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Effect of process parameters on sheath forming of continuous extrusion sheathing of aluminum

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Abstract: The effect of flow passage length in the die cavity and extrusion wheel velocity on the shape of aluminum sheath during the continuous extrusion sheathing process was analyzed by using finite element methods based on software DEFORM 3D and experimentally validated. The results show that by increasing the flow passage length, the velocity of metal at the cross-section of sheath tends toward uniformity, the values of the bending angles of sheath gradually approach the ideal value of zero and the cross-section exhibits a better shape. The extrusion wheel velocity has negligible effects on the bending shape and cross-section of the sheath product when a long flow passage is used.

Key words: continuous extrusion sheathing; aluminum sheath; sheath forming; die design; extrusion wheel velocity; finite element

1 Introduction

The continuous extrusion aluminum sheathing process based on the continuous extrusion technology presents the advantages of high efficiency and substantial energy conservation. This technology uses the frictional forces generated between the wheel and feedstock as the driving force to continuously produce products of unlimited length. The continuous extrusion sheathing process can produce aluminum sheath as a loose fit around a core cable, and this process is called the indirect cladding process [1,2]. Continuous extrusion sheathing technology is an ideal production process for fabricating external protection for cable sheaths, which is one of the key factors to ensure the cable service life [3]. With the increase of electricity consumption, more and more high voltage cables with large section are needed [4]. Hence, it is necessary to research that how to produce larger section and better quality of the cable aluminum sheath. As shown in Fig. 1, a rotational extrusion wheel has two grooves in its periphery, which accommodates two aluminum rods and transfers the metal to the fixed chamber. In the chamber, the plasticized aluminum from two grooves converges and is welded around the mandrel before exiting from the die in the form of a near-seamless tube. Meanwhile, the core wire is fed through the hollow mandrel in the tangential direction, and the aluminum tube is wrapped loosely around the cable core for fabricating into a sheathing product.

The geometry of the die chamber is complicated. Thus, metal flow during the entire continuous sheathing process is complex. The current understanding of metal flow in the continuous sheathing process is mostly based on the earlier research conducted with basic experiments, photo plastic simulation, and analytical studies. By establishing photo plasticity experimental procedures, the three-dimensional strain distributions in the die chamber were obtained [5,6]. Using experimental studies as bases, SONG et al [7] and LIU et al [8] established the theoretical velocity field in the deformation zone and put forward the theoretical expressions related to the geometric parameters of the convergence chamber and homogeneity of metal flow. These methods are constrained when incorporating thermal effects into the process, and therefore have limited practical use in optimizing die design and sheathing extrusion. Few studies that explore the continuous extrusion sheathing

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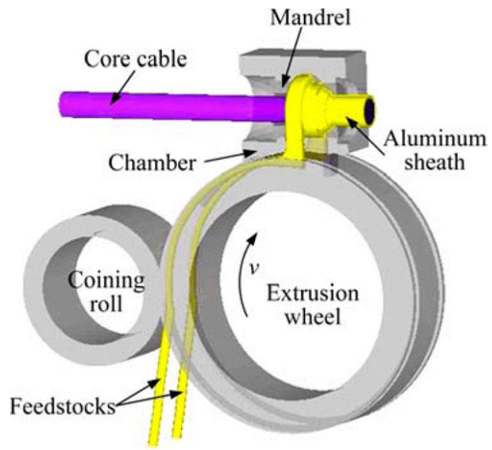

Fig. 1 Principle of continuous extrusion sheathing

process, especially under the 3D finite element mode, have been conducted.

In the continuous extrusion aluminum sheathing process, metal flows through the die bearing tend to bend up or down with an elliptical cross-section, especially for a sheath of large diameter. Difficulty is encountered as the cable core enters the aluminum sheath with a large bending angle. Non-uniform metal flows cause bends and twists at the die outgoing port in continuous extrusion process [9]. ZHAO et al [10] proposed that non-uniform metal flow is caused primarily by the up-down non-symmetrical structure of the die cavity, which can cause different flow resistances and varied temperatures in the die cavity. The current work aims to minimize the bending phenomenon and elliptical cross-section using FEM simulation to select the appropriate combination of die cavity design and process parameters.

In the continuous extrusion process, no pre-heating of feedstock is conducted and the adjustable process parameters are less than conventional extrusion. The extrusion wheel velocity is one of the most important process parameters because it affects the maximum temperature and uniformity of metal flow in the continuous extrusion process. Some researchers studied the influence of the extrusion wheel velocity on the continuous extrusion process by FEM simulation. KIM et al [11] revealed that the wheel driving velocity did not cause remarkable changes on the material flow, unless it reached an extremely high value. CHO et al [12] investigated the influence of wheel velocity on surface defect occurrence, while WU et al [13] analyzed the distributions of effective stress, effective strain, and temperature of copper concave bus bar under different extrusion wheel velocities. This work focuses on investigating the influence of the extrusion wheel velocity on the shape of product.

The die cavities with different horizontal passage lengths were designed and the extrusion wheel velocity was varied. The extrusion velocity, temperature, extrusion wheel torque, bending phenomenon, and cross-section shape of aluminum sheath were predicted and experimentally validated. A production sheath with an external diameter of 45 mm and a thickness of 2 mm was simulated using DEFORM 3D.

2 Design of die cavity with different flow passage lengths

Figure 2 shows the longitudinal section of the flow passage in the die cavity, which is composed of the chamber, mandrel, and dies. The flow passage in the chamber is the space where the metals from different grooves converge, weld, and form the final round shape. Passage length H consists of two parts: H_1 and H_2, where H_1 denotes the horizontal flow passage and H_2 represents the preformed passage. The die cavities with horizontal passage lengths (H_1) of 37, 44, 51 and 58 mm were adopted in the extrusion simulation. When H_1 is changed, the value of H_2 is fixed.

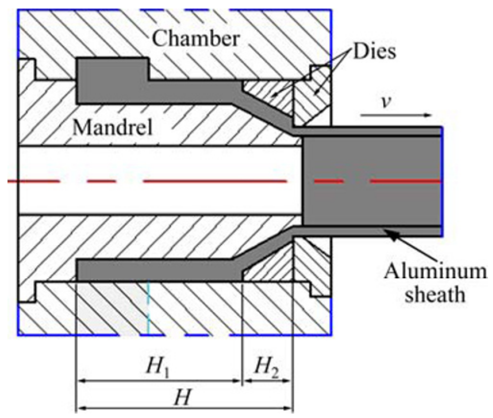

Fig. 2 Schematic diagram of flow passage in die cavity

3 Finite element model

A sophisticated finite element model was employed to investigate the continuous extrusion sheathing process and optimize the tool design by an commercial software DEFORM 3D. The software adopts implicit FEM to calculate the rigid-visco-plastic deformation behaviour of the workpiece incorporated with thermal effects [14]. The material properties of Al 1100 in the DEFORM database were used in the simulations. AISI H13 was chosen for the extrusion wheel, coining roll, mandrel, dies, and chamber. Being the symmetric part, only 1/2 of the geometry was considered in the simulation. The 3D assembly models and meshes used in the simulation are shown in Fig. 3. The core cable was simplified in the simulation, because the process was indirect cladding. An extrusion wheel velocity of 8 r/min was adopted initially.