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Metallographic investigations of metal plate edges after cutting

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Methodology of research

ABSTRACT

Purpose: Cutting sheets of various materials is a commonly used product finishing process in industrial conditions. If high quality of cut edges is required, defects caused by cutting on a guillotine make this process of finishing practically unsuitable. The Authors evaluated quality of plates after cutting in laboratory, on industrial guillotine and a rotary slitter, in order to specify a cutting method least disturbing to the product's edge.

Design/methodology/approach: Samples of multi-layered aluminium lithographic plates, divided by cardboard and paper sheets were cut in industrial conditions on a guillotine and a rotary slitter. A specially designed laboratory test stand was built, allowing measurements of forces and applying a vertical, controlled movement of the cutting blade. Surfaces of edges of the samples were examined with the use of a Scanning Electronic Microscope; results of these scans were compared and evaluated.

Findings: Comparison of surfaces after cutting allowed drawing conclusions regarding methods causing minimum disturbances to the cut edges. The best quality of the cut edges was obtained on a laboratory guillotine test stand, applying a unique, vertical movement of the cutting blade.

Research limitations/implications: Results of laboratory experiments should be continued and verified on larger scale in industrial conditions.

Practical implications: If vertical cutters could deliver the same edge quality as rotary slitters, a substantial reduction of production costs can be expected as in many cases guillotines are far more efficient than rotary slitters.

Originality/value: Vertical, controlled movement of the blade during cutting metal sheets offers substantial advantages to the finishing process compared to standard guillotine cutting. In all cases, when high quality of the edge surface is required, proposed vertical cutting combines high efficiency with simplicity of operations and assures high quality of the finished products.

Keywords: Metallographic; Electron microscopy; Sheet metals; Guillotine cutting

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1. Introduction

Production processes of lithographic plates of New generation belong to so called High Tech technologies. Aluminum Plates, divided by thin sheet of paper are bundled into packages of fixed number i.e. 30, 50 or 100 with dividing cardboard sheets between them. These packages have a „Sandwich”- like structure. Quality of edges after cutting depend on a type of cut material, type of tool used for cutting, sharpness of cutting edge and conditions of the process of cutting [3]. In available literature there is no information about cutting technique assuring the highest edge quality, which means the lowest disturbance to the texture of the material. In particular there is little information on cutting lithographic plates. The most ideal cutting process would allow division of atomic bonds on the surface alongside defined Line without Any disturbance to the physical condition of the material. At this moment the most frequently applied basic cutting and punching of various materials differ substantially between each other, taking into account costs and quality aspects of final product. In general the following cutting methods are used:

- cutting with oxygen,
- cutting with plasma,
- cutting with electric arch,
- cutting with water,
- laser cutting [6],
- mechanical cutting.

Most frequently applied techniques in industrial conditions for cutting are oxygen and plasma cutting [1,7,16]. In this paper, metallographic investigations of metal plate edges structures [2,5,11] are presented, after mechanical cutting.

Cutting aluminum plates causes several defects, inevitably related to the cutting process:

- cold welding, caused by small particles adhering to each other
- dents and other damaged caused for example by no sharp knife,
- edge folding of metal plate,
- edge „roughness”, caused by small particles of coating pressed into the edge’ surface
- burr [14],
- „vertical damage”, caused by knife condition.

One of the most frequent defects, occurring during sheet separation, are cutting burrs. They are defined as undesired, protruding, plastically deformed wire-like material at the edge, occurring in almost all machining processes.

Another defect is the edge bending (Fig. 1). 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, condition of the cutting blade, burrs and rigidity or stiffness of the cardboard pad used as a separator [8].

In this paper the Authors are not going to discuss the origins of each defect, but will try to show which cutting method assures the best quality of edges for thin metal plates.

Determination of the edge „roughness’ of for pre-sensitized plates is performed by the operator through organoleptic check. Results of such a check are naturally largely influenced by the level of experience and individual perception of the technician. Based on this judgment, a decision is made regarding the condition of the cutting blade. Extend of roughness of the plate’s edge after cutting depends on several factors, mainly:

- conditions of the cutting process, grinding geometry of the cutting blade,
- wear/tear of the cutting blade, vibrations during cutting, rigidity of the guillotine blade and the cut object,
- chemical composition of the plate’s coating and homogeneity of the material to be cut.

