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SHAPING THE EDGES USING FLOWDRILL TECHNOLOGY

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In this paper, was presented the results of experimental studies of the edgetrimming process obtained using technology Flowdrill, shows distributions of thickness and height of recurving edging and its microhardness made of aluminum, mild steel and stainless steel.

Key words: shaping, edges, Flowdrill, microhardness, burring rims

INTRODUCTION

The Flowdrill technology, also known as thermal drilling or thermoforming drilling is a chip less process of shaping rims of holes through burring and it is an alternative to conventional technology of hole rims burring, realized using presses or welded nuts to obtain threaded joints [1, 2, 3].

It is applied everywhere, where it is necessary to obtain threaded joints of high strength without application of additional connecting elements.

Application of this technology allows to reduce mass of the structure and eliminates need of using the countering elements, especially when access is hindered or impossible.

Making rims of holes with the Flowdrill technology consists of several stages (Figure 1):

- tip of the conical part of the drill comes into contact with the material surface, making it malleable and soft (Figure 1a, b),
- cone of the drill pushes the material in two directions: inside the shape, a bushing is formed (Figure 1c), around the upper surface (a collar occurs),
- the drill runs through the material, its cylindrical part finally forms the bush and the collar is cut off by the forming flange of the drill (Figure 1d, e),
- the tool is detracted and the rim cools down on its own (Figure 1f).

An important role in the thermal drilling process is played by the temperature, which may cause damage of the material structure (e.g. burns), influence shape of the formed rims disadvantageously and change the material microstructure in the hot drill-material contact zone [4, 5].

It matters significantly in the case of materials characterized by a high temperature conductivity, as too fast decrease of temperature in the zone of drilling may cause the malleability to drop and fractures may occur [3, 5, 6].

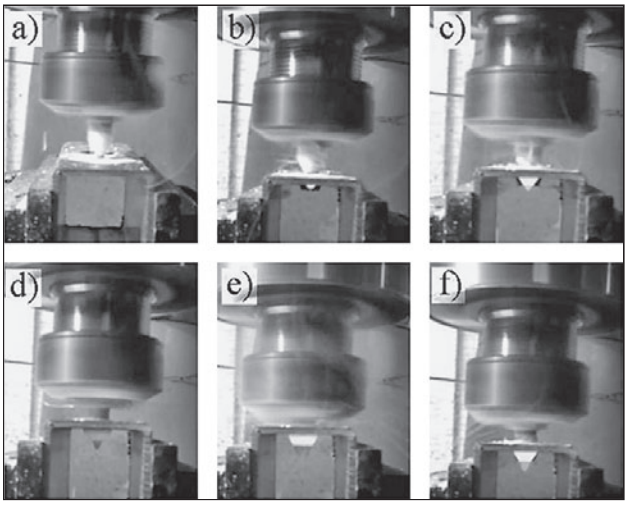

Figure 1 Flowdrill stages: a) contact of the tool and the material; process after: b) 2 seconds, c) 3 seconds, d) 5 seconds, e) 6 seconds, f) tool retraction [own study]

RESEARCH METHODOLOGY

The study was conducted on rectangular shapes of dimensions 40 x 30 x 2 mm, made out of stainless steel 4301, Low-Carbon steel S235JRH and aluminum 6060. The main chemical elements of the used materials is presented in the Table 1.

Table 1 **Main chemical elements of used materials / wt %**

Material	C	Mn	Si	Cr	Fe	Ni	Mg
4301	0,04	1,00	0,39	18,252	-	8,165	-
S235JRH	0,10	0,43	0,21	0,04	-	0,01	-
6060	-	≤ 0,1	0,3 ÷ 0,6	≤ 0,05	0,1 ÷ 0,3	-	0,35 ÷ 0,6

Hole drilling in the selected shapes was carried out using a milling and drilling center JET JMD-18VS (Fig-

