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Finite Element Simulation of Flashless Radial Extrusion Process

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Abstract: *In this paper, the flashless radial extrusion process of flange form is considered. The material behavior, stress-strain state and variation of punch and upper die loads by using a theoretical and numerical method as the rigid-plastic finite element method for two different schemes of flashless radial extrusion, viz, single-ended and double-ended at several stages are investigated. The die geometry parameters, billet dimensions and power mode parameters are determined. Based on the simulation results, deformation patterns (gridlines distortion), distributions of effective strain and stress, the punch load vs. the punch stroke and the upper die load vs. the non-filling of upper die cavity for single-ended and double-ended flashless radial extrusion process are shown.*

Keywords: *Cold forging, Finite element simulation, Flashless forging, Radial extrusion*

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I. Introduction

Flashless forging process has been used to produce different manufacturing parts and also can be considered as a branch of forging technology with cold, warm and hot forming. In recent years, there has been a greater need for flashless cold forging technology to provide precision parts with various shapes. Extrusion process with room temperature is type of cold forging process. There are principal types of extrusion process such as forward, backward, radial, and combined. The radial extrusion using flashless or closed-die is an important branch of extrusion process. In this process, the cylindrical solid or tubular billet is located in the die cavity and is squeezed by punches and more multiple rams. The billet is compressed with one or two opposite punches movement and the billet material fills the die cavity. The radial extrusion using flashless or closed-die has several advantages, such as high dimensional accuracy, better mechanical properties of parts, Finished product quality and cost aspects [1,2].

II. Method of Analysis

Numerical solution and method such as finite element (FE) is an important method to analysis material behavior and stress-strain state in metal forming processes. In this study, a rigid plastic finite element program QForm 2D was used to investigate flashless radial extrusion process [3].

III. Purpose of Investigation

In this paper, deformation patterns (gridlines distortion), distributions of effective strain and stress by using a theoretical method as finite element for two different schemes of flashless radial extrusion, viz, single-ended and double-ended at several stages of process are investigated. The variation of punch and upper die loads with punch travel for single-ended and double-ended flashless radial extrusion and loads comparison between processes as determined from the simulations are shown [4-6].