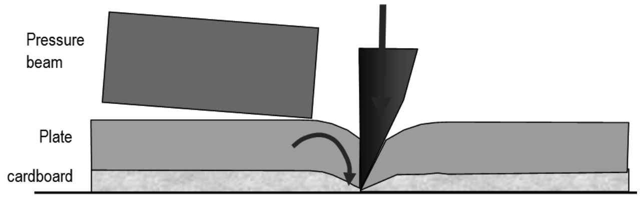


Fig. 1. Mechanism of the Edge Bending [8]

Cutting burr (Fig. 2) can be defined as undesired, protruding sharp plastically deformed material at the edge of the sample, occurring during machining of metal objects. It can cause injuries during handling and damages to the machine parts. Burrs can be minimized or controlled by choosing right process parameters, like velocity of the blade movement, blade geometry etc. While in most cases removal of burrs belongs to routine finishing processes, burrs at the edges of lithographic plates cannot be removed without damaging the sensitive coating layer and therefore they should be avoided as much as possible.

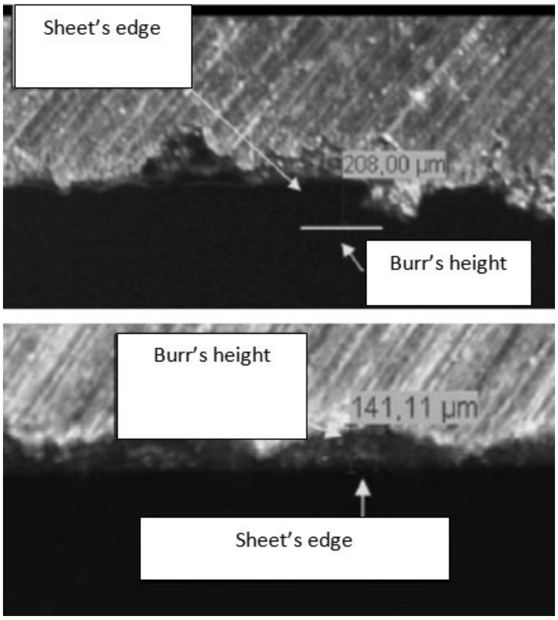


Fig. 2. A burr [phot. A. Skibniewski]

The Authors in their research tested various numerical and investigative aspects of cutting on guillotines [10,12,13]. In previous works the structure of plate edges after cutting was not discussed in detail.

2. Description of the approach, work methodology, materials for research, assumptions and experiments

In this paper results of metallographic investigations of aluminium plate edges will be presented after slitting by various techniques: rotary knives, industrial guillotine and a specially built laboratory test stand. The main advantages and disadvantages of each method and tools have been shown. An interesting work concerning comparison of guillotine cutting and slitting with rotary knives is [17]. However, this work mainly refers to numerical investigations.

2.1. Slitting with rotary knives

Rotary knives with parallel axis (Fig. 3) enable slitting sheet metal in strips, single pieces and slitting circles of large diameter. Maximum thickness of slit material reaches approximately 30 mm. Disadvantage of this method is creation of an edge fold on both sides of slit material, difficulties in reaching rectangularity of finished products, difficulties with maintaining straightness of edges and burr, created during slitting on both sides of finished element. Main parameters of this type of knives are as follows [15]:

- dimensions of rotary knives for slitting sheets of thickness bigger than 10 mm: D=(25-30)g, h=50-90 mm,
- dimensions of rotary knives for slitting sheets of thickness below 3 mm: D=(35-40)g, h=20-25 mm.

Cutting - division of material - is realized by rotary movement of a ring-shape knife.