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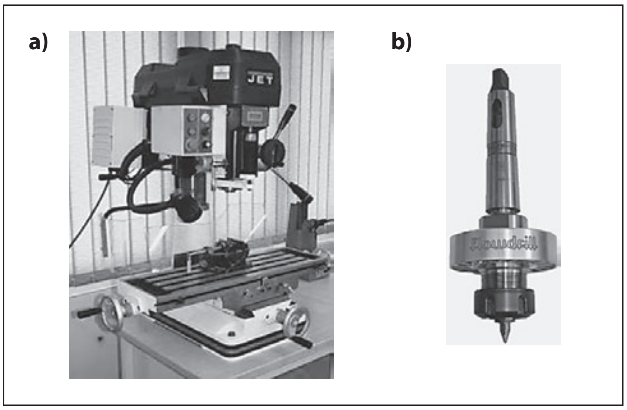

Figure 2 Milling and drilling center JET JMD-18V (a), Flowdrill tool (b)

ure 2a) with a head for thermal drilling, equipped with a tool handle with a cooling disc, a collet and a Flowdrill drill of ø 7,3 mm diameter (Figure 2b).

The shape surface was covered with a protective paste to increase the tool durability, then 5 holes were made in each material. Drilling process was conducted with angular velocity of the Flowdrill tool as recommended by the producer, depending on the used material (Table 2).

Table 2 **Angular velocity of the drill in dependence on used material of the shape**

Shape material	Drill angular velocity
4301	2 490 rpm
S235JRH	3 200 rpm
6060	1 470 rpm

After the thermal drilling process was finished, the samples were cleaned from the remainders of the paste and each rim was cut to prepare a polished section. These sections were used to measure height and thickness of hole burring, as well as the microhardness.

Photographs of the samples were taken using a NIKON Optiphot-100 metallographic microscope and a digital camera with high resolution.

Measurements of height and thickness of hole burring were performed using a NIKON NIS-elements software for image analysis. Scheme of measurement of height and thickness of hole burring is presented in the Figure 3.

Height of burring of a hole in a sample was measured from a measuring base, which was assumed at external, not deformed part of a sample shape. Measurement of burring thickness of holes in samples was performed perpendicularly to the internal edge of rim of a hole, at 1 mm intervals from the measuring base. Particular results of measurements of height and thickness of rims are all averages of 10 measurements.

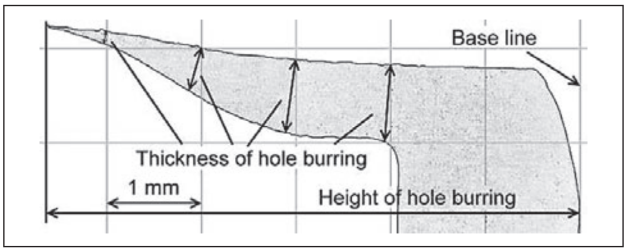

Figure 3 Scheme of measurement of height and thickness of hole burring

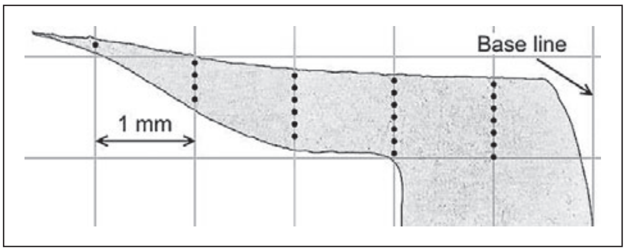

Figure 4 Locations of measurement of sample microhardness – marked with dots

Measurements of the microhardness of a sample using the Vickers method were carried out on a Walter UHL VMH002VD device, in accordance with the PN-EN ISO 6507-1 standard. Load of the penetrator was 25 grams and its feed was equal to 15 μm/s. The measurement was performed in locations shown in the Figure 4.

Microhardness was measured at a distance of 60 μm from the internal edge of a rim, at 120 μm intervals, up to 780 μm. Measurements along the rim were performed at 1 mm intervals from the base line of a sample. To determine changes of the microhardness values in places of shaping a rim of a hole, microhardness was also measured in the base material.

RESEARCH RESULTS

Measured and averaging values of height of burring of hole rims made during the experiments are presented in the Table 3.

Table 3 **Average values of burring height**

Material	Burring height / mm	Std. deviation / mm
S235JR	5,96	0,10
4301	5,64	0,25
6060	7,08	0,36

The greatest value of height of a hole rim burring was obtained in the aluminum shape (length of 7 mm) and it is 18 % greater than in the case of the low-carbon steel and 25 % greater than the stainless steel. It results from plasticity and thermo-physical properties of the burred aluminum material.

