Journal of Materials Processing Tech. 249 (2017) 229–245

Contents lists available at ScienceDirect

Journal of Materials Processing Tech.

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

Burr-free cutting edges by notch-shear cutting

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A R T I C L E I N F O

Keywords:
Shear cutting
Burr deformation
Deburring

A B S T R A C T

Shear cutting is used to separate a sheet metal into two parts. During the cutting process, the material is deformed by two moving parts until its formability is exhausted. When a material is sheared, a burr deformation can often be observed on the cutting edge. Due to different disturbing effects, the burr must often be deburred before the next process of machining.

The objective of the paper is the production of sheets without a burr under industrial boundary conditions. Therefore a progressive die is built in order to perform the necessary experiments. In addition to the experiments the simulation tool Abaqus is used to reduce the number of experiments to a suitable minimum. Adjusting a notching with a cutting process a burr-free cutting edge should occur. The notching results in a local change of formability on the blank sheet. Subsequently, the sheet metal is cutted in a normal shear process at the same position of the sheet metal where the notch at first was pressed into the bottom of the sheet. Due to the lowered deformability at this part of the sheet, the cutting edges of the sheet metal cannot build up any burr.

Therefore, the impact of different parameters on the cutting edge is analyzed to create a notch geometry as well as shear cutting parameters without burr deformation, furthermore continuous strokes are performed to show the impact of this new cutting process for industrial applications on the tool material. Additionally to the burr free cutting edge, the new method shows less wear than the normal shear cutting.

1. Introduction

The shear cutting process is one of the most common separation processes in the automotive industry for sheet metals (Wick, 1984). Generally every sheet metal goes through a various number of separation processes during the manufacturing of the different sheet metal parts (Ramalingam and Watson, 1977). A good knowledge of the cutting process and its parameter settings is fundamental to a good cutting result (Yamasaki and Ozaki, 1991).

The characteristic cutting edge (conjugated) manufactured by the shear cutting process is usually described in VDI 2906 (1994), see Fig. 1.

Small amounts of rollover and fracture depths are needed. The burr deformation can cause an injury risk, decreasing of tool wear and less corrosion protection and leads to lack of quality in the whole production process (Gillespie, 1979). Due to this tremendous disadvantages caused by the burr deformation a deburring process is often used in order to reduce the burr height of the sheared edge (Querry, 1979).

Commonly known deburring processes such as the frictional or vibratory grinding require an additional amount of money and time in order to perform such deburring process (Emerson and Emerson, 1975). Although up to 80% of the manufacturing costs can occur in the deburring process (Johannesen, 1977), deburring process are widely popular due to the lack of an economical alternative.

In this paper a new, completely unknown method is presented to achieve a burr-free cutting edge of the conjugated strip the high cost of the deburring processes. Concerning this new cutting process the fracturing and material separation should occur before the burr deformation is taking place. This results in a high quality, burr-free cutting edge with no further post processing. This new cutting process is performed in two steps. First, a notch geometry is pressed in the scope of potentially burr-deformed sheet metal, followed by the cutting process, see Fig. 2. The new cutting process is defined as notch-shear cutting.

The first step (notching process) leads to plastic deformation at the bottom of the sheet metal. This results in a hardening and lowering of the formability of the sheet metal. In the next step the material is separated by the cutting process. Due to the lower formability of the sheet metal, the whole separation process begins before the burr deforming mechanism of the shear cutting occurs. Therefore a burr deformation cannot occur. In this research project, only the conjugated strip has been researched.

The objective of this research project is to determine and scientifically justify the necessary parameters of the notch geometry as well as the parameters of the cutting process for a burr-free cutting result.

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http://dx.doi.org/10.1016/j.jmatprotec.2017.06.003
Received 26 October 2016; Received in revised form 31 May 2017; Accepted 3 June 2017

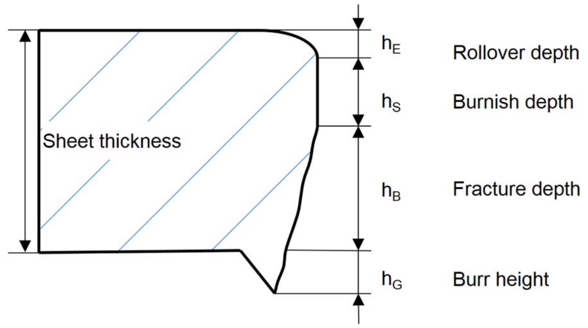

Fig. 1. Sheared edge (VDI 2906, 1994).

Furthermore, continuous strokes are accomplished to clarify the potential of the notch-shear cutting in the industrial manufacturing process.

