Journal of Materials Processing Technology 227 (2016) 190–199

Contents lists available at ScienceDirect

Journal of Materials Processing Technology

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

Automatic centring with moving die for cold small clearance punching of die-quenched steel sheets

H. Jaafar[a,b,*], K. Mori[a], Y. Abe[a], K. Nakanishi[a]

[a] Department of Mechanical Engineering, Toyohashi University of Technology, Toyohashi, Aichi 441-8580, Japan
[b] School of Manufacturing Engineering, Universiti Malaysia Perlis, 02600 Arau, Perlis, Malaysia

ARTICLE INFO

Article history:
Received 21 May 2015
Received in revised form 6 August 2015
Accepted 7 August 2015
Available online 13 August 2015

Keywords:
Cold punching
Automatic centring
Die-quenched steel sheet
Moving die
Eccentricity
High quality

ABSTRACT

An approach for automatically correcting the eccentricity of the die to the punch with a moving die in small clearance punching of die-quenched steel sheets having low ductility was developed to improve the quality of the sheared edge and tool life. Although small clearance punching has the advantage of high quality of sheared edges for high strength steel sheets, it is not easy to set the die and punch for the small clearance concentrically. This brings about deterioration of the quality of the sheared edges and failure of the tools. In automatic centring, the position of the moving die is corrected by an imbalanced force during punching. It was found that small clearance punching with automatic centring is effective for not only the improvement of surface quality of the sheared edge but also the prevention of tool failure and delayed fracture in cold punching of die-quenched steel sheets having 1500 MPa in tensile strength.

1. Introduction

For the reduction in weight and improvement of crash safety of automobiles, the use of high strength steel sheets having a high specific strength remarkably increases. The high strength steel sheets are mainly employed in body-in-white components to enhance the passenger safety. As the strength of the high strength steel sheets rises, cold stamping of the sheets becomes difficult due to high stamping load, large springback, small tool life, etc.

Hot stamping of quenchable steel sheets is attractive for producing ultra-high strength steel parts. Heated steel sheets are hot-stamped, and then the stamped sheets are die-quenched by holding at the bottom dead centre of a press. The formed parts have a tensile strength of 1.5 GPa. Neugebauer et al. (2006) reviewed sheet metal forming processes at elevated temperatures including hot stamping. Karbasian and Tekkaya (2010) reviewed hot stamping processes of ultra-high strength steel parts. By heating the sheets, the forming load is remarkably reduced, the springback is prevented and the formability is greatly improved. Merklein and Lechler (2006) measured flow stress curves of the quenchable steel sheet at different temperatures. Bruschi et al. (2008) investigated the formability of steel sheets in hot stamping. Since a furnace is generally employed to heat steel sheets, the heating time is comparatively long and the drop in temperature of the sheets transferred from the furnace to dies is large. Mori et al. (2005) developed a hot stamping process having rapid resistance heating, 900 °C in only 2 s. Kolleck et al. (2009) applied induction heating in hot stamping as another approach to reduce the heating time.

Since the shape of blanks for hot stamping is roughly determined by developing that of products, the dimensional accuracy of edges of the stamped parts is not very high, and thus laser cutting is generally employed in order to trim and make holes for the hard stamped parts. Keles et al. (2006) studied the influences of the workpiece thickness and beam waist position on the kerf size and striation pattern at the sheared edge of high strength steel sheets using CO_2 laser cutting. Lamikiz et al. (2005) investigated the effects of cutting speed and power of the beam emitted by the generator in the CO_2 laser cutting of advanced high strength steel sheets. Fritz (2011) reviewed optimisation strategies for laser cutting of the die-quenched parts and recent improvements in productivity and production cost using laser cutting. In spite of improvement in processing time, high installation costs are disadvantageous to laser cutting.

So et al. (2012) included a warm blanking stage in hot stamping to reduce the blanking force. Choi et al. (2014) half-trimmed a sheet during hot stamping to improve tool performance, and subsequently performed complete trimming at room temperature. The

* Corresponding author at: Department of Mechanical Engineering, Toyohashi University of Technology, Toyohashi, Aichi 441-8580, Japan. Tel.: +81 532 44 5213; fax: +81 532 44 6690.
E-mail addresses: jaafar@plast.me.tut.ac.jp, arscenu17@gmail.com (H. Jaafar).