Exemplary sections of burred rims of holes for the three analyzed materials are shown in the Figure 5.

Dependency of wall thickness of a burred hole in a function of its height is presented in the Figure 6.

Thickness of burring in an aluminum shape (Figure 5c) decreases at the most uniform rate along with increase of the burring length and it can be described with a very good accuracy using a polynomial equation, in which the determination coefficient equals 0,99 (Figure 6).

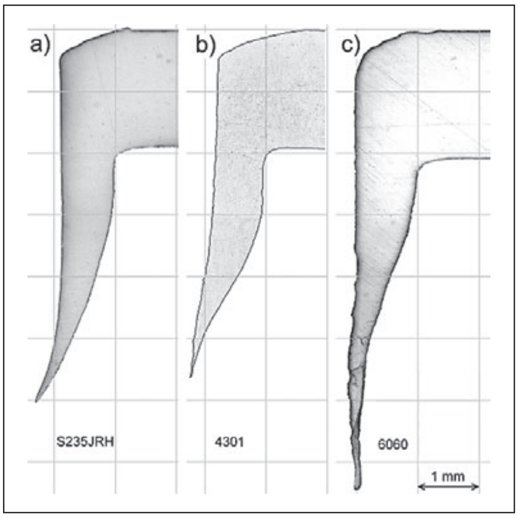

Figure 5 Section of rim of a hole in material: a) S235JRH, b) 4301, c) 6060

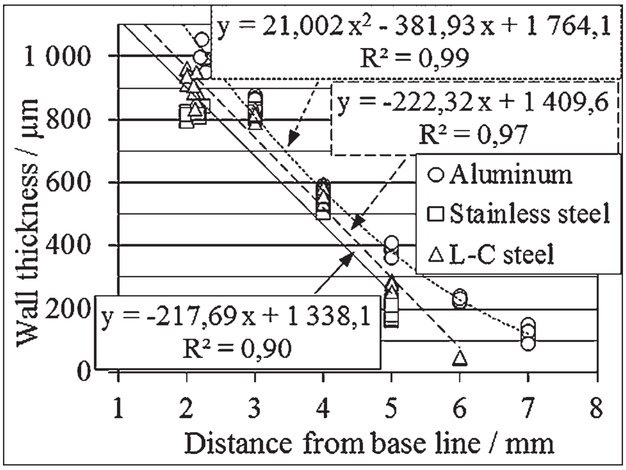

Figure 6 Wall thickness of burred holes in function of height

Despite the greatest height of the burred rim of a hole, equal to 7 mm, at its end there is a significant decrease of thickness (approx. 120 μm), which can result in breaking of the obtained thread. On height of a hole rim equal to 5 mm, wall thickness of the burr is 45 % greater than in comparison with the low-carbon steel and more than two times greater than in comparison with the rim made in the stainless steel.

The least accurate description of burring of a hole rim was achieved for the 4301 stainless steel (R^2=0,90) It is caused by a slight decrease of thickness of burring of a hole rim at the height of 2 and 3 mm, where thickness equals approx. 800 μm (Figure 5b). Above 3 mm, thickness of the rim decreases linearly. In low-carbon steel S235JRH, thickness of a hole burring can be described with a good accuracy using a linear function (R^2=0,97) At the end of the burred rim (6 mm from the base line), there is a clearly visible narrowing of approx. 40 μm, In all the analyzed cases, for heights 3 and 4 mm from the upper surface of a hole, values of thickness of the hole rim burring are similar and equal approx. 815 μm for 3 mm and 530 μm for 4 mm (Figure 6).

The Figures 7-9 present results of averaging measurements of the Vickers microhardness of sections of the hole rims. Value of the microhardness of a base material for S235JRH steel equals 182 HV 0,025, for 4301 stainless steel – 270 HV 0,025 and for the aluminum shape 6060 – 80 HV 0,025.