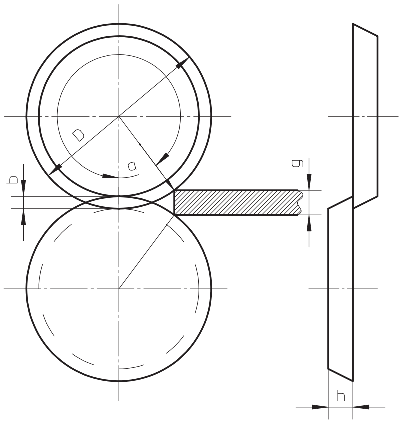


Fig. 3. Diagram of rotary slitters [15]

2.2. Cutting on guillotines

Guillotines are most commonly used for cutting packages of metal sheets, in industrial conditions where large number of sheets with the same dimensions are required. Thickness of sheet metal, depending on the size of the guillotine and strength of material can reach up to 60 mm. The cutting line is straight, Major disadvantages of guillotine cutting are:

- edges of finished products usually have burrs,edges are folded or bent,
- frequently corners deviate from specification requirements,
- cutting line is not always straight; deviation from required straightness cannot be repaired.

Most commonly the following types of drives are used in industrial guillotines:

- mechanical (Fig. 4),
- hydraulic,
- electro - mechanical.

The knife movement is in most cases under a certain angle (i.e. close to 45^{o}., pendulum - like and sometimes, but rarely vertical.

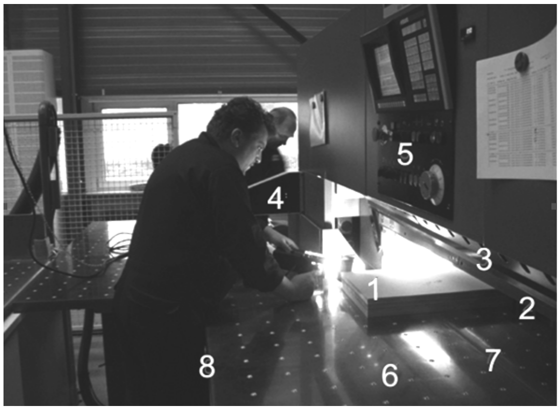


Fig. 4. Front view of guillotine during testing in industrial conditions [8]; 1 - bundle, 2 - pressure beam, 3 - cutting blade with knife holder, 4 - safety curtain, 5 - control, 6 - pneumatic table, 7 - cutting stick, 8 - manual mode push buttons

2.3. Cutting on the laboratory test stand

For detailed laboratory investigations of guillotine cutting process, a special test stand had been built (Fig. 5), and installed on a MTS 858 Vertical Tensile Testing Machine. Opposite to ordinary guillotine, where the knife moves under 45 degrees towards the table, on the test stand the knife moves vertically downwards. The knife movement had been here purposely simplified to perpendicular to the table, and is originally different from other guillotines used for cutting metal - mainly aluminum sheets.

Knife movement is driven directly by the hydraulic system of the MTS 858 Tensile Testing Machine, but pressure under the model of the pressure beam is created by two screws tightened in controlled manner before the test.

3. Description of obtained results

After cutting, edges of cut material were photographed with the use of a scanning electronic microscope LEO Gemini 1525, with Roentgen energy dispersive (EDS) micro analyzer Roentec.

The purpose of these analyses were to determine relationship between the cutting or slitting method and edge quality of the cut product. It should give an answer to the question if vertical movement of the cutting blade has any influence on the quality of the product's edge. Results of scans (topography) of the edge surfaces were compiled for plates cut on guillotine in industrial conditions slitters with rotary knives and the laboratory test stand [4]. Results were shown as sets of pictures, with several magnifications. Samples of material used for testing had several configurations: a bundle of 30 pre-sensitized lithographic plates 0.1 m wide and 0.5 m long. Each of the plates was divided by an interleaf sheet of thin paper and a top and a bottom of each package of 30 sheets was covered by a approx. 0.7 mm thick sheet of ordinary cardboard, made of recycled paper material. Various types of cardboards have been used - stiff, flexible or in some instances no cardboard sheets had been used. Investigations of the cut edges' surfaces were carried out according to the scheme shown in Fig. 6. For each package samples had been taken from the top, in the middle and from the bottom of the package, directly above the cardboard sheet.