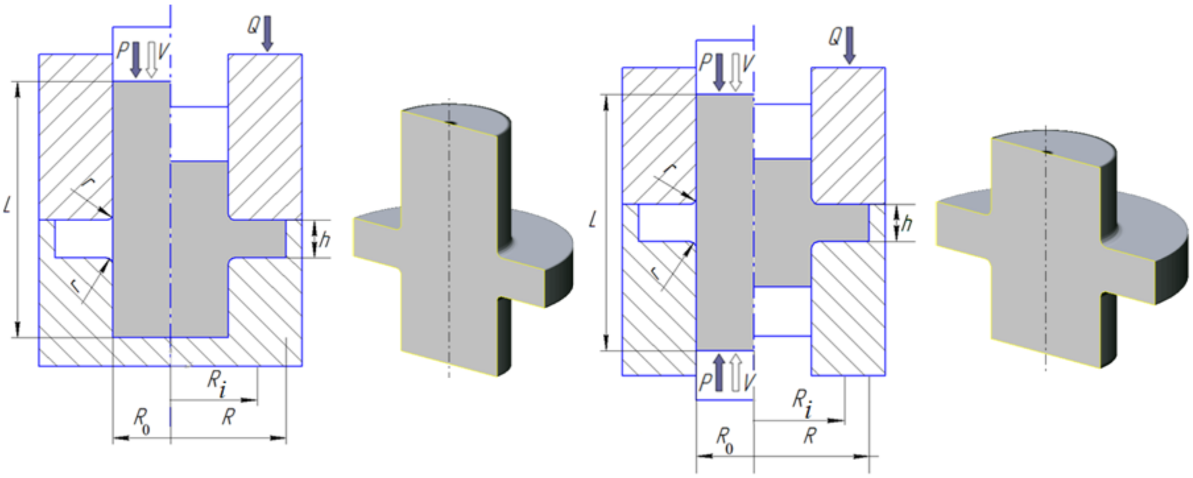
IV. Flashless Radial Extrusion Process

The die schemes, die geometry, billet dimensions and the formed part for single-ended and double-ended flashless radial extrusion are shown in Fig. 1. A cylindrical billet is considered. The die geometry parameters, billet dimensions and power mode parameters are as follows: R_0 – the radius of billet (R_0 = 18mm), R_1 – the radius of flange or formed part (R_1 = 36mm), R_i – the intermediate flange radius, L – the billet height (L= 100mm), h – the flange height (h=11.7), r – the die tip radius (r=2mm), V – punch velocity (V=1mm/s), P – punch load, Q – upper die load, The friction factors between the billet and tools are constant. (Zibel's law, μ=0.08).

V. Material Property

In this study, the material used for the simulation is AA 6060 aluminum alloy. The relationship between flow stress and effective strain for AA 6060 aluminum alloy can be approximated by:

$$\bar{\sigma} = 191.55\,\bar{\varepsilon}^{0.202}\ (MPa) \qquad (1)$$

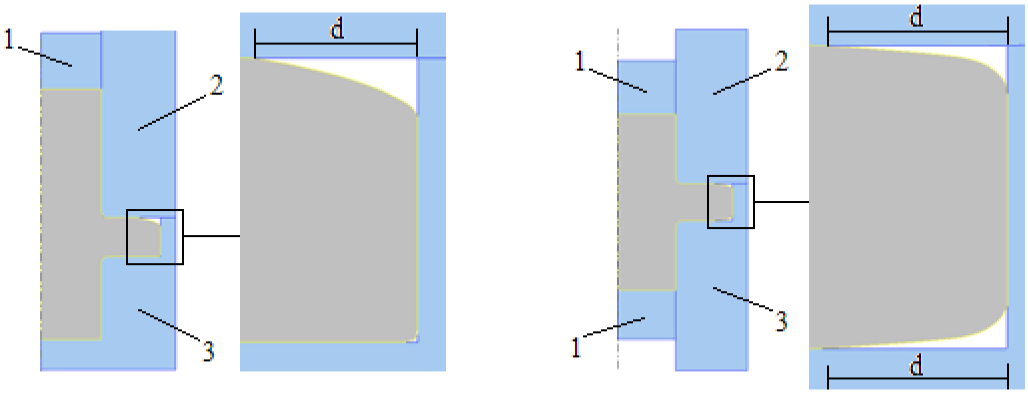


(a) (b) (c) (d)

Fig. 1: Die scheme of single-ended flashless radial extrusion process (a) and formed part (b); die scheme of double-ended flashless radial extrusion process (c) and formed part (d);

VI. Analysis of Flashless Radial Extrusion Process

The design of flashless radial extrusion process has been used some tool parts such as an upper, a lower die and some movable punches. Metal flow and dies cavity filling are very important in this process. The material flow behavior and the influence of various factors involved in the processes were explored. Simulation based on the finite-element (FE) method is considered. During the simulations by QForm2D, it is seemed that the billet is rigid-plastic and upper, lower dies and punches are all rigid. Fig. 2 shows non-filling of dies cavity with variable amount as (d) in single-ended and double-ended processes. Deformation patterns (gridlines distortion), distributions of effective strain and stress for single-ended (Fig. 3) and double-ended (Fig. 4) processes are shown. It is observed in the figures that the maximum amounts will be in a relationship $R_i/R_0=2$. The load variations on the punch and upper die with punches travel as determined by finite element simulation in single-ended and double-ended flashless radial extrusion processes. Fig. 5, 6 depict the punch load vs. the punch strokes (Fig. 5) and the upper die load vs. the non-filling of upper die cavity (Fig. 6) in single-ended and double-ended processes. As the diagram (Fig. 5) presents, three principal stages as follows: coining stage, steady and unsteady state stage. It is observed from these curves, as the initial billet diameters increase, the punch load increase along the any stage of the deformation. A loads comparison between two curves in Fig. 5, 6 are shown that the punch and upper die load values in single-ended greater than double-ended du to asymmetrical material flow.