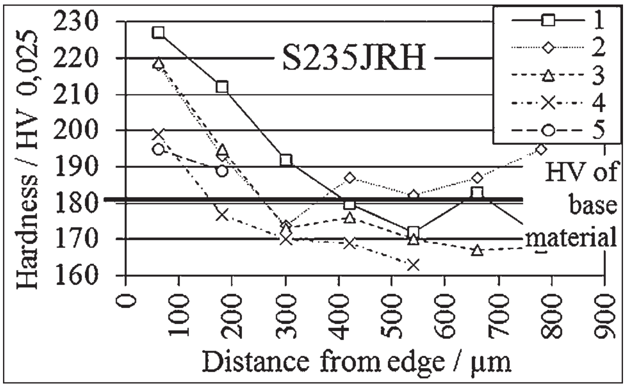

Figure 7 Microhardness of a shape in function of distance from the edge – S235JRH material

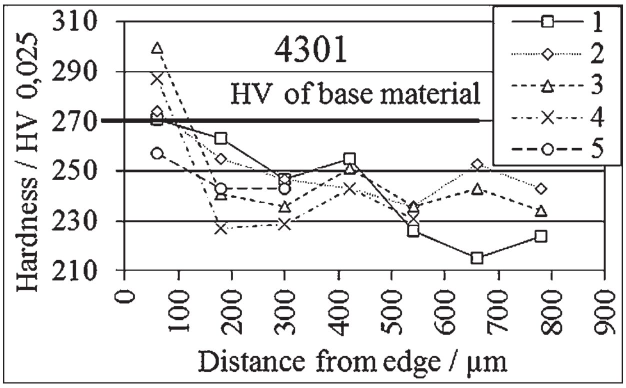

Figure 8 Microhardness of a shape in function of distance from the edge – 4301 material

For the shape made out of the S235JRH steel (Figure 7), at a distance of 60 μm from the edge of the hole rim, an increase of the microhardness value occurred in comparison to the base material. At location of the greatest section of a rim (at 1 mm height), the microhardness value is 25 % greater than in the base material, at 3 and 4 mm height it is 20 % greater and at location of the minimal measured section, the microhardness value increased only slightly (approx. 8 %). These changes are caused by the strain hardening, which results in decrease of the grain size in the material. Along with increase of the distance from the edge of a hole rim, the microhardness value decreases for heights of 3, 4 and 5 mm.

The Figure 8 presents relation between the microhardness values and the distance from the edge of a hole rim for the stainless steel.

Observing the presented relation, it can be stated that increase of the microhardness values occurs only for heights of 3 and 4 mm from the upper surface of the shape (free part of the rim) at a distance of 60 μm from the rim edge, the values equal respectively: for the height of 3 mm – 300 HV 0,025, 4 mm – 287 HV 0,025. In the rest of the free surface of the burring, the microhardness values decrease.

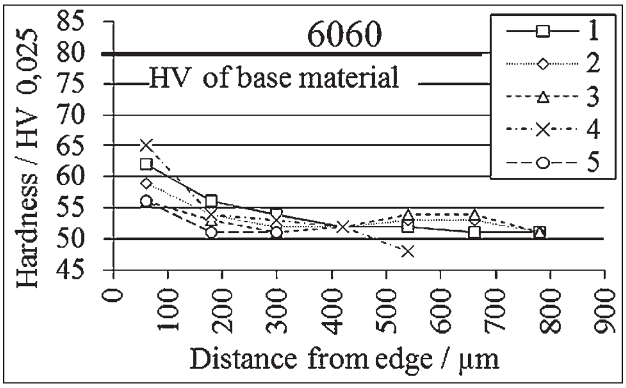

Figure 9 Microhardness of a shape in function of distance from the edge – 6060 material

Burring a hole rim in a shape out of the 6 060 aluminum causes a decrease in the microhardness values in comparison with the base material, through the whole section (Figure 9).

At a distance of 60 µm from the burring edge, the microhardness value changes from 42 % for height of 5 mm to 23 % for height of 4 mm. In the rest of the free part of the burring, a drop of the microhardness value was observed, as high as 53 % in comparison with the base material.

CONCLUSIONS

In the case of the materials used for the study, up to 3 mm of height decrease of a rim section was not observed, which can have a relevant influence on the quality and strength of an obtained thread.

Decrease of the microhardness values was observed in locations set further from the rim edge – inside the material, which may additionally improve the thread properties – it will keep a durable surface and a malleable core.

Application of too small feed ensured proper distribution of temperature, but it led to a non-uniform cooling of a rim, which made higher layers of material cool down more rapidly than the lower layers, worsening the surface quality.

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Note: F. Gorski is responsible for English language, Poznan, Poland