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Process analysis and die design in 12 cells condenser tube extrusion of Al3003

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ABSTRACT

Condenser tubes are mainly produced by precision extrusion with a porthole die and are used to allow flow in refrigerant cooling systems in automobiles. To produce condenser tubes, the recent goal has been to develop a tube that has high strength to allow for multi-cellizing and flattening, and to minimize the wall thickness, and to increase the heat transfer area and heat efficiency. This study was designed to produce Al3003 condenser tube for industrial production, including extrusion die design, inspection of die design through the results of FE simulation and performance of trial extrusion. Chamber shape dimension and initial temperatures of tool and die were variables and the possibility of extrusion was estimated from the forming load, welding pressure, and stress analysis of die in this paper. The validity of the simulated results was verified by extrusion experiments on the condenser tubes.

1. Introduction

The Al 1000 and 3000 series have generally been used for condenser tubes because of their excellent heat efficiency and corrosive resistance. Condenser tubes are mainly produced by precision extrusion with a porthole die and are typically used in the flow pass of refrigerant cooling systems in automobiles. For condenser tubes, the recent goal has been to develop a tube that has high strength for multi-cellizing, flattening and minimizing the thickness of its walls so that the heat transfer area and efficiency are increased. Consequently, it has a harmonica-style sectional shape of multi-cells and thin walls. In general, high tube strength can be achieved by using alternative materials and strengthening the cross-section design of the tubes, although the mechanical properties of the materials limit the increase in strength that can be achieved.

This study was designed to produce Al3003 condenser tube that could be industrially produced. Consequently, the die design was extruded and evaluated using FE simulation and a trial extrusion (Xie et al., 1990; Kim et al., 2005). In order to improve the productivity and quality of the tube, the exit speed of the extruded tube had to increase and the exit temperature had to be within 600 °C. However, increasing the ram speed was difficult without changing the condition because the maximum load capacity of extruder used in this study is 1250 t. Thus, process and design parameters such as the outlet temperature of extrusion product lower than 600 °C have been kept, and the speed of product has been increased for higher productivity. Variables in this paper are the dimensions of the

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chamber shape and the initial temperature of the tool and die. In porthole extrusion, the most important point is welding strength which has the greatest effect on the mechanical properties and aspects of the products because the neighboring billets are welded together. This welding pressure is the most important point. To increase welding strength, the metal has to flow properly so an Al alloy with good extrudability and superior mechanical properties has to be developed. Welding strength is affected by many parameters, such as extrusion ratio, extrusion speed, die shape, bearing length, billet, and container temperature.

The subject of this research is Al3003 12 cell condenser tube which can be produced by porthole die extrusion. The flow conditions of the porthole die extrusion of the condenser tube and the welding pressure of the billet in the chamber have been estimated by the rigid-plasticity finite element method. The elastic strains of the porthole die have been estimated by the means of stress analysis. The validity of the simulated results was verified by extrusion experiments on the condenser tubes.

2. FE analysis of porthole die extrusion

2.1. FE model of porthole die extrusion

In general, the condenser tube used as the main part of heat exchanger has several fine holes for refrigerant to flow into the section and, the thickness of its walls is less than 0.3 mm. In this study, as shown in Fig. 1(a), the shape of the condenser tube is assumed to be 12 cells and thickness of the wall is 0.3 mm. The designs are designated by their width, thickness, and number of voids, i.e., 14 mm × 1.2 mm × 12 mm cells. The section was built symmetrically. The aluminium alloy used for this work was Al3003, a common industry alloy. Fig. 1(b) shows schematic of porthole die.

Fig. 1(c), (d) and (e) shows the constructions of the porthole die used in this paper. The porthole die is composed of the container, porthole, the mandrel and the chamber. Although it is similar to the typical a hollowness porthole die typically, this is characterized by harmonica-shaped mandrel to extrude the tube.