http://dx.doi.org/10.1016/j.jmatprotec.2015.08.010
0924-0136/

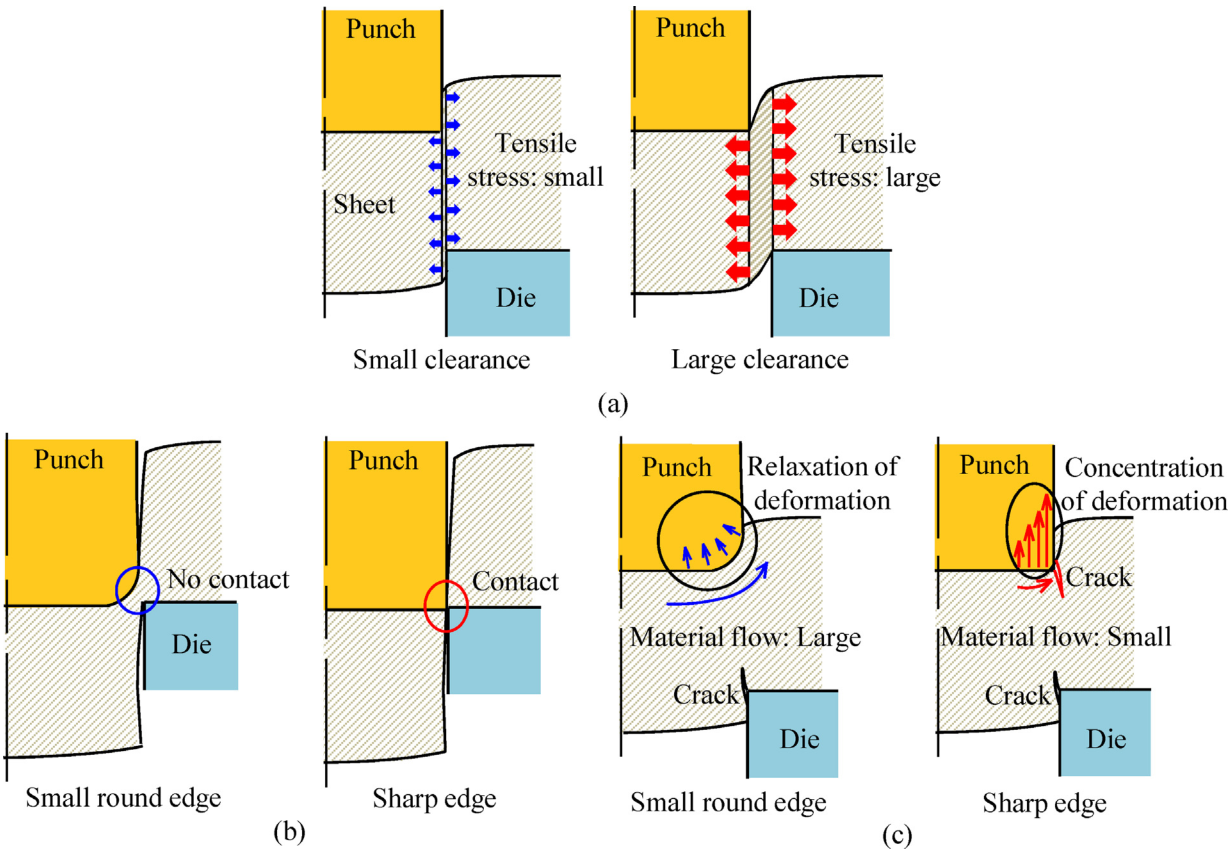

Fig. 1. Punching process of ultra-high steel sheet. (a) Effects of clearance ratio, (b) avoidance of direct contact between punch and die edges and (c) relaxation of concentration of deformation around punch edge.

structure of die sets becomes complicated, because hot punching including die quenching is generally a one-shot process, and thus increases the production cost. In addition, it is not easy to design additional cooling channels for a fast cooling system.

Mori et al. (2012) facilitated punching of die-quenched steel sheets by local heating of the shearing zone and improved the quality of the sheared edge. Hoffmann et al. (2010) reduced the cutting force during shearing of advanced high strength steel sheets by optimising the shear angle, sheet positioning angle and clearance. Volk et al. (2015) investigated the heat generation during the blanking process of the sheet metal. Thomas (2012) examined the effects of clearance on the quality of the sheared edge in punching of high strength steel sheets. Nothhaft et al. (2012) investigated the effect of the chamfer angle of the punch on the cutting force, tool stress and sheared edge quality in cutting of die-quenched steel sheets. In punching of die-quenched steel parts, the tool life is remarkably reduced by large punching load. The worn tools bring about the deterioration not only in dimensional accuracy of the punched hole but also in the quality of the sheared edge. In addition, delayed fracture is risky for cold punching of die-quenched parts. Eriksson and Olsson (2011) examined the effect of coating of tools on the material pick-up tendency in sliding tests of ultra-high strength steel sheets. Casellas et al. (2013) reported that the fatigue behaviour of die-quenched and high strength steel sheets cut by laser cutting and shearing is dependent on the pre-existent cracks and defects generated at the cut edges.

In the present study, a cold punching process of die-quenched steel sheets having high strength and low ductility was developed. The die-quenched steel sheets were punched under a small clearance to improve the quality of the sheared edge surface. A moving die was utilised to automatically correcting the eccentricity of the die to the punch. By setting a gap between the moving die and

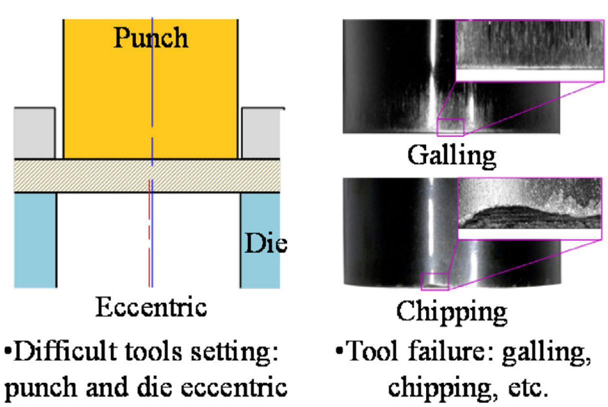

Fig. 2. Problems in small clearance punching of ultra-high strength steel parts (Mori et al., 2013).

holder, the die is shifted by imbalanced force, and the punch and die become concentric after several strikes.

2. Automatic centring with moving die

2.1. Approach of automatic centring with moving die in small clearance punching using punch having small round edge

To improve the quality of sheared edges in cold punching of ultra-high strength steel sheets, Mori et al. (2013) developed a small clearance punching process using a punch having a small round edge. By the small clearance, the tensile stress in the shearing region during punching is reduced (see Fig. 1(a)), and thus the onset of cracks is delayed for ultra-high strength steel sheets having