CAUSES OF EDGE DEFLECTION IN STACK CUTTING OF ALUMINUM SHEETS

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Summary

In the process of cutting sheet metal using guillotine, defects may occur in the section of the machined object, resulting in the impossibility to perform further machining of the material (sheet metal). The publication presents the process of edge bending during bundle cutting of sheet metal. The experiments have been conducted using an original test stand and high speed Phantom cameras have been applied in the tests. The paper presents a study based on previous work carried out at the Department of Theoretical and Applied Mechanics [2,4,7].

Keywords: cutting of bundle, guillotine, cutter replacement, edge bending, chipping

PRZYCZYNY POWSTAWANIA ZAGIĘCIA BLACHY PODCZAS CIĘCIA PAKIETÓW BLACH ALUMINIOWYCH

Streszczenie

W trakcie przeprowadzania procesu cięcia pakietu blach na gilotynie, w przekroju przedmiotu poddanego obróbce, mogą pojawić się defekty, których skutkiem jest niemożność dalszych procesów obróbkowych materiału (blach). W pracy przedstawiono proces powstawania zagięcia i pionowego uszkodzenia krawędzi blach podczas cięcia pakietów blach na gilotynie. Badania eksperymentalne przeprowadzono na autorskim stanowisku badawczym, a do badań zastosowano kamery do pomiaru zjawisk szybkozmiennych Phantom. W pracy zaprezentowano badania bazujące na wcześniejszych pracach prowadzonych w Katedrze Mechaniki Teoretycznej i Stosowanej [2,4,7].

Słowa kluczowe: cięcie pakietu, gilotyna, wymiana noża, ugięcie krawędzi, wyszczerbienie

1. WSTĘP

The correct preparation of the material separation eliminates the occurring faults - and thus, also – the random defects. It also effects in the increased durability of the blade used in the process of cutting.

There are four main groups of causes for the cutter replacement:

- damages of the cutter, chipping and discontinuities of the cutting edge, cold welds, damage to the protective coating which decrease the friction of the cutter,
- damages of the sheet metal, burrs, edge bending, coarseness, vertical defects,
- damages related to the sensitivity of a certain type of sheets, blue spot on edge,
- changes related to the organization of work, changes in product dimensions, maintenance, tests.

One of the most frequently occurring defects in the sheet separation are burrs. Burrs are defined as unwanted, protruding, plastically deformed material at the edge, which occurs in all machining [8]. The process of burr formation has been well described in scientific literature, including the process of machining [6], face milling [3], shearing [9] and cutting [1]. Based on own research, some of the authors reach own conclusions concerning the reduction of burrs, e.g. by applying proper process parameters, that is, the speed of the process, the geometry of the cuter etc.

Another occurring defect is the edge bending. It is a sporadic phenomenon. The effect of bending of the plate edge is difficult to observe. The causes of the phenomenon depend on the thickness and the type of the cut material, the built-up edge, cutter chipping and the rigidity of the cardboard pad used as a separator. The mechanism of edge bending has been presented in fig. 1. It should be noted that the bending occurs in plates which are directly on the cardboard separator. Depending on the type of the cut material, the deflection of the cardboard separator may lead to permanent deformation of the edge. No research in this subject area has been found in scientific literature.

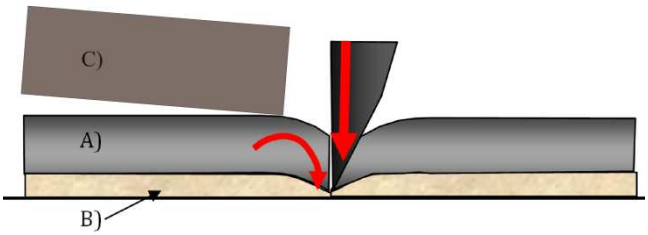

Fig. 1. Mechanism of edge bending a) bundle of aluminum sheet b) cardboard c) pressure beam [2]

While cutting long elements, an adverse phenomenon can also occur: edge bending in the form of arch (fig. 2). This effect occurs despite the high rigidity of the cutter and the holder. The convex bending of the plate is most often an effect of a too small load of the pushing bar and applies to thin plates made of soft materials.

The shearing deformation in guillotining is accompanied by a bending deformation, as the sheet has to conform to the inclination of the knife. Both deformations influence each other, leading to the development of shape defects which increase with increasing rake angle and decreasing width of the cut-off strip [10].

