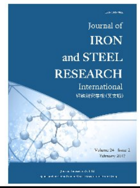
Journal of Iron and Steel Research, International 24 (2017) 138－146

Contents lists available at ScienceDirect

ScienceDirect

Journal of Iron and Steel Research, International

journal homepage: www.chinamet.cn



Characteristics of metal flow in cold extrusion under electric-hydraulic chattering

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ARTICLE INFO

Key words:
Cold extrusion
Electric-hydraulic chattering
Finite element analysis
Material flow

ABSTRACT

An experimental setup for cold extrusion process with electric-hydraulic chattering was developed and its working principle was introduced. The finite element (FE) model for a kind of cup part (material: 20Cr) was built by using the software Deform-3D. FE simulation experiments with and without electric-hydraulic chattering were carried out to analyze the velocity fields and the metal grid flow lines. The extrusion experiments of the cup part were also performed under different conditions. The difference of metal flow lines with and without electric-hydraulic chattering was discussed via a scanning electron microscope (SEM) and the Keyence super-depth three-dimensional microscopic system. The results showed that with the electric-hydraulic chattering, the velocity of material flow increases, whereas deformation resistance decreases. Electric-hydraulic chattering results in easy metal flow, small bending degree of metal flow lines, slender and dense metal grains, and thereby an improved quality of the deformed parts.

1. Introduction

Cold extrusion technology has some advantages such as good mechanical properties, energy saving and low cost. Thus, it has been widely used in the automotive, light, aerospace, military, hardware and other industries. The metal flow during cold extrusion was studied by Kydhakob[1]. The metal flow rule and formation mechanism of extrusion funnel during the extrusion process of brass were analyzed by Schweissguth[2]. Viscoplasticity method was developed by Thomsen et al. [3] by combining the metal flow experiments with stress calculation to deal with plastic deformation theory. Different metal flow characteristics of aluminum during forward extrusion and backward extrusion were presented by Kang[4]. And taking forward extrusion process as an example, the effects of process conditions on metal flow were also discussed. Using finite element (FE) simulation and experimental methods, the effects of mold complexity on metal flow rule and forming dead were discussed by Qamar[5]. Combining experiments (grid method) with FE simulation, metal flow characteristics during plastic forming process were presented by Valberg[6]. These above-mentioned results show that the uniformity of metal flow and rational distribution of the metal streamline during cold extrusion process directly affected the surface quality and mechanical properties of extruded parts, product defect rate and the die life. Good metal streamline can reduce deformation resistance, improve the die life and reduce extrusion defects.

However, enormous extrusion pressure is required to force metal to be plastically deformed at room temperature, which causes huge friction between the blank and the dies. The huge friction increases deformation resistance, resulting in relatively difficult metal flow and machining dead zone possibly formed in the finishing stage. This not only causes processing defects of parts, but also seriously decreases the life of the dies. In recent years, several scientific and effective ways have been developed to solve these problems from “surface effects” and “volume effects” both at home and abroad.

Blaha and Langenecker[7] found that additional ultrasonic vibration can reduce the deformation resistance of a single crystal of zinc during plastic deformation, namely the Blaha effect. Then, several researchers carried out theoretical and experimental researches on the application of vibration during metal plastic processing. The ultrasonic vibration drawing technology was systematically reviewed by

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Received 3 May 2016; Received in revised form 21 October 2016; Accepted 1 November 2016
Available online 15 February 2017
1006-706X/

Gebhardt and Funke[8]. The mechanism of ultrasonic vibration to improve the drawing technology was quantitatively studied by Haysdhi et al.[9]. They found that the maximum stress was significantly decreased when the ultrasonic vibration direction is consistent with the drawing direction or perpendicular to the drawing direction, and it fell even more sharply under the former condition. Based on finite element method (FEM), the effects of extrusion speed, vibration frequency and amplitude, friction coefficient and other parameters on metal flow, stroke load and equivalent strain were presented by Mousavi et al.[10]. Ultrasonic vibration drawing experiments were carried out by Li et al.[11]. And a method was proposed to determine the sound speed, frequency, polarization current and other parameters. Xie et al.[12] also carried out some ultrasonic vibration drawing experiments[12] and found that the drawing force decreased after ultrasonic vibration frequency of 20 kHz was applied on the drawing die, and there was a critical amplitude that led to a significant decrease in the drawing force. At present, vibration plastic processing experiments are mainly carried out for punching, cutting, rolling, and drawing of pipes and profiled materials[13-21], and high-power ultrasonic vibration (called power ultrasonic vibration) is mainly used[22-26].

