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FRICTION FORCE OF THE NATURAL LEATHER CUTTING PROCESS

OPORY TARCIA PRZY WYCINANIU SKÓR NATURALNYCH

Key words: friction coefficient, natural leather, leather-like material, toe puff material, cutter.

Abstract Cutting natural leather is a first stage of a technological process of leather goods. It consists of dividing flat materials into shoe components. Cutting can be done by hand or mechanically. Cutters are the main cutting device in mechanical process. During utilization of cutters, the durability of its usage is an important issue. To increase its endurance, optimal force conditions are required. These depend on the following: the friction coefficient between cutting machine and cut material, the angle of sharpening of cutter, the blunting of the edge, using a cutting pad, and the type and kind of steel of which is produced. Friction is a component of a cutting force and its value depends on several factors, one of which is shape of the cutter. It is a parameter often ignored in the literature; however, according to the studies conducted by the authors, the value of the friction during cutting depends on the shape of the cutter. In this study, results of force value measurements required to cut elements of different shapes with equal circumferences with steel cutters are presented.

Słowa kluczowe: współczynnik tarcia, skóra naturalna, tworzywo skóropodobne, materiał podnoskowy, wykrojnik.

Streszczenie Rozkrój skór naturalnych na elementy jest pierwszą fazą procesu technologicznego produkcji wyrobów galanterii skórzanej. Są to czynności polegające na podziale materiałów płaskich na elementy składowe wyrobu. Rozkroju można dokonać ręcznie lub mechanicznie. Głównym narzędziem wycinającym w procesie mechanicznym są wykrojniki. Podczas eksploatacji wykrojników bardzo ważnym zagadnieniem jest trwałość jego ostrza. W celu zwiększenia trwałości ostrza wykrojnika dąży się do optymalnych warunków siłowych procesu. Są one zależne od: współczynnika tarcia pomiędzy narzędziem skrawającym a wycinanym materiałem, kąta zaostrzenia wykrojnika, stępienia krawędzi ostrza, stosowanego podkładu, rodzaju oraz gatunku stali, z jakiej jest on wykonany. Składową siły wycinania jest siła tarcia, której wielkość uzależniona jest od wielu czynników. Jednym z parametrów kształtujących siłę tarcia występującą podczas wycinania jest kształt wykrojnika. Jest to parametr pomijany w literaturze, jednak z badań przeprowadzonych przez autora wynika, że wielkość siły tarcia występującej podczas wycinania jest uzależniona od kształtu wykrojnika. W pracy przedstawiono wyniki pomiarów siły potrzebnej do wycięcia ze skóry naturalnej, tworzywa skóropodobnego i materiału podnoskowego elementów o różnym kształcie ale o takim samy obwodzie wykrojnikami stalowymi.

INTRODUCTION

Cutting of the materials is the first stage of shoe production. Modern shoe factories chose cutting method based on type of the material, size, production profile, and available equipment. Cutting female shoes produced in a limited series is most commonly done by a cutting plotter coupled with CAD/CAM system to design and technologically develop shoe pattern. This system is effective in small series; however, in mass production, it turns out to be uneconomical **[L. 1–4]**. For that reason, traditional cutting of natural leather by cutting machines with the use of cutters is the common practice.

Mechanical cutting is economically reasonable in serial and mass production, or in shoe patterns with standard elements. Such cutting is made on machines called presses, by a cutter, where the cutting edge form the contours of the material. The cutter placed on

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a pressed material forms an arm of the down-thrust machine. The durability of the blade is a major concern during usage of a cutter. Optimal force conditions, needed to increase the durability of the blade, depend on angle of sharpening of cutter, blunting of the edge of blade, the used undercoat, and the type and kind of steel used in its production. Numerous studies of this process have proven that, for the vast majority of shoe materials, angles of blades from 20° to 22° are optimal **[L. 1, 3]**. Increasing the angles results in prolonged durability of the cutter; however, the force needed to cut the elements increases as well. Additionally, the quality of the materials is worsened, and the cutting press is overloaded. An angle that is too acute, on the other hand, shortens time of exploitation of the sample (due to destruction of the blade).