2.2. Condition of FE analysis

Al3003 and hot tool steel (H-13) were used as material for condenser tubes and the porthole die used in simulation. And the material of mandrel is used to WC. The initial temperature of the tools and billet were 450 °C. The ram speed assumed a material speed of approximately 1000 mm/s in the die bearing part of the porthole die. The friction factor is assumed to be a constant of 0.6 in the interface between the punch die and billet (SFTC, 1995). It is used in common non-lubricant aluminium extrusion processes. The billet size is Φ152 mm × h150 mm. The FE simulation is used 1/4 section of the billet and porthole die because the struc-

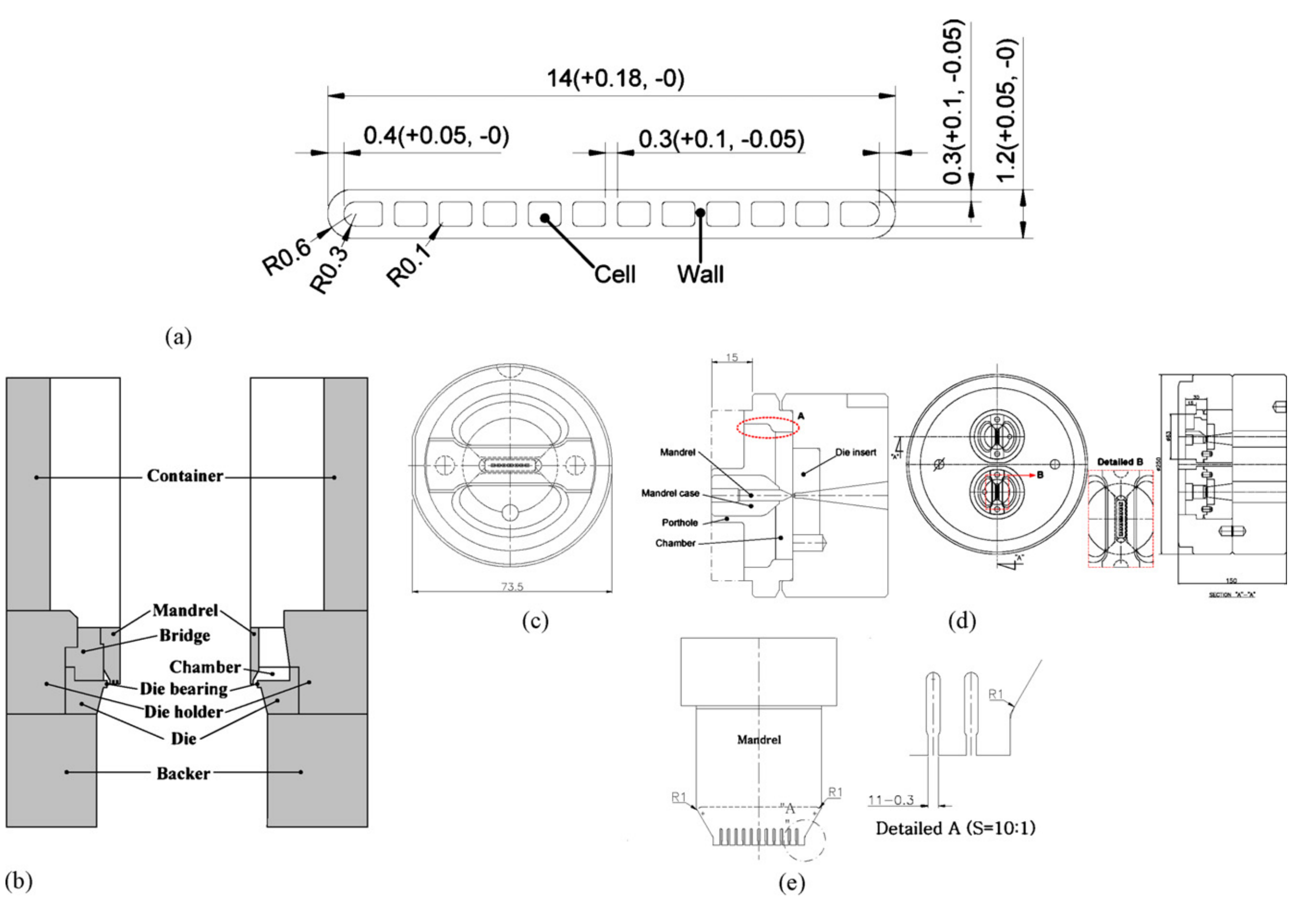

Fig. 1 – Condenser tube shape and constructions of porthole die. (a) Shape of required dimension and specific composition of condenser tube, (b) Schematic of porthole die, (c) Bridge and die, (d) Backer and LIP and (e) Mandrel.