2. Experimental setup

The research study about the notch-shear cutting process requires a progressive die to reason the influence of the different parameters on the cutting edge. First the construction of this progressive die is explained in this chapter. In order to reduce the number of experiments to a meaningful ratio and to show the different occurring mechanisms of burr deformation, the finite element method (FEM) is used. The simulation model is explained in the second part of this chapter.

2.1. Progressive die

The tool system considers the closed and open cut as well as a high stiffness for a good accuracy of positioning of the sheet metal. Small tolerances and a quick change of the active parts of the tool are fundamental in order to manage a time effective performance of the experiments (Kyuttner, 1974). Fig. 3 shows the tool and the feeding system.

The two different cutting procedures are explained on the metal strip of the used sheet metal, see Fig. 4.

All tested materials have the widths of 50 mm and the thickness of 1 mm. Other geometries could not be researched in this project due to economical reasons. At the beginning, two holes are stamped into the sheet metal in order to position the strip in the following steps (A). These holes are on both sides of the strip. Therefore, enough space for the notching-cutting is available. In the next step, a round notch geometry is notched into the strip (B). The diameter of the notch is 10 mm. Due to the fact that the impact of different notch geometries should be researched, the changing of a notch geometry can simply be obtained by exchanging this round element of the tool. In order to reach a complete penetration of the notch into the strip, a punch is used to compress the notch. The material separation of the closed cut is performed in the next step (C).

The open cut of the notching-cutting can be seen in the next step (D and E). The notch geometry got a length of 20 mm on the width of the strip. Therefore, a comparison between the notching-cutting (middle of the strip) and the normal shear cutting (edges of the strip) can be done in the open cut (D). As well as the closed cut the notch geometry can also be changed on this tool system. Therefore the impact of different notch parameters can be observed. In the last step the material separation of the open cut is accomplished. Due to the space between the open and closed cut, the open as well as the closed cut can be done without influencing each other.

2.2. Simulation process

In order to reach a better understand of the occurring cutting mechanisms and to reduce the amount of experiments to an efficient level, the notch-shear cutting is simulated with the finite element method (FEM). First, the notching process is simulated, followed by the cutting process, see Fig. 5.

The active parts of the tool are modelled as rigid bodies in order to achieve an efficient time for the simulations. Furthermore, the sheet metal is simulated as elastic-plastic with a fine mesh in the region of notching and cutting (minimum element size: 0.002 mm × 0.005 mm). The red border on the left side of the sheet metal in Fig. 5 shows the constraint of the mesh in horizontal direction, whereas the green border on the right side shows the constraints in horizontal direction for the closed cut.

On the boundary edge a plain stress occurs. With a small distance away from the boundary (around sheet thickness) the stress states moves to plain strain (see Fig. 6) Thus the domination length of the cutting line can be described with plain strain condition.

The edge of Fig. 6 shows a different amount of burnish depth than the constant one. The focus on this project is to simulate the cutting in the dominating area beside the boundaries. Therefore, the whole process is simulated in 2D, plain strain boundary condition (Wang, 1988). The plain strain boundary condition is also used to simulate the closed cut, since only small amount of stresses occur in the radial direction.

The flow curves for the Materials DC04, 1.4301, AA6014 and CuSn6

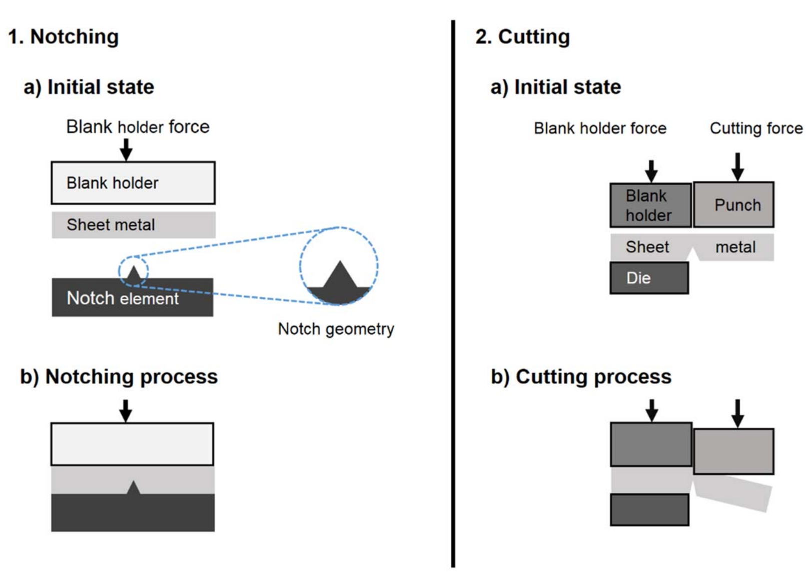

Fig. 2. Notch-shear cutting.