EVALUATION OF SELECTED PARAMETERS IN BLANKING

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Abstract. The course teaches students, among other methods, also shearing technology. A laboratory exercise was prepared, in which cylindrical shaped cuts of two different metallic materials and of three various thicknesses were made using a cutting tool (blanking punch and blanking die) and a universal testing machine. The blanking punch was 10.0 mm in diameter, the blanking dies 10.3 mm or 10.8 mm diameter. The blanking was made of Cu 99.9 sheet metal of 5 mm thickness and Al 99.5 sheet metal with thickness of 3 mm, 5 mm and 10 mm. The course of the instant shear force in response to the displacement of the push plates was recorded during the experiment. The objective of the performed experiments was to determine the real and theoretical maximum shear force and work required to cut. The quality of the shearing area was assessed by the ratio to the size of the area burnish and fracture from the point of view of the effect of clearance between the blanking punch and the blanking die (Al 99.5, thickness 10 mm, punch Ø 10.0 mm and die Ø 10.3 mm or punch Ø 10.0 mm and die Ø 10.8 mm), from the point of view of the type of the cut material (Cu 99.9 and Al 99.5, thickness 5 mm, punch Ø 10.0 mm and die Ø 10.3 mm) and from the point of view of the thickness of the cut material (Al 99.5, thickness 3 mm, 5 mm and 10 mm, punch Ø 10.0 mm and die Ø 10.3 mm).

Keywords: aluminum, copper, sheet metal, cutting, laboratory tests.

Introduction

The division of metallic and non-metallic materials is one of the important processes in the engineering and manufacturing industries. We can use several methods to perform this task in practice. Selection of the optimal method mainly depends on the type of divided material, shape and the dimensions of the starting semi-finished product and the required shape and dimension of the final product. In practice the commonly used method, for example, is cutting by saws, pinning to lathe, sheet metal cutting [1], heat cutting using an oxygen-acetylene flame[2], cutting using energy of a water jet [3-4], laser [5] or plasma [6]. Each of these methods has its own benefits, but also shortcomings, and therefore also an area of optimal use.

Among the most widely used methods of processing sheet metal is by cutting (shearing). Cuts produce workpiece for direct use (e.g. washers under nuts of screw connections), but also semi-finished cut-outs for further processing by other cold metal shaping methods (e.g. bending, drawing, extruding or stamping) and also hot (e.g. forging in dies) [7]. A great boom of this technology can be dated to the end of 19th and start of the 20th century [8-14].

In technical practice, the technological forming processes are commonly divided by how external force influences the material being shaped. From this perspective, we recognize shearing, bending, drawing, extruding, stamping, forging, rolling and other forming operations [15]. In our teaching, students at our department are acquainted with both cold forming and hot forming theoretically (at lectures) and practically (in exercises). When performing new exercises from the subjects “Manufacturing Technology I” and “Basic of Manufacturing Technology” they have the opportunity to become practically familiarized with selected cold metal forming technologies, specifically with cutting, bending, drawing and stamping technologies. From the area of cold forming, the prepared exercise was on the topic of “Evaluation of selected parameters in blanking”.

Materials and methods

Shearing technology is characterized by separation of the material across the cross-section. It is defined as making cuts of different shapes by separating the material along a closed contour, or separation of parts of the material edge. The product created by cutting is called a blank or slug. In the blanking process, the final product is the removed portion from the sheet. In the punching process, the final product is the metal sheet from which metal is removed [15-16]. Basic terminology is obvious from Fig. 1.

DOI: 10.22616/ERDev2018.17.N025

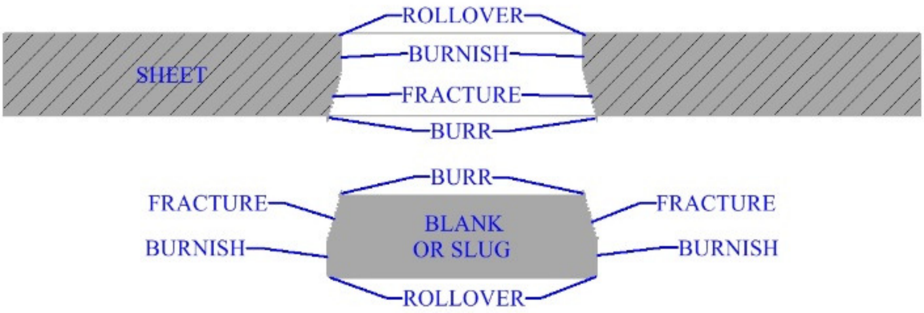

Fig. 1. **Cutting – terminology [17]**

Shear force *F*, N is calculated using the formula

$$F = l \cdot t \cdot T\ , \tag{1}$$

where l – length of periphery to be cut, mm;
t – sheet thickness, mm;
T – shear strength, MPa.