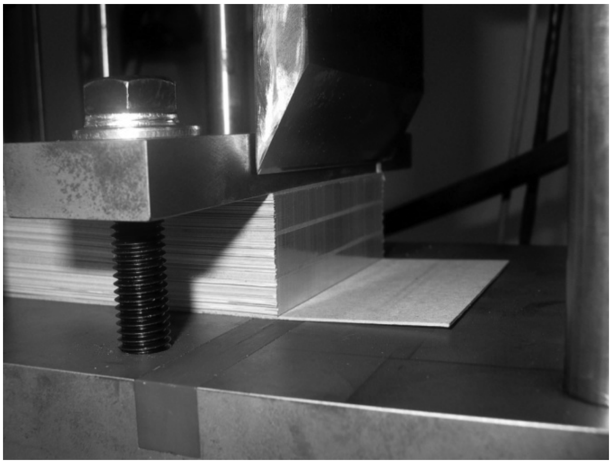


Fig. 5. A side view of the designed test stand

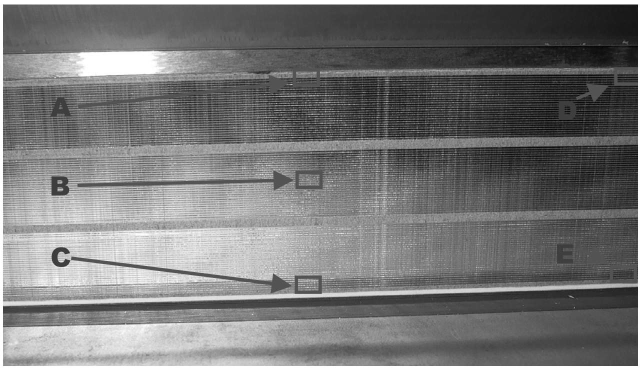
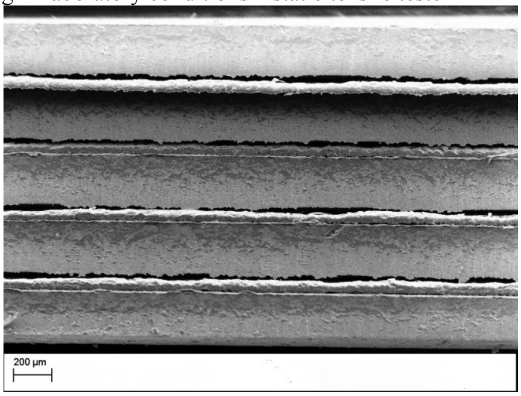


Fig. 6. Location of the test samples of plates chosen for metallographic investigations: A) upper package, the centre of the cut sample, B) central package, the centre of the cut sample, C) lower package, the centre of the cut sample, D) upper package, the upper corner, E) lower package, the lower corner

First tests performed on the static tensile tester were aimed at determination of the force, necessary for cutting a package of 90 sheets. Edges of plates were analyzed with the EDS analyzer which led to conclusion that in direct vicinity of the cutting line many cardboard particles and lithographic coating were present. Changing cutting conditions from static to dynamic had a substantial influence on the edge quality - concentrations of coating debris and cardboard particles were substantially lower.

Slitting with rotary knives results in substantially lower disturbance to the plate's edge compared to guillotine cutting.

Cutting in laboratory conditions – static tensile tester



General view of the cut package

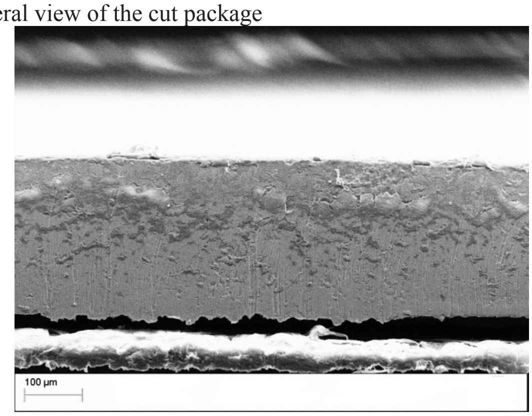
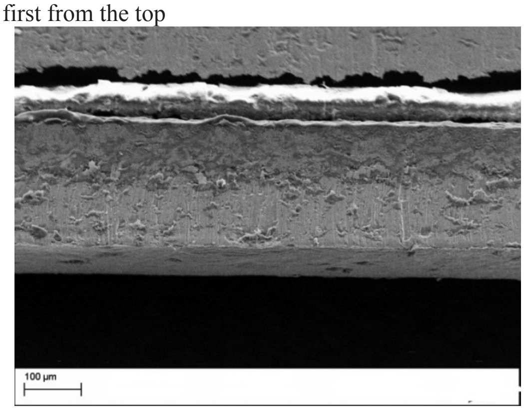