(a) (b)

Fig. 2: The non-filling of dies cavity in single-ended (a) and double-ended (b) flashless radial extrusion processes, 1 – punch, 2 – upper die, 3 – lower die

VII. Conclusion

The flashless radial extrusion processes, viz, single-ended and double-ended are considered. The material behavior, stress-strain state and variation of punch and die loads by finite element method (QForm 2D) are investigated. The simulation results are shown that the maximum amounts stress-strain will be in a relationship $R_i/R_0=2$, and the punch and upper die load values in single-ended greater than double-ended du to asymmetrical material flow.

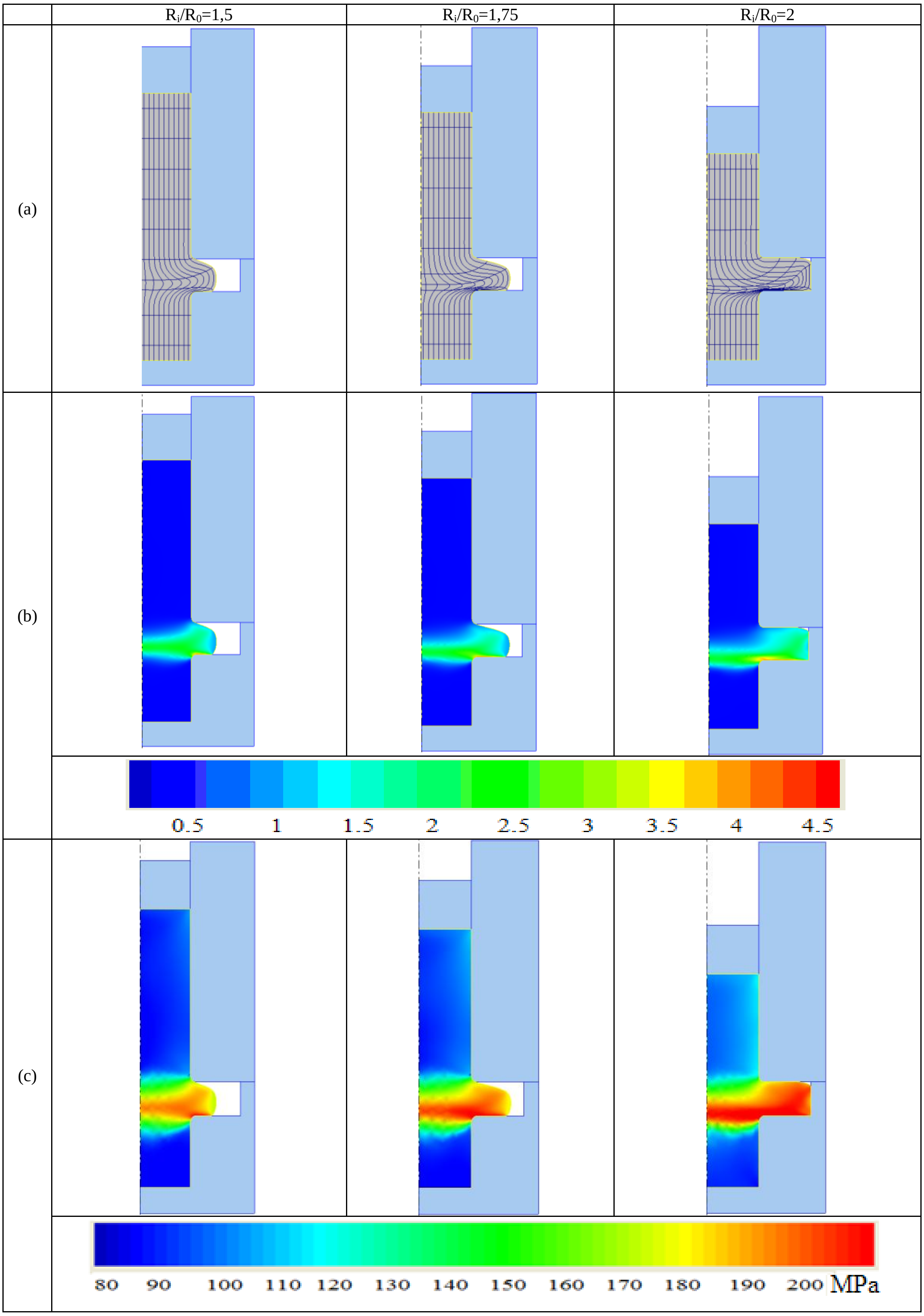


Fig. 3: Gridlines distortion (a); distributions of effective strain (b); distributions of effective stress (c) with different stage R_i/R_0 in single-ended flashless radial extrusion process