The cutting process may be divided into four steps. In the first step, the cutting edge is pressed on the whole circumference into material so that the force increases slowly and the first layer is stretched and deflected under the blade of cutter.

In the second step, the external layer of the material is cut and the cutter penetrates further into material. The cutting force increases significantly due to fraction of the material against the surface and reaches its maximal value, when the blade descends into 0.75–0.85 of the depth of the material.

The third step consists of breaking apart the material under the force of the blade of the cutter. The force value decreases quickly and the cutting edge moves closer to the foundation surface.

When the cutting blade reaches the foundation, the fourth stage begins, during which the force increases rapidly due to blade piercing into foundation to a depth of approximately 0.2–0.5 mm.

Force distribution in each stage depends on type of material and its thickness. The quality and precision of the cut material of the shoe element depend on the following: the dullness of the blade of cutter, the position of the cutter against the material, cutting speed, the properties of the material, the thickness of the material or quantity of the cut layers, and the construction of the cutter.

The dullness of the blade of cutter, an essential component of the quality of the cut materials, depends directly on the friction of the cutter and cut material. The shape of the cutter significantly affects the traction force during cutting by increasing tribological relationships between cutter and material **[L. 5–6]**.

MATERIALS AND METHODS

Die from cold rolled tape, hardened and sharpened at 21 mm height and 2 mm width were used. The cutters had the same circumference (40 cm) but different shapes **(Fig. 1)**: circular, square, regular hexagon, equilateral triangle, isosceles trapezoid, and right triangle.

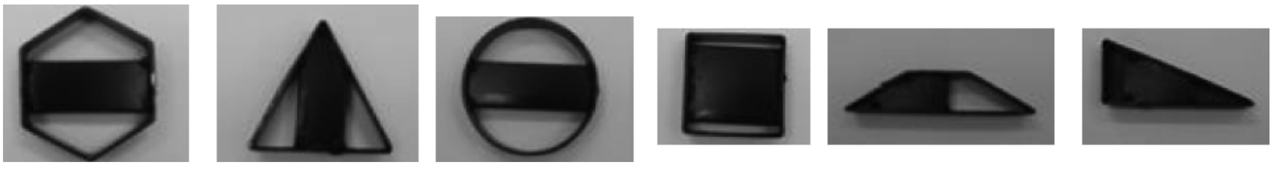


Fig. 1. Shapes of the cutters used in the study
Rys. 1. Kształty wykrojników użytych do badań

The cut materials were the following:
– Cowhide with corrected grain,
– A leather-like material, and
– Toe puff material.

The width of the materials prior to measurements was matched to the same value, and study specimens were sampled from rump leather.

Research was undertaken at a work station **(Fig. 2)** and consisted of cutting natural leather by cutters of different shapes, but each shape had an equal circumference and registering value of the force of friction with the measurement system **(Fig. 3)**.

Cutting force was registered by strain gauge **(Fig. 4)**, which was earlier calibrated by a testing machine ZMGi 1000.