Plate first from the top



Bottom plate

Fig. 7. The cutting surface made on a static strength testing machine

Changing cutting conditions from static to dynamic (Fig. 9) had positive effect on the quality of surfaces after cutting. Deformation of the plate's edges Concentration of particles originating from the coated surface was substantially lower.

Fig 6. shows the surface of the cut edge's performed on the static tensile testing machine. Lower edge of the plate was significantly disturbed ("saw teeth").

Cutting on a guillotine - whether on an industrial machine or a laboratory stand, contaminates material with debris originating from the coating layer(s), paper and cardboard inserts etc. These particles have detrimental effect on the quality of edges after cutting (Fig. 7). In some processes requiring the highest accuracy of finished edges it can disqualify guillotine cutting as a production process, increasing production costs and influencing productivity.

3.1. Metallographic investigations of the plate's edges after cutting

Pictures of cutting edge surfaces after slitting with rotary knives (Fig. 8) were similar to pictures of the plates taken after dynamic cutting on the laboratory test stand with the knife velocity of 0,2 m/s. In both cases scratches in the vicinity of the cutting line are vertical - perpendicular to the plate's surface.

Particles of "foreign" material, originating from paper and cardboard sheets as well as lithographic coating were not observed on samples slit with rotary knives in industrial conditions (Fig. 9).

It seems that burr-free surfaces can be obtained only in close to ideal conditions - during slitting with rotary knives or during cutting on a guillotine with perfectly sharpened blade.

Contamination with paper particles, coating and other small particles - dust (Fig. 9) may have detrimental effect on quality of the finished product.

Looking at the topography of the lithographic plate edge after guillotine cut we can conclude that:

- upper surface of the plate (Fig 9) shows serious deformations concentrated at the plate's edge, many cracks of the coating layer and aluminum oxide,
- the last picture - with higher magnification a thick, cracked aluminum oxide layer can be seen, Between the cracks - pure aluminum.

Naturally these particles, together with debris originating from cardboard, paper and steel can seriously influence quality of the finished product after cutting. The following Figures show plate surfaces at the cut edge's, at various magnifications and the profile of the bottom plate's surface after cutting in industrial conditions. We can see cracks in the aluminum oxide layer close to the cutting line and visible between them surface of pure aluminum sheet. It had been concluded, that only the edge of the bottom plate of the package - touching directly the cardboard sheet is bent or folded. Sometimes the measured profile shows no deviations from the straight line, there are no measurable cutting burrs, but a rough surface could be felt in organoleptically.

Analysis of plate corners after cutting confirm a very distinct deformation in cutting direction, resulting in a specific "flatness" of the upper part and bending of the lower part of the plate (Fig. 10).

Edge's surface after cutting on a laboratory guillotine test stand was significantly less disturbed than surfaces investigated after cutting in industrial conditions - with rotary knives or on a guillotine (Fig. 11).

At the plate's edges after cutting, taking into account results of chemical components analysis EDS in micro-zones , sporadically some particles originating from cardboard sheets and pre-sensitized layer containing hard aluminum oxide debris.

