than in the through-thickness direction. A bi-layer (or multilayer) hybrid can achieve this. In the case of kitchenware products, where one side of the saucepan is heated irregularly, however, a uniform temperature distribution is required at the other side [2,3]. To overcome these problems, and to obtain a high thermal conduction value, composite materials have been developed, new material structures have been introduced [4] and numerical optimizations have been accomplished with respect to the temperature distributions of the layered plates [5].

While in materials, such as steel, large temperature-gradients occur [1,6,7], among materials such as copper under a similar heat flux only small temperature-gradients ensue [8]. The target of a constant temperature-distribution on the non-heated side of a plate may be realized by using a layered structure with materials of varying thicknesses and different thermal conductivities, e.g., copper and cast iron [9]. In another study, the copper and St-304 steel layers were pressed together for 30 minutes under a pressure of 12 MPa at 800 °C [10].

With the highly-conductive material, all the surface is approximately at the same temperature. On the other hand, the less-conductive material is warmer close to the heat source, but is much cooler elsewhere. In this study, the main aim has been finding a solution to the problem of non-uniform distribution of temperature on the