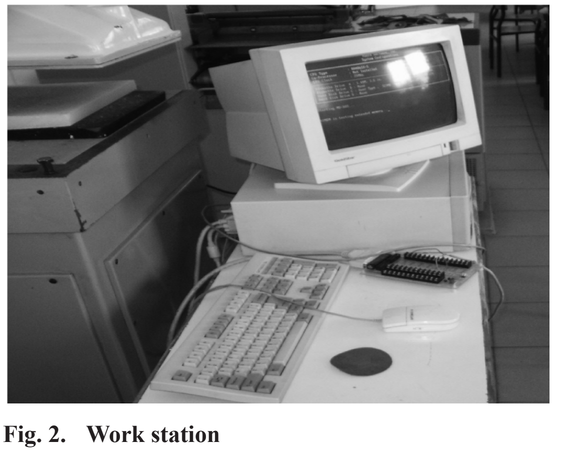


Fig. 2. Work station
Rys. 2. Widok stanowiska badawczego

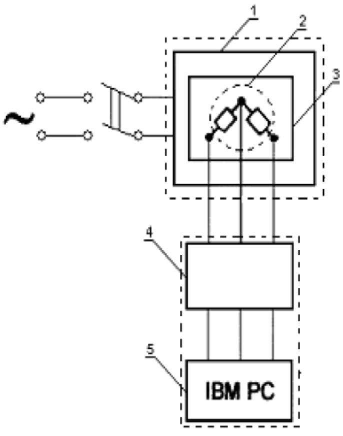


Fig. 3. Measurement system: 1 – strain gauge, 2 – bridge circuit, 3 – strain beam, 4 – analogue-digital system, 5 – computer with force measurement software

Rys. 3. Układ pomiarowy: 1 – czujnik tensometryczny, 2 – mostek tensometryczny, 3 – belka tensometryczna, 4 – układ analogowo-cyfrowy, 5 – komputer z oprogramowaniem do pomiaru siły

Fig. 4. Strain gauge measuring force of cutting

Rys. 4. Czujnik tensometryczny do pomiaru siły wycinania

The experiment consisted of employing cutters of different shapes and selected natural leather. Measurements were undertaken at room temperature and included the following:

- Cutting force, and
- Cutting time.

The arithmetic mean of results of at least 3 attempts formed the basis for the evaluation of the cutting force. Additionally, results could not contain values requiring rejection based on statistical Dixon test.

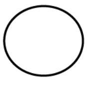
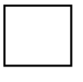
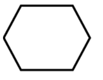
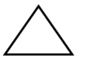
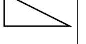
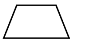
RESULTS AND DISCUSSION

Results of force measurements of analysed material systems, depending on shape of cutter and cut materials, are presented in **Tab. 1. Figures 5, 6, and 7** present graphic interpretations of the results.

Analysis of obtained results of force measurements required to cut natural leather and shoe materials with cutters of different shapes of equal circumference allows ascertaining that the shape of the cutter impacts the force value needed to cut the studied materials. It was noted that the force value depends on number of angles and their values. The more angles (or the lesser their value), the greater force was detected during measurements. The reason for that is increased friction between material and cutting edge of cutter during the second cutting phase as a result of stress accumulation in the spaces of sharp bends in the die shape. This phenomenon is less significant for shapes with curves (circle) or obtuse angles.

Table 1. Mean force values required to cut with cutter analysed materials

Tabela 1. Wielkość średniej siły potrzebnej do wycięcia określonym wycinakiem przebadanych materiałów wyrażona w [kN]

Cutter / Material	Thickness [mm]						
Cutter number		1	2	3	4	5	6
Cowhide with corrected grain	1.6	21.5	22.5	23	24.1	21.1	21.3
Leather-like material	1.5	23.5	23.5	25.5	26	23.5	23.5
Toe puff material	0.7	22.5	23	25.2	24	22.5	23

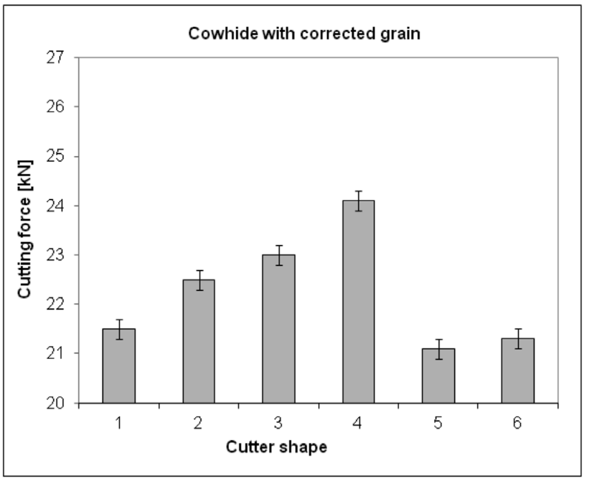


Fig. 5. Cutting force values with different cutters for cowhide with corrected grain

Rys. 5. Wielkość siły wycięcia różnymi wycinakami skóry bydlęcej z poprawionym licem

The dependences of cutting force values on the shape of the cutters for cowhide with corrected grain are dependent on the angle of the flare of the shape of the cutter and their quantity. The biggest force (24.1 [kN]) was needed to cut an equilateral triangle and the smallest force (211 [kN]) was for a right triangle.