Cutting work *A*, J is calculated using the formula

$$A = \frac{k \cdot F \cdot t}{1000}\ , \tag{2}$$

where k – coefficient, which is dependent on the type and thickness of the cut material (here: $k = 0.75$).

The process during the experiment was the following: using the cutting tool (blanking punch and blanking die) placed in the stand (Fig. 2) we cut the workpiece in the shape of a cylinder from various metal materials of various thicknesses (Table 1). A universal testing machine LabTest 5.50 ST was used to exert the required force. Load speed was 10 mm·min^{-1}. During the experiment, we recorded the course of the shear force and maximum shear force F_{real}. Taking into account the experiment time demand there was always only a single cut made of each combination, i.e. a total of five specimens (Table 1).

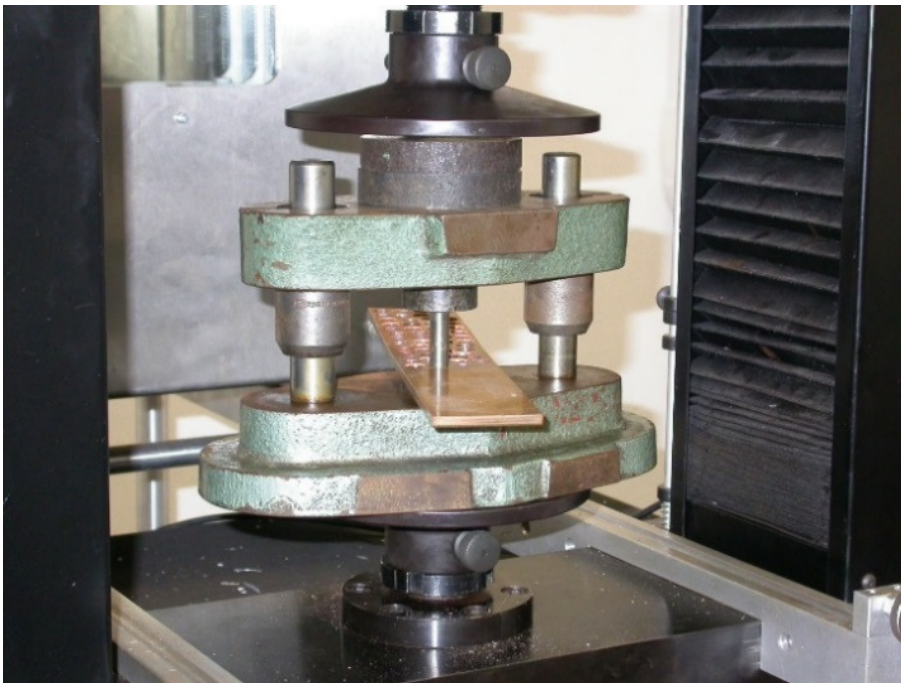

Fig. 2. **Running the experiment**

Table 1

Overview of materials to be cut

Specimen	**Material [18, 19]**	**Sheet thickness *t*, mm**	**Punch diameter *D*, mm**	**Die diameter *d*, mm**	**Shear strength *T*, MPa**
1	Al 99.5	10	10.0	10.3	60
2	Al 99.5	10	10.0	10.8	60
3	Al 99.5	5	10.0	10.3	60
4	Cu 99.9	5	10.0	10.3	185
5	Al 99.5	3	10.0	10.3	60

Results and discussion

From the graphic record (Fig. 3) instant magnitude of shear force in the movement of pressure plates was determined by the polar planimeter defined by the area under the curve, which is proportional to the real cutting work A_{real}, consumed to make a specific cut-out. Based on the data above we used mathematical relations. We used the mathematical relations (1) and (2) to calculate the theoretical magnitude of the shear force F_{theor} and the cutting work A_{theor} (Table 2). When blanking, it is necessary to consider the diameter of the die *d*, when punching, it is necessary to consider the diameter of the punch *D*.

