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Reduction of burr formation for conventional shear cutting of boron-alloyed sheets through focused heat treatment

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Abstract

Conventional shear cutting is the most commonly used manufacturing process in sheet metal working. Due to its good automation capacity it is high productive and therefore it has a significant economic importance. However, the occurence of burr is still a remaining issue of the conventional shear cutting process. The burr has to be removed as they pose a high risk for functional and ergonomic aspects. Deburring requires additional processing steps in the production line, which are expensive and time-consuming. In the case of automotive industry components, the removal costs make up 15 % to 20 % of production costs. When it comes to precision components, such as engine parts, the cost equals even up to 30 %. Thus, it is worthwhile to aim for the avoidance or at least the reduction of burr formation.
In this work, different heat treatment methods were applied to 4 mm thick 22MnB5 sheets, in order to increase the strength of the material and thereby reduce burr formation. For this purpose, the heat treatment methods case hardening, flame hardening, and plasma nitriding were studied. After punching the hardened sheets, the characteristic cutting surfaces were determined by tactile measuring. The results of the different heat treatment methods were compared regarding the resulting burr and evaluated by means of Vickers hardness measurements and microstructural analysis.

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Keywords: 22MnB5, shear cutting, burr

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1. Introduction

In the industry, shear cut components are subject to a wide variety of requirements. This includes burr-free cutting edges, which allow safe handling and further processing of the components. Therefore, it is of considerable importance to strive for a reduction of burr formation in order to avoid the subsequent deburring. In the industrial environment, this is currently performed in a subsequent processing step, such as mechanical deburring [1, 2], belt grinding [3], slide grinding [4], or burr embossing [5]. The material removal due to a cutting process leads to a lower dimensional accuracy [6]. All the above-mentioned techniques are time, cost, and labor intensive. The method of counter shearing enables the manufacturing of burr-free components in a reliable process, but it also presents a die-roll on both sides of the metal sheet [7] along the cutting edge [8, 9]. The roll blanking procedure, developed by [10], is a combination of the sheet metal extrusion process and rolling for processing burr-free components. For several years, the reduction of burr has been an important topic at the Institute of Metal Forming and Casting, Technische Universität München. By using the notch shear cutting procedure [11], which was developed at the institute, demonstrated a possibility to prevent burr formation in the processing of hardened steel 22MnB5. [12] adapted the notch shear cutting process for materials with high ductility, which results in burr-free components while reducing or even avoiding tool wear.

According to [13] the burr formation on high-strength material is just minor compared to deep-drawing steel, especially with progressive tool wear. As a countermeasure, the material properties must be altered to increase the strength over the cross section of the sheet. This can be achieved by targeted heat treatment. The Institute of Metal Forming and Casting evaluated the heat treatment methods case hardening, plasma nitriding, and flame hardening in terms of burr formation during the shear cutting process. Omitting an additional tool station or another manufacturing step provides an advantaged

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over other procedures [8, 10, 11, 12] when processing press-hardened steels. Various factors influence the burr geometry, such as cutting clearance, cutting edge condition, sheet orientation angle, sheet temperature and hardness of the plate. The aim of the research is to achieve a burr with low height and firm connection to the component by constant shear cutting parametes and different hardening procedurs cutted at room temperature.

1.1. Case hardening

In [14] the concept of case hardening is described as a carburization followed by a hardening step. The hardening process is either performed right after the carburization or after a reheating to a specific hardening temperature subsequent to a cooling period. The carburization usually takes place between 880 °C and 1050 °C. During this process, the workpiece is surrounded by carburizing agents, from which carbon atoms diffuse and accumulate in the edge layer. This increases the hardenability of the steel components. [14]