Slitting with rotary knives

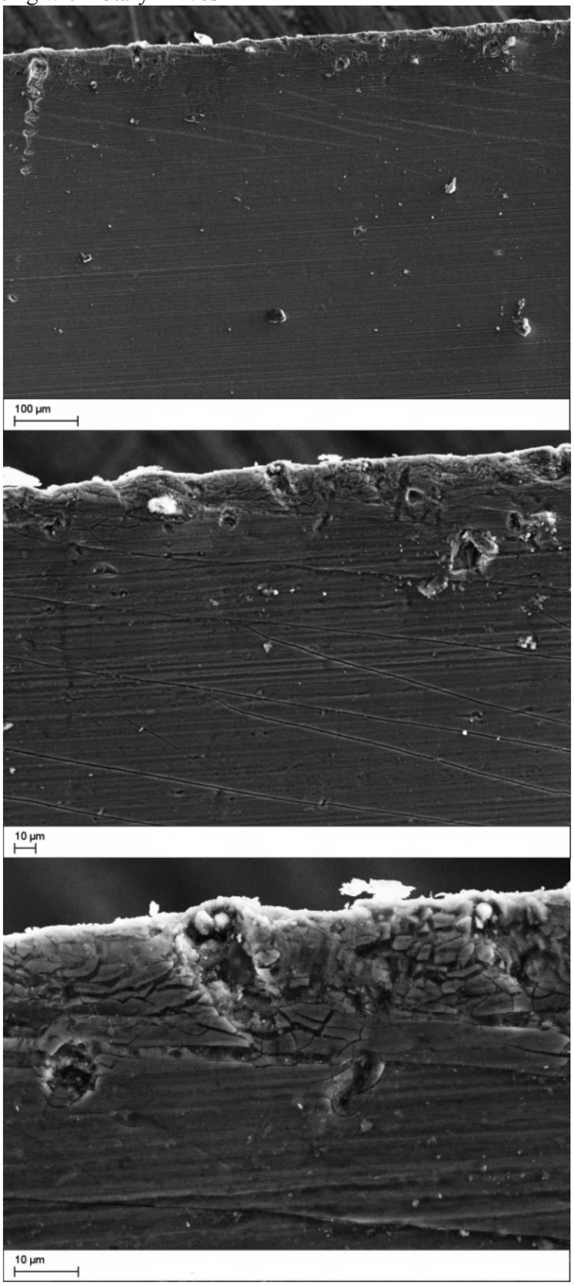


Fig. 8. Topography of aluminium printing strip after slitting with rotary knives

Guillotine cut (view from the bottom, uncoated side)

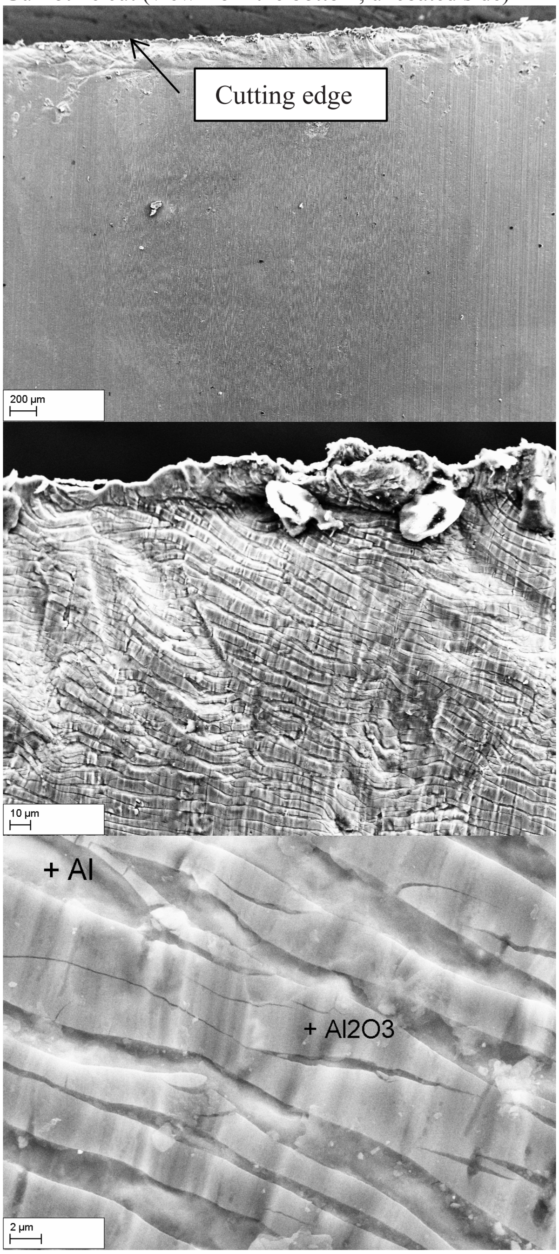
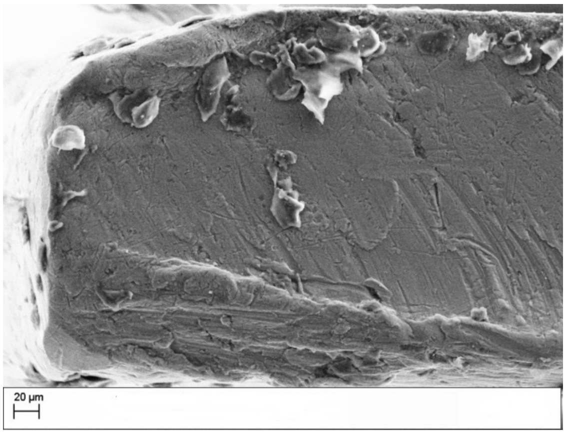