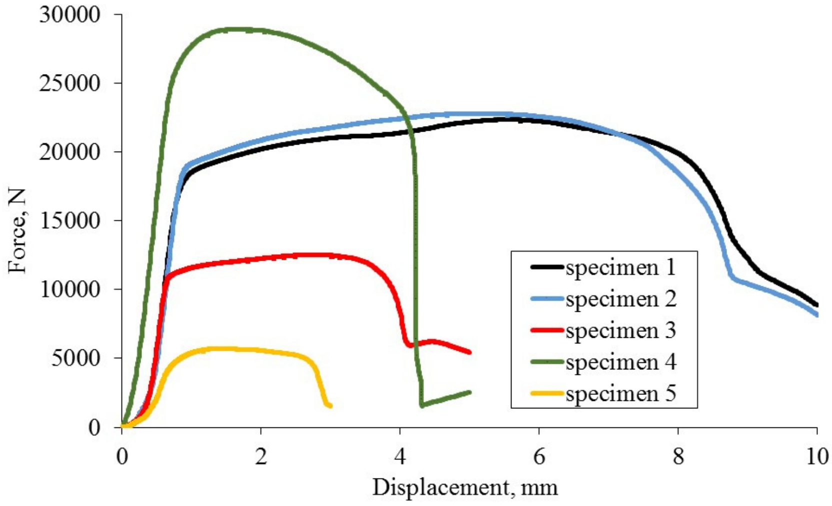

Fig. 3. **Course of cutting force**

Table 2

Real and theoretical magnitude of force and work

Specimen	F_{real}, **N**	F_{theor}, **N**	F_{theor}/F_{real}	A_{real}, **J**	A_{theor}, **J**	A_{theor}/A_{real}
1	17500	19415	1.11	146.8	145.6	0.99
2	19167	20358	1.06	139.1	152.7	1.10
3	10833	9708	0.90	39.8	36.4	0.91
4	29333	29931	1.02	100.1	112.2	1.12
5	5667	5825	1.03	11.6	13.1	1.13

From the data stated in Table 2 it is evident that the magnitude of the theoretical (calculated) force differs from the magnitude of the real force (detected by the experiment) by 2 to 11 %. The magnitude of the theoretical work differs from the magnitude of the real force by 1 to 13 %.

The size of the area shear and fracture was evaluated visually and by a microscope (Fig. 4). Arsenal SZP 11-T ZOOM stereoscopic microscope, Artray camera, and a personal computer with Quick Photo Industrial 2.3 were used for the measurement.

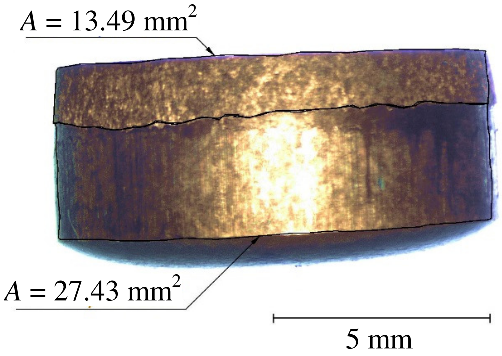

Fig. 4. **Measuring size of area burnish and fracture**

The effect of clearance between the punch and the die was detected when cutting from Al 99.5 sheet thickness 10.0 mm using a ∅10.0 mm punch in combination with ∅10.3 mm and ∅ 10.8 mm dies (specimens 1 and 2). Through the experiment we found that when using a ∅ 10.3 mm die, 73.3 % of the material area was cut, whereas when using a ∅ 10.8 mm die 57.7 % of the material area was cut.

Impact of the type of the cut material was discovered when cutting from Al 99.5 sheet thickness of 5 mm and Cu 99.9 sheet thickness 5 mm using a ∅ 10.0 mm punch in combination with ∅ 10.3 mm die (specimens 3 and 4). It was discovered that with Al 99.5 sheet, the size of the burnish area was 50.3 % and for Cu 99.9 sheet, it was 68.5 %.

The impact of the cut material thickness on cutting was discovered when cutting from Al 99.5 sheet metal of 3 mm, 5 mm and 10 mm thickness using a ∅ 10.0 mm punch in combination with ∅ 10.3 mm die (specimens 5, 3 and 1). However, the results were not clear. On 3 mm thickness sheet metal 62.3 % of the area was cut, and on 5 mm thickness 50.3 % was cut and on 10 mm thickness 73.3 % of the area was cut.

Burnish and fracture surfaces (Fig. 5) were examined with SEM (scanning electron microscopy) using a microscope MIRA 3 TESCAN at the accelerating voltage of the pack (SEM HV) 10.0 kV. On Fig. 5a) we can see an overall view of the cut surface with designation of detailed pictures taken at greater magnification. On Fig. 5b) we can see a detail D4 on Fig. 5a). On Fig. 5a) we can see the border between the fracture area (on top) and burnish area (on bottom) on cut area of workpiece made from Al 99.5 sheet metal thickness of 10 mm when using 10.0 mm diameter punch and 10.8 mm diameter die.