2. DESCRIPTION OF THE TEST STAND

To conduct the experiments, a specialist test stand has been prepared (fig. 3). The stand has been placed on the MTS 858 fatigue testing machine. Unlike the movement of the guillotine cutter (swinging motion with an angle of ~45 degrees), the movement of the cutter of the test stand is vertical. The drawings below present the design of the test stand with consideration to the measurement sensors applied:

- cutting force sensor located over the cutter,
- force sensor located under the test stand for the measurement of the force resulting from the impact of the cutter on the bundle of plates in the first phase of cutting,
- 2 force sensors in the pushing bar for the verification of the correct pressure of the bar on the bundle of plates,
- 2 distance sensors for the verification of the pushing bar distance from the cutting edge of the blade.

The movement of the cutter is performed directly by the MTS 858 machine, using hydraulics, while the pressure of the pushing bar is performed with two screw mechanisms.

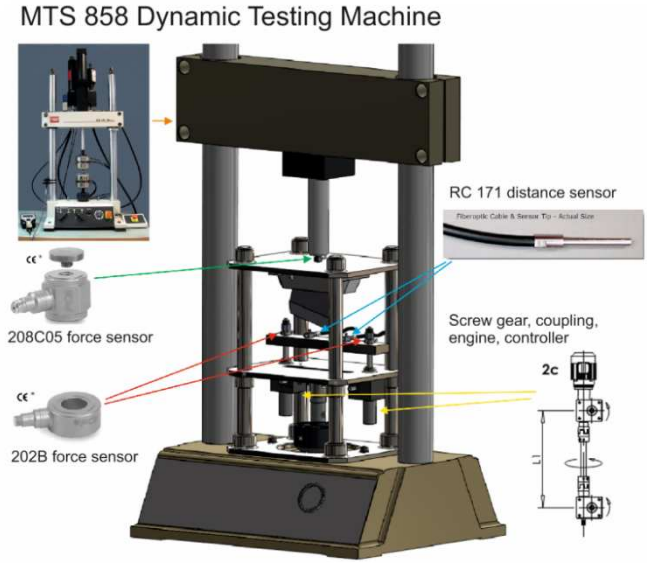

Fig. 3. The test stand with auxiliary measurement equipment

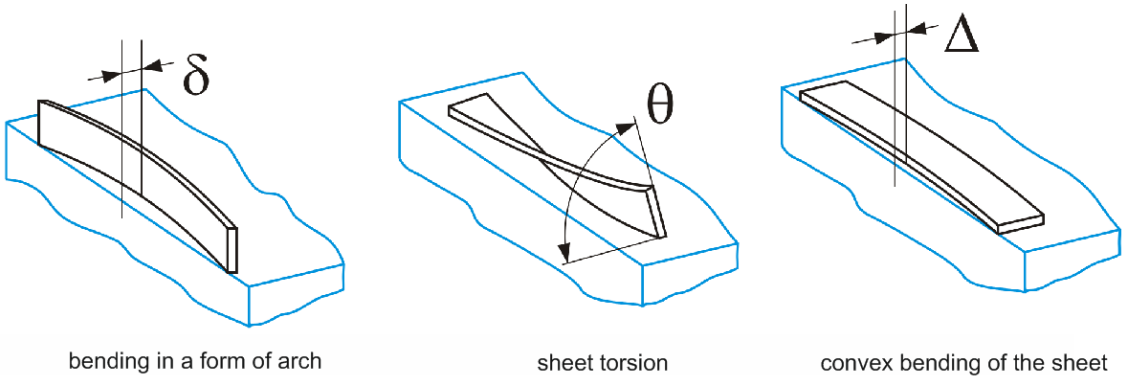

Fig. 2. Possible bending to occur in plate cutting [2, 10]

In fig. 4, the concept of measurements using the Phantom 9.1. high speed camera has been presented. The recording of the cutting has been performed using 6000 frames/s frequency, which allowed for an accurate monitoring of the plate bending phenomenon during the guillotine cutting.

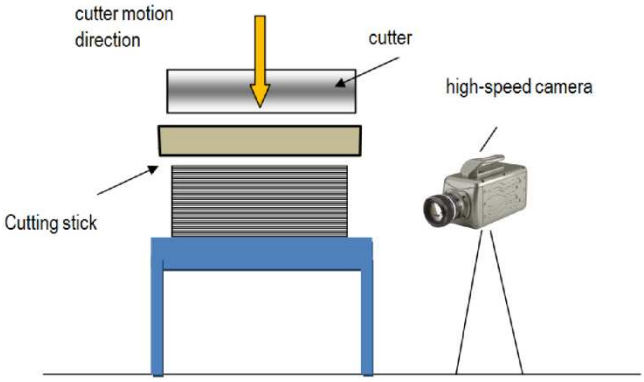

Fig. 4. The design of the test stand with consideration to the location of the high speed camera [2]

3. EXPERIMENT RESULTS

The cardboard bundle is used for the separation of individual layers of metal sheets. Due to the weight of the bundles, special robots with manipulators which recognize the cardboard separators and may transport a proper number of prepared bundles are used. Phantom V.9.1. high speed camera has been applied for the observation of the plate and cardboard behavior (fig. 5).

