Materials and Design 32 (2011) 2891–2899

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Investigation of material deformation in multi-pass conventional metal spinning

Lin Wang, Hui Long *

School of Engineering and Computing Sciences, Durham University, DH1 3LE, Durham, United Kingdom

ARTICLE INFO

Article history:
Received 17 August 2010
Accepted 8 December 2010
Available online 15 December 2010

Keywords:
Multi-pass conventional spinning
Material plastic deformation
Finite Element analysis

ABSTRACT

This paper reports a study on material deformation during a multi-pass conventional spinning. A Finite Element (FE) analysis model has been developed based on a 5-pass conventional spinning experiment. The explicit Finite Element solution method has been used to model this multi-pass spinning process. Effects of mass scaling and reduced integration linear element used in the FE simulation have been evaluated by using various energy histories obtained from the FE analysis. The numerical results suggest that among three tool force components the axial force is the highest while the tangential force is the lowest. Certain correlations have been found between the FE analysis results and measured dimensions of the spun part. The blank thickness decreases after each forward pass and there are almost no thickness changes during the backward pass. Stress distributions of the local forming zone of the workpiece in both forward and backward passes have also been analysed, which gives an insight into the material deformation during the spinning process.

1. Introduction

In the conventional metal spinning process, a blank is gradually formed onto a pre-shaped mandrel by a moving roller using multiple passes. During this process, the blank is clamped between the mandrel and a backplate; these three components rotate synchronously at a specified spindle speed. Fig. 1 illustrates the setup of the multi-pass conventional spinning process. Materials used in spinning process include non-alloyed carbon steels, heat-resistant and stainless steels, non-ferrous heavy metals and light alloys. The process is capable of forming workpiece of thickness from 0.5 mm to 30 mm and diameter of 10 mm–5000 mm [1].

Metal spinning process has seen significant development in recent years and spun products have been widely used in various industries. Advantages of spinning process include low forming load, simple tooling and process flexibility, good surface finish and improved mechanical properties of spun parts [1]. Although the spinning process has already been known for centuries, its process development still relies highly on specialised spinners who use their experience combined with trial-and-error methods. The process design remains a challenging task and material failures (wrinkles and cracks) significantly affect the production efficiency and product quality. Understanding of material deformation mechanics during the spinning process is essential to prevent material failures and to maintain product quality.

During the process of the conventional spinning, a local plastic deformation zone is generated at the roller contact area. The stress patterns of this zone depend on the roller feeding direction [1–3]. In the forward pass (the roller feeds towards the edge of the blank), tensile radial stresses and compressive tangential stresses are induced, as shown in Fig. 2a. The tensile radial stresses lead to a material flow towards the edge of the blank causing thinning of the blank, which is balanced by the thickening effects of the compressive tangential stresses, maintaining an almost constant thickness. Whereas in the backward pass (the roller feeds towards the mandrel), the material builds up in front of the roller, generating compressive radial stresses and compressive tangential stresses, as shown in Fig. 2b.

In published research literature, most of the researchers focused on the shear forming [4–12], or simple one-pass conventional spinning [13–19]. Limited investigations were carried out on multi-pass conventional spinning, and the majority of the published work studied only forward passes or linear passes. There is a considerable knowledge gap between academic research outcomes and requirements of industrial production. Based on experimental studies of multiple roller passes using linear, concave and convex curves, Hayama et al. [20] suggested that a special type of concave curve – involute curve path, gave the highest spinning ratio (ratio of blank diameter to the mandrel diameter) without material failures. By using the grid marking method, Razavi et al. [21] experimentally analysed strain distributions of a spun part by using three forward passes. They reported that the hoop and radial strains at roller working zone did not balance each other, thus indicating there were some thickness strains existing in the workpiece. Sebastiani et al. [22] developed a Finite Element (FE) model which used multiple linear roller passes, including both forward passes and backward passes. In the forward pass, local bending effects

* Corresponding author. Tel.: +44 191 3342515; fax: +44 191 3342408.
E-mail address: hui.long@durham.ac.uk (H. Long).

0261-3069/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.matdes.2010.12.021