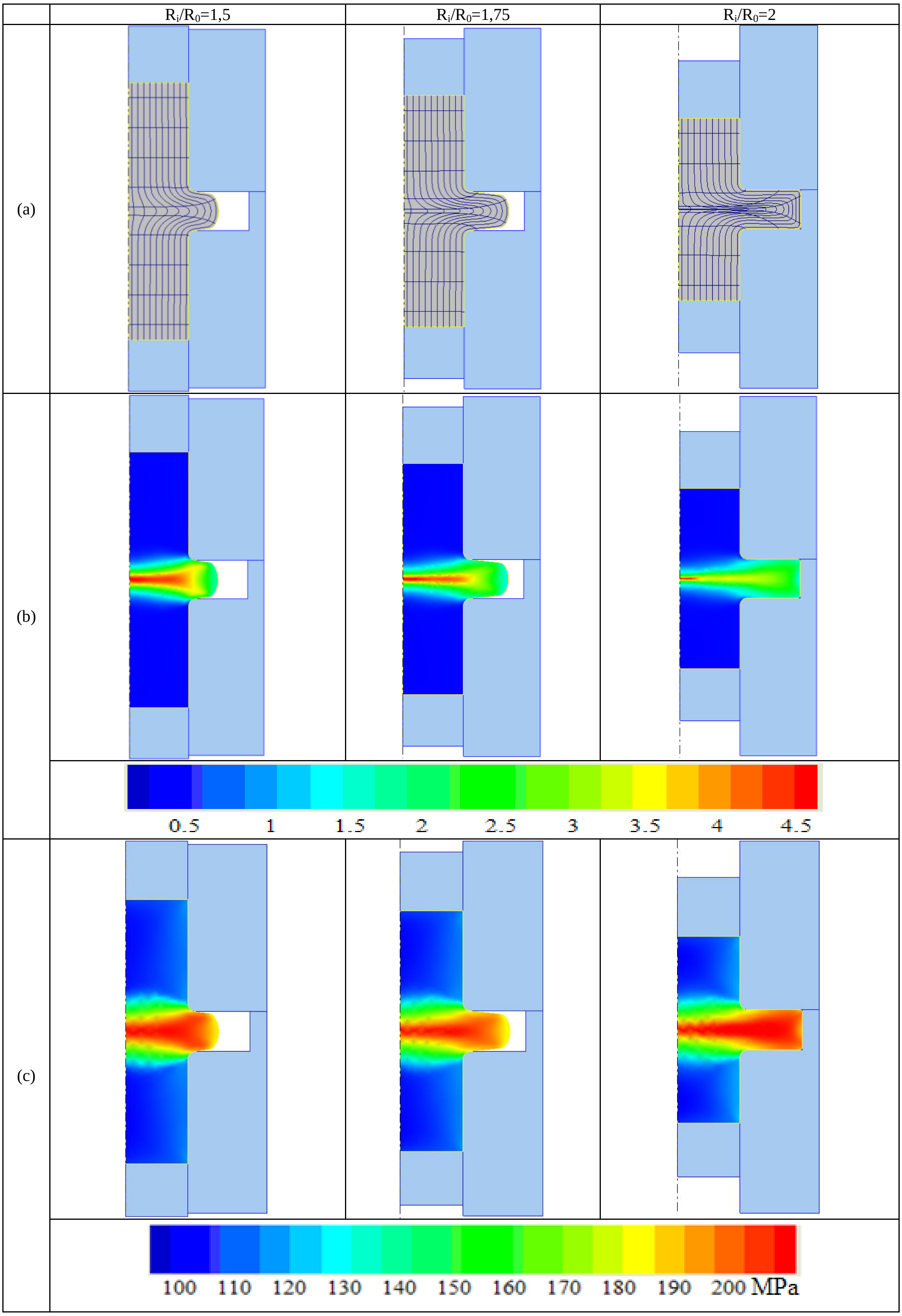


Fig. 4: Gridlines distortion (a); distributions of effective strain (b); distributions of effective stress (c) with different stage R_i/R_0 in double-ended flashless radial extrusion process

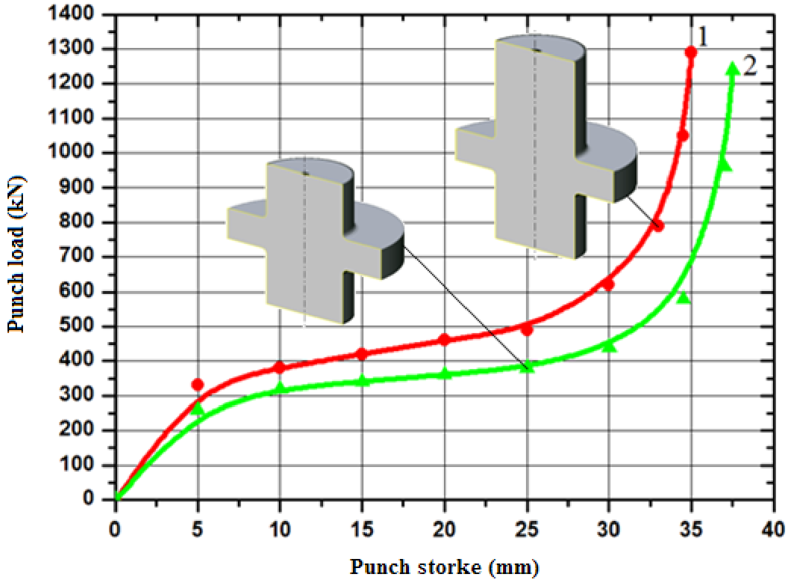