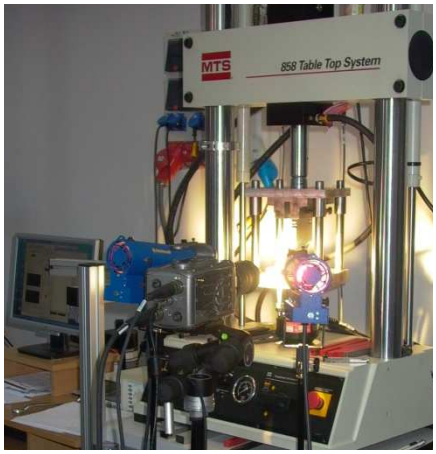

Fig. 5. The test stand for high-speed measurements, Phantom V.9.1. camera and halogen lighting

As a result of the observation of the behavior of cardboard and sheet metal placed directly on it, it has been noticed that while using low-quality and rigidity cardboard, two adverse effects occur [2]:

1. The bending of the sheet metal placed directly on the cardboard, which may be the direct cause of burrs and bending of plate edges. In figures 6-9, the effect of sheet deflection during the cutter blade passage has been presented; the value of the deflection, which in the extreme case reaches the thickness of the sheet, that is 0.3 mm, has been read using the Tema Automotive software. Several times it has been noted that the deflected sheet did not recover its primary position and a visible bending of its edge could be noticed. This effect does not occur when using rigid cardboards which additionally clean the blade of the aluminum oxide sediments, which may have a direct impact on the tool life.

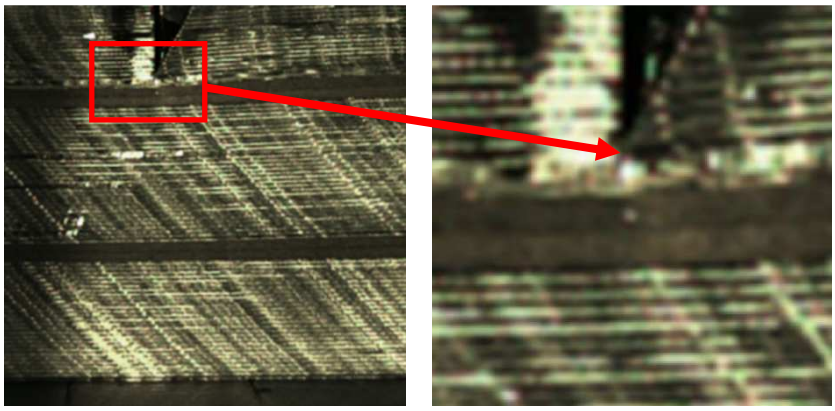

Fig. 6. The first phase of cutting, the blade cuts through individual sheets and approaches the cardboard, no deflection visible [2]

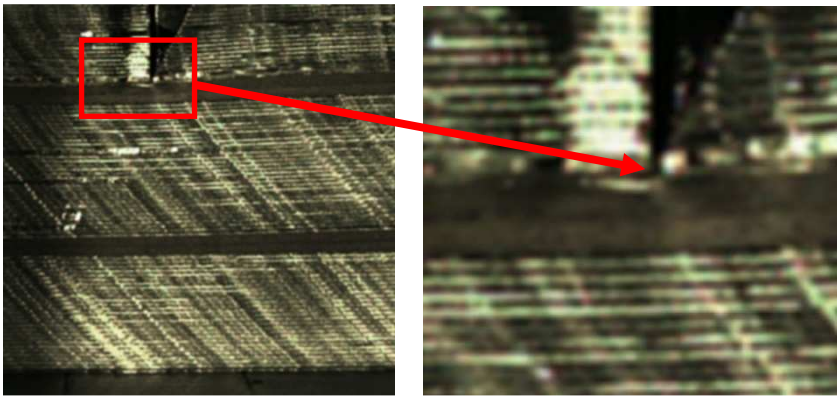

Fig. 7. Second phase, the blade is directly above the cardboard, small deflection if the plate placed directly on the cardboard is visible [2]

