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Effects of chamber shapes of porthole die on elastic deformation and extrusion process in condenser tube extrusion

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Abstract

This paper describes a 3D FEM simulation of porthole die extrusion process for producing condenser tubes used for a cooling system of automobiles. In general, condenser tube is mainly manufactured by the conform extrusion method, but this process is less effective as compared with the direct extrusion method in productivity per unit time and in the equipment investment. Therefore, it is essential for the conversion to the direct extrusion with porthole die that can produce condenser tube with competitiveness in costs and qualities compared with the existing conform extrusion. However, an experimental method to quantify the deformation behavior of porthole die for condenser tube extrusion has not been established yet, due to its complicated die assembly and complexity of metal flow. FEM is a good alternative to evaluate the three-dimensional deformation behavior of metals in condenser tube extrusion. Especially, an understanding of metal flow in porthole die extrusion is important, because it provides necessary information in die design for high performance extrusion. This study was designed to evaluate material flow, welding pressure, extrusion load, and the tendency of mandrel deflection that is affected by variation of chamber shape on porthole die. An estimation was carried out using FE analysis in non-steady state. Also, this study examined into the mandrel fracture behavior through investigating elastic deformation of mandrel during the extrusion.
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Keywords: Extrusion; Welding pressure; Porthole die

1. Introduction

Recently, a condenser tube, used for a cooling system of automobiles, is mainly manufactured by the conform extrusion method. The conform extrusion process provides outstanding features including extrusion of long seamless products, high extrusion ratio, no pre-heating and post-mechanical treatments, but this process is less effective than the direct extrusion method in productivity per unit time and in the equipment investment. Moreover, conform method may not supply condenser tubes for home appliances market that is growing into the major market of the cooling system hereafter. Therefore, it is essential for the conversion to the direct extrusion with porthole die. The direct extrusion with porthole die can produce condenser tube with competitiveness in costs and qualities compared with the existing conform extrusion [1].

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In general, porthole die extrusion has a great advantage in the forming that produces the hollow sections, which are difficult to produce by the conventional extrusion methods with a mandrel on the stem. The product with hollow section can be extruded using special dies based on welding chamber with spider die, porthole die, bridge die, etc. Billet in the container flows through the porthole and welds by high pressure in the welding chamber. This process is suitable only for aluminum and some of its alloys because of their capacity for pressure welding. Lubricants cannot be used as they prevent rewelding during extrusion.

Aluminum condenser tube is below 0.5 mm in thickness and has a hole for a way of refrigerants in the section. Materials of multi-cell tube are mainly used Al or Cu alloy that have a good heat efficiency because of the characteristics of a cooling system. Also, it is structurally designed in thin thickness and multi-cell shape to improve the heat efficiency.

In general, because of this shape, condenser tube extrusion has complicated conditions in manufacturing with the direct extrusion method. For example, extrusion rate is being shown maximum (1400–1700:1) over normal range (40–70:1), also, the range of dead metal zone in condenser tube extrusion is bigger than other products in die. In order to overcome these problems, a choice of die, and billet material as well as extrusion process resulted from the change of materials and die condition according to working temperature are very important variables which have to be considered.

Especially, a condenser tube manufactured by porthole die is a sophisticated part, and requires a tight dimension tolerance and a good surface finish than any other parts. In the present day, main objectives of the development of condenser tube used in heat-changer for a cooling appliances are lightweight, the subminimizing of the multi-cellize, the flatten, and the minimizing of pin [2–4]. Thus, in order to obtain the detailed material flow, to assist in the design of proper die shape and size, and to improve the quality of products, in the first place, it is important to understand the metal flow. However, experimental methods to quantify the deformation behavior of porthole die for condenser tube extrusion has not been established yet, due to its complicated die assembly and complexity of metal flow. FE analysis is a good alternative to evaluate the three-dimensional deformation behavior of metals in condenser tube extrusion.

For above mentioned reasons, this study was designed to evaluate material flow, welding pressure, extrusion load, the tendency of mandrel deflection that is affected by variation of chamber shape and extrusion speed in porthole die. An estimation was carried out using FE simulation in non-steady state. Also, this study examined into the mandrel fracture behavior through investigating elastic deformation of mandrel during the extrusion. In order to confirm the general metal flow of porthole die extrusion, the 3D FE analysis was performed on hot porthole die extrusion in non-steady state by using DEFORM 3D, and a pattern of elastic deformation was investigated on porthole die through the stress analysis using ANSYS 5.5 during extrusion process.

2. FE analysis of porthole die extrusion

2.1. Extrusion parameter and FE model of porthole die

The success of condenser tube extrusion depends not only on mechanical property of material, but also on the condition under which deformation occurs such as temperature, strain, strain rate and die geometry. In order to obtain condenser tubes with better quality, understandings on the pattern of mandrel deflection and metal flow through a porthole, welding chamber, and die bearing during extrusion are of great importance to run the condenser tube extrusion process, because they are closely related to the quality of condenser tube.

In general, condenser tube used to be the main part of heat exchanger has several fine holes to be able to flow refrigerant in the section and the wall thickness is below 0.5 mm. In this study, as shown in Fig. 1, the shape of condenser tube is assumed to be five holes and all of uniform thickness walls of 1.8 mm. Also, the section was built in symmetrically.

There is a dimension of porthole dies for the FE analysis of condenser tube extrusion as shown in Fig. 2. Porthole die is composed of container, porthole, mandrel and chamber. Although this is similar to the typical hollowness porthole die typically, this is characterized by harmonica-shaped mandrel to extrude the tube.

In order to understand the effect of chamber shape in porthole die during die elastic deformation and extrusion process in condenser tube extrusion, three different porthole die models with the same exit shape are designed and suggested. First, the height of chamber is 10 mm (Flat 10 mm). Second, the height of chamber is 15 mm, finally, the height of chamber is 10 mm with 10° inclination between chamber bottom and die bearing part. The length of die bearing part was assumed to be 4 mm in consideration of thickness wall (1.8

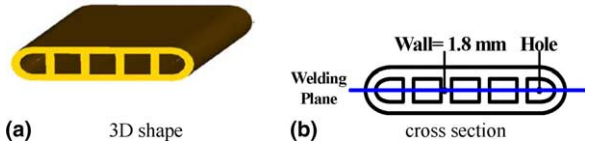

Fig. 1. Model of condenser tube: (a) 3D shape and (b) cross-section.

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