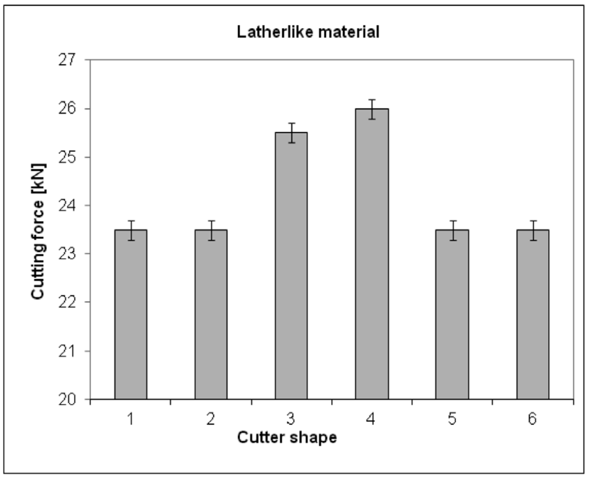


Fig. 6. Cutting force value with different shapes of cutter for leather-like material

Rys. 6. Wielkość siły wycięcia różnymi wycinakami tworzywa skóropodobnego

Similar relationships were noted during cutting leather-like material. The biggest cutting force (26 [kN]) was needed for equilateral triangle shaped cutter, while the smallest force (23.5 [kN]) was needed for circular, square, trapezoid, and right triangle cuts.

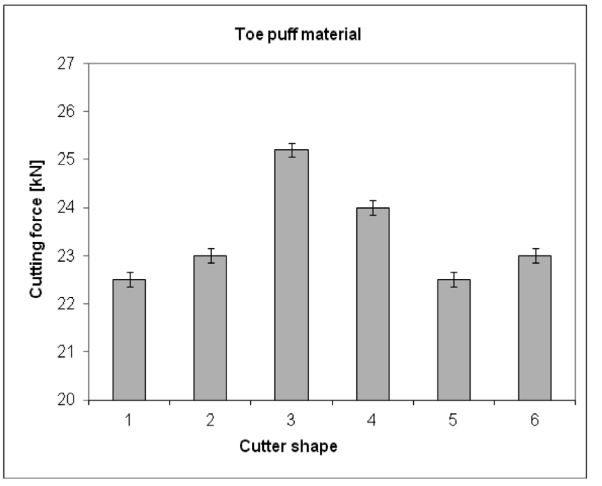


Fig. 7. Cutting force values with different cutter for toe puff material

Rys. 7. Wielkość siły wycięcia różnymi wycinakami materiału podnoskowego

Increasing of the force needed to cut depending on number of acute angles was also noted for toe puff material. The biggest force (25.2 [kN]) was used with a hexagon cutter, and the smallest force (22.5 [kN]) was used with the circular and right triangle shaped cutters.

CONCLUSIONS

Based on conducted research, the relationship between cutting force and the shape of the cutter was established. The least favourable shape of the cutter is an equilateral triangle. For each studied material, this shape required the biggest force values. On the contrary, cutters with the obtuse angles or curvatures required the smallest amounts of force. This difference is associated with increased friction in tight spaces of acute angles of sharp cutters.

A comparison of the results indicates that which cutters have right angle (or larger) or considerable curvatures require much less force than those with acute angles. The force needed to cut material depends on many factors that further rely on the structure and type of the material, the greater or lesser impact of friction of the cutter on cut material, the possibility of local squashing of the cut material when using cutter with acute angles, which is accompanied by increased contact force and friction in such cases, and the angle created by fibres and the edge of cutter. The thickness and finish of the material (first layer) are important factors that affect cutting force. It is best demonstrated in cases of cutting shoe materials when the first layer of finish is plastic. This layer increases hardness, which requires bigger force to cut it.

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