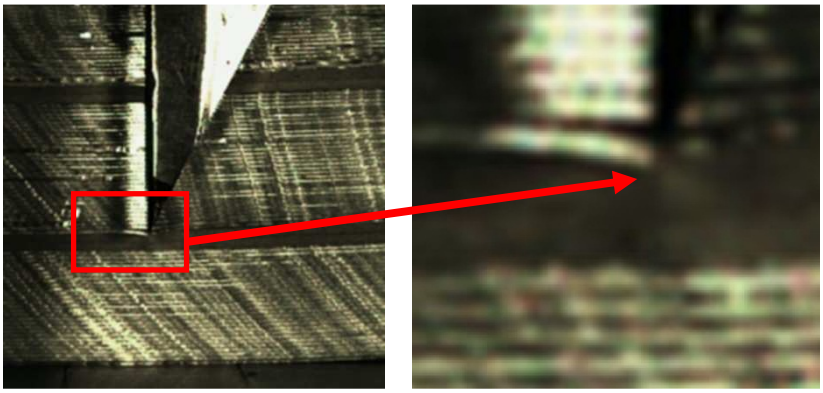

Fig. 8. Third phase, the blade approaches another cardboard area, large deflection of the plate placed directly on the cardboard visible [2]

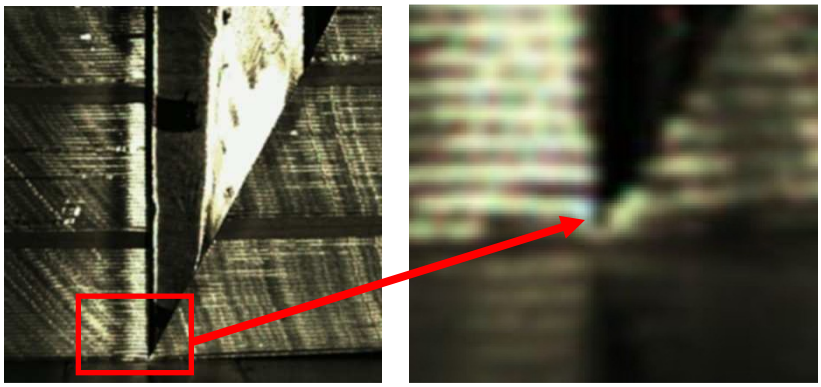

Fig. 9. The fourth phase, the blade approaches the area of a more rigid cardboard, no deflection of the plate is visible [2]

2. The formation of impurities in the cutting zone. In the recording, fragments of paper which may stick to the surface of the blade and form a dangerous built-up edge along with the aluminum oxide have been noticed.

Scientific literature includes publications concerning the modeling of cutter damages in guillotine cutting [4]. In this work, the author attempts to present the complicated process of damage formation of the cutter blade, using the finite elements method. The article provides the presentation of experiments conducted at the test stand.

Further research concerned different blade angles for the evaluation of cutting force and blade angle dependence. The test has been conducted for two blade angles: 23.5°, 28.5° [7].

In the process of cutting with the cutter with 23.5° blade angle, a damage of the cutter occurred, namely a chipping of the blade (fig. 10). After another cutting performed with the same cutter, in a way so as the damaged part of the blade did not take part in the cutting, the cutter has been damaged again. A new, slightly smaller chipping occurred. In both cases, this has been a cause of damage to the cutting surface of the sheet metal bundle (fig. 10).

Fig. 10. Chipping of the 23.5° angle blade, cutting speed of 0.1 m/s [2, 7]

Tab. 1. A comparison of the results for different blade angles

Blade angle	Cutting time	Bundle thickness	Cutting speed	Max force	Average force
degree	s	mm	m/s	kN	kN
23,5	0,34	33.62	0,1	7,23	3,34
28,5	0,34	33,33	0,1	5,86	4,19

4. SUMMARY

Based upon the experiments it may be asserted that:

- The course of the measured forces at different blade angles indicates that the force is decreasing with the decrease of the blade angle. After the measurement of the two different blade angles, it may be asserted that the optimal angle is 28.5°.
- In long operation of the tool, built-up edge may occur at the blade, which, as a result, will adversely affect the increase of the blade angle and may be a cause of the increase of the forces necessary for the cutting as well as cause damage to the surface of the cut sheets [7].
- The phenomenon of sheet metal bending occurs in sheets placed directly above cardboard separators. High flexibility of the cardboard separators and the inertial forces occurring in the cutting process cause that the plates undergo permanent damage. The bending of the edge forms in the cutting process. Next, the plastic-elastic deflection of sheets in the contact area of the blade and the bundle occurs. The highest deflection occurs in the plate located directly over the cardboard separator, and may be a plastic deformation,
- The cardboard used as a separator of sheet bundles should be characterized by high rigidity, which prevents the bending of sheet edges placed directly above it,
- The cardboard separator should be made of high quality paper, preventing the sedimentation of paper fragments on the blade and the propagation of build-up edge on the blade,
- The angle of the blade is important and it is the decisive factor for the value of the force necessary to separate the cut material. It must however be noted that the decrease of the blade angle does effect in the possibility of blade chipping and results in the occurrence of nicks which eliminate the cutter from further operation [7].

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