Fig. 5: The punch load vs. the punch stroke in single-ended (1) and double-ended (2) flashless radial extrusion processes

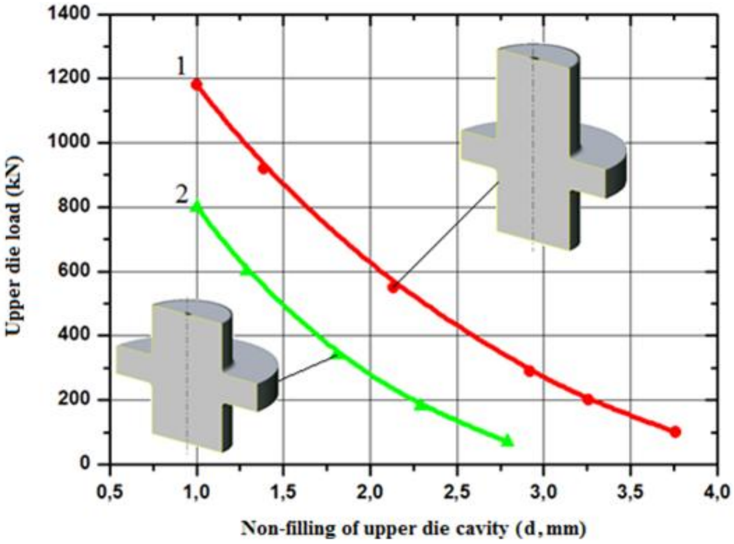


Fig. 6: The upper die load vs. the non-filling of upper die cavity in single-ended (1) and double-ended (2) flashless radial extrusion processes

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