1.2. Plasma nitriding

According to [14], the plasma nitriding process involves nitrogen molecules build up in the edge layer of the workpiece. The process requires the workpiece connected to a cathode and the furnace wall to an anode. After evacuating the furnace system, a voltage is applied between the cathode and anode. As soon as a certain current is reached, a glow discharge occurs, which cause the molecular nitrogen to ionizie. The nitrogen ions get absorbed by the material surface. Plasma nitriding is performed below the eutectoid temperature in the iron-carbon-diagram and takes long times between several hours and several days. After the nitriding the nitrogen gas and the workpiece are cooled down to room temperature. The plasma nitriding process creates a hardened surface layer similar to the case hardening process. [15]

1.3. Flame hardening

Flame hardening is a surface layer hardening method using a gas-powered torch, with a shape adapted to the contour of the workpiece. The torch is closely followed by a water sprinkler or by compressed air nozzle, scanning the surface of the workpiece. The depth of the austenitization depends on the feed of the torch, the temperature of the flame, and the distance between the sheet and the torch.

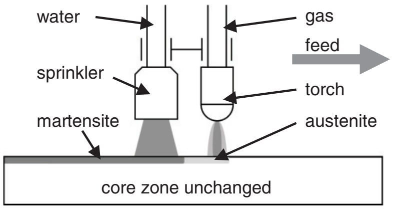

Fig. 1. Schematic representation of the flame hardening process according to [15].

A slow feed combined with a high temperature results in a deeper austenitization. The austenitized material is quenched by the water sprinkler or air nozzle, which causes the formation of martensite. [15] Fig. 1 illustrates schematically the flame hardening process with a water sprinkler.

2. Material

In this study, boron alloyed sheets (22MnB5) of 4 mm thickness were used. According to the data sheet [16], the material has a yield strength of 300 – 450 MPa, a tensile strength of 500 – 700 MPa and a strain ≥ 15 %. With water quenching, the hardness value can reach up to 48 HRC The chemical composition of 22MnB5 is shown in Table 1.

Table 1. Chemical composition in weight percentage of 22MnB5 (max. values) according to [16].

Element	C	Si	Mn	P	S	Al	N	Cr	Ti	B
wt %	0.25	0.4	1.35	0.023	0.01	0.08	0.01	0.25	0.045	0.004

In the automotive industry, boron alloyed steel is mainly used for load-bearing body parts and safety-relevant structural parts, such as B-pillars, lateral protection structures, suspension components, and bumpers. [11]

The cutting active elements are made of tool steel 1.2379 with a hardness of 58+2 HRC. Besides a low amount of distortion, this type of steel combines a high ductility with excellent wear resistance and compressive strength. [17]

3. Experimental setup

3.1. Experimental heat treatment setup

During the case hardening process the specimens were carburized with a C-potential of 0.75 % at a specimen temperature of 930 °C for 8 h. In the subsequent process the specimens were hardened with a C-potential of 0.65 % at a specimen temperature of 850 °C for 2 h, whereby the C-potential was reduced to 0.06 % during the last half an hour.

The plasma nitriding was done with a nitrogen content of 42 % at a temperature of 500 – 510 °C for over 28 h.

In the flame hardening process a oxy-acetylene ring-type burner was aimed on the middle of the sheet specimen at a distance of approximately 40 mm. The process gases are oxygen and acetylene. The specimen was placed on top of a 100 x 100 x 100 mm copper block, which functioned as a chill casting to detect heat from the underside of the sheet. The cooling plate was intended to prevent through heating and to allow a hardening gradient over the cross section of the sheet specimen. The copper block was attached to a carrier sheet in order to cool the copper block down after each test by lifting it into a cold water basin. A thermocouple was screwed with a threaded pin into a clearance hole through both the carrier sheet and the copper block. Its tip touched spring loaded the underside of the sheet specimen. For each test, the topside of the specimen was heated up to the desired maximum temperature and subsequently quenched. The temperature was measured at the underside of the specimen. The oxygen-acetylene-ratio as well as the distance between the torch and the specimen remained constant throughout all tests to ensure a repeatable heating rate. The experimental setup is shown in Fig. 2.