Fig. 9. Topography of aluminium printing strip after cutting on industrial guillotine. Visible cracks in the Al_2O_3 layer.

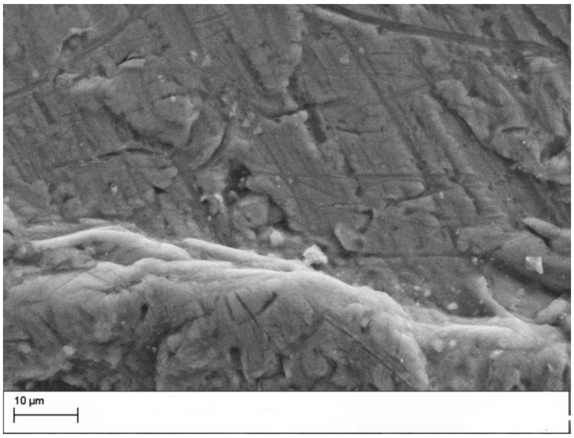
4. Conclusions

Comparing topography of lithographic plate's edges after cutting on a guillotine, slitting with rotary knives and cutting on a special laboratory test stand we can conclude that:

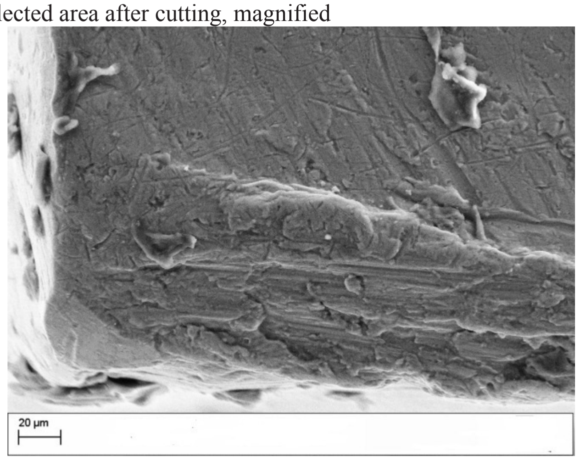
- cutting is a dynamic process of dividing materials into pieces, resulting in serious disturbance to the structure of materials at the cutting edge.
- coated surfaces cut show numerous cracks to the coating layer, especially if these layers are stiff, porous like for example aluminum oxide,
- the thickness of aluminum oxide layer can be quantified - determined after cutting, as between cracked aluminum oxide particles a surface of pure aluminum can be seen.