Cold extrusion processing always needs a huge extrusion pressure, but ultrasonic vibration output force is small. Thus, it cannot effectively transmit vibrations to the mold. Then, a new kind of electric-hydraulic chattering cold extrusion technology is proposed. And mechanism of stroke load reduction after electric-hydraulic chattering has been studied[27-30]. In this paper, a kind of cup part was selected as the research object. Combining FEM with experimental results, the effect of electric-hydraulic chattering on metal flow was proposed.

2. Experimental

2.1. Experimental setup

The schematic diagram of electric-hydraulic chattering cold extrusion process is shown in Fig. 1. The electro-hydraulic chattering cold extrusion processing system includes three subsystems: (1) an electric-hydraulic chattering system, (2) a cold extrusion system, and (3) a control and data acquisition system. This system can realize conventional cold extrusion process (dies fixed) and the electric-hydraulic chattering-assisted cold extrusion process (dies chattering). With this setup, the chattering frequency, amplitude, extrusion speed and other parameters can be controlled. And it can collect experimental data, including stroke and load.

The schematic diagram of forward extrusion for the cup part is shown in Fig. 2. It consists of electric-hydraulic chattering platform, lower die, upper die and other accessories. The chattering platform is controlled by a high-frequency exciting valve, and the axial micro-amplitude vibration of the elastic cover which is a part of chattering platform can be achieved. Because the elastic cover is rigidly connected with the lower die, the micro-amplitude vibration of the lower die can be realized.

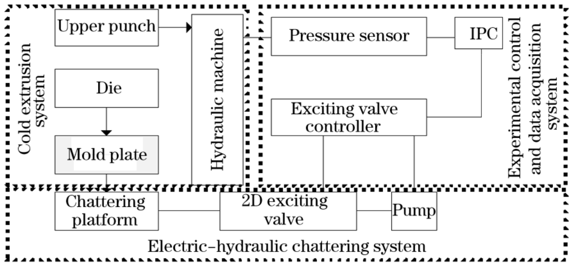
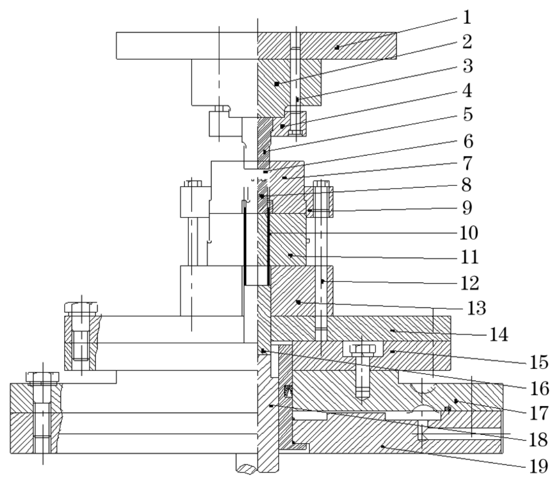


Fig. 1. Schematic of electric-hydraulic chattering cold extrusion processing system.



1—Upper mold plate; 2—Upper bearer; 3—Punch-connection bolt; 4—Upper punch holder; 5—Upper punch; 6—Blank; 7—Container; 8—Lower punch; 9—Die holder; 10—Ejector sheet; 11—Lower bearer; 12—Container-fixed bolt; 13—Grommet; 14—Lower mold plate; 15—Chattering platform roof; 16—Die ejector rod; 17—Upper plate; 18—Hydraulic machine ejector rod; 19—Lower plate.

Fig. 2. Schematic of forward extrusion for the cup part.

The experimental hardware platform is also built. The photo of the experimental setup is shown in Fig. 3.

2.2. Experimental procedure

As shown in Fig. 4, an ultra-high speed/high accuracy laser displacement sensor manufactured by KEYENCE with the model of LK-H055 was used to measure the chattering amplitude of the lower die. The measurement range is ± 10 mm, the resolution is 4 μm, and the sampling frequency is 392 kHz. The experimental results show that the chattering amplitude is about 0.012 mm when the oil pressure is