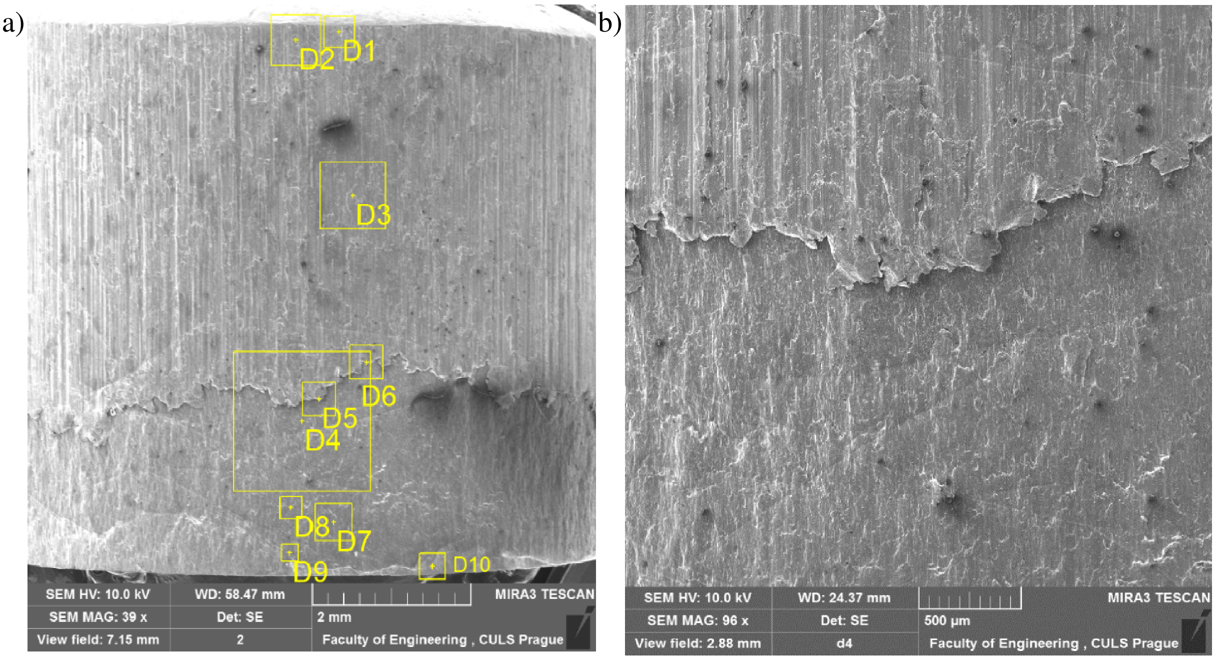

Fig. 5. **Burnish and fracture surfaces:** a – full view, b – detail D4

The results of the performed tests stated above prove the known fact that the definition of optimal parameters for cutting from various materials of various thickness by one tool is practically impossible. Two different materials with significantly different shear strength were used in the experiment. Similarly, the thickness of the cut material was distinctly different.

Conclusions

The article presents blanking technology studies. The workpieces were made using shears (blanking punch and blanking die) of own design. The source of the required force was a universal testing machine. The punch had a 10.0 mm diameter. The two used dies had diameters of 10.3 mm and 10.8 mm. The workpieces were made from Cu 99.9 sheet metal with the thickness of 5 mm and from Al 99.5 sheet metal, which had a thickness of 3 mm, 5 mm and 10 mm. During the experiment, we recorded the course of the magnitude on instant shear force in response to the displacement of the pressure plates and maximum shear force.

Through the performed experiments, we gained the following knowledge, which was then used in classes.

1. We discovered the real and theoretical maximum cutting force necessary to make the cylinder shaped blank.
2. We discovered the real and theoretical work required to make the cylinder shaped blank.
3. We evaluated the quality of the cut areas using the ratio of the shear area and fracture area.
4. We evaluated the quality of the cut areas from the perspective of impact:
   - clearance between the punch and the die – when cutting from Al 99.5 sheet metal of 10 mm thickness using a Ø 10.0 mm punch in combination with Ø 10.3 mm die (specimen 1), or Ø 10.0 mm punch with Ø 10.8 mm die (specimen 2); specimen 1 compared to specimen 2 shows: less shear force, greater cutting work, better surface quality of the cut areas;
   - type of the cut material – when cutting from Al 99.5 sheet metal of 5 mm thickness (specimen 3), or from Cu 99.9 sheet metal of 5 mm thickness (specimen 4), using a Ø 10.0 mm punch in combination with Ø 10.3 mm die; specimen 3 compared to specimen 4 shows: less shear force, less cutting work, worse surface quality of the cut areas;
   - thickness of the cut material – when cutting from Al 99.5 with thickness of 3 mm (specimen 5), 5 mm (specimen 3) and 10 mm (specimen 1) using Ø 10.0 mm punch in combination with Ø 10.3 mm die; specimen 5 compared to specimens 3 and 1 shows: lowest shear force and lowest cutting work.

Using all of the results obtained through the above stated experiment, we were able to prepare and test a new laboratory exercise for students of the subjects “Manufacturing Technology I” and “Basic of Manufacturing Technology”. Depending on the field of the study, all students of our faculty are studying one of these subjects.

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