General view



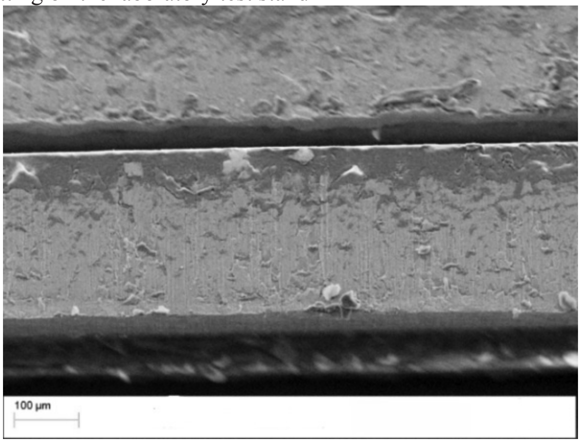
Selected area after cutting, magnified



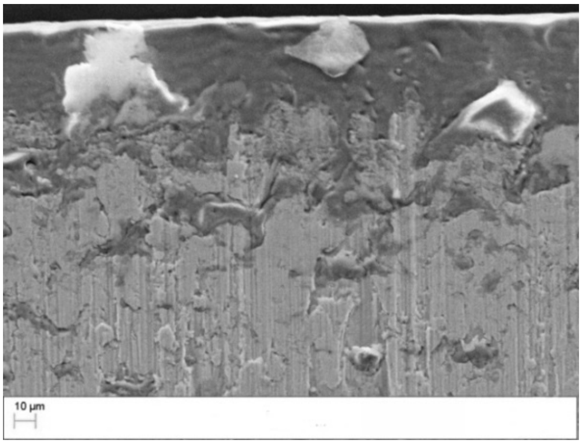
Lower/bottom part

Fig. 10. The surface of the corner - first strip from the top in the package, cut on an industrial guillotine

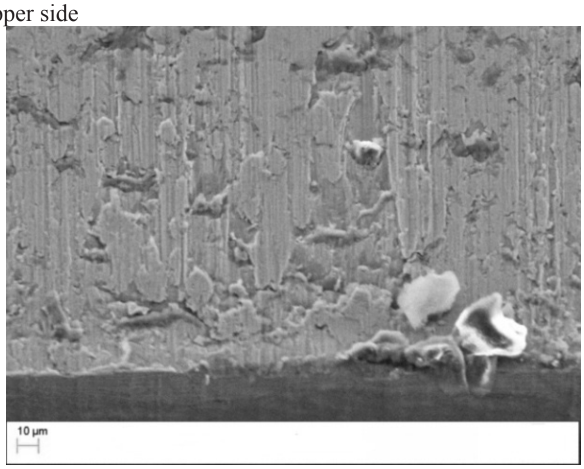
Cutting on the laboratory test stand



General view



Upper side



Lower (bottom) side

Fig. 11. The dynamic cutting surface (V=0.2 m/s) on a test stand - the lower (bottom) strip in the package

- guillotine cutting in industrial conditions causes major disturbance to the edges of cut material. All known defects to the edges are visible - cutting burrs, edge folding and edge "roughness" - caused by pressed small particles of lithographic coating, aluminum oxide, paper and cardboard dust,
- independently from the size of the bundle cut on a guillotine, edges of the plates are bent exclusively in the vicinity of the cardboard sheet. Therefore the higher the stiffness - or density of cardboard inserted between lithographic plates, the lower deformation can be expected.

Results of laboratory investigations showed, that vertical movement of the cutting blade - perpendicular to the cut plates allows obtaining a very good quality of edges, comparable with smooth surfaces obtained after slitting with rotary However, exact position of the knife should be determined, as it influences the process of dividing the two parts of material.

Vertical, controlled movement of the blade during cutting metal sheets offers substantial advantages to the finishing process compared to standard guillotine cutting. In all cases, when high quality of the edge surface is required, proposed vertical cutting combines high efficiency with simplicity of operations and assures high quality of the finished products.

Comparison of surfaces after cutting allowed drawing conclusions regarding methods causing minimum disturbances to the cut edges. The best quality of the cut edges was obtained on a laboratory guillotine test stand, applying a unique, vertical movement of the cutting blade.

Extend of cutting burrs, acceptable for lithographic plates is limited to 45 (preferably 30) µm according to the ISO Standard 12635:2008 “Graphic technology - Plates for offset printing - Dimensions”.

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