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Improving the sheared edge in the blanking of commercial AZ31 sheet through texture modification

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Abstract

Commercial rolled magnesium sheets of alloys AZ31 (Mg-3 mass%Al-1 mass%Zn) and ZE10 (Mg - 1 mass% Zn - <1 mass% Rare Earths) in O-temper condition were used for blanking experiments near room temperature. A serrated fracture surface can be observed in case of AZ31 but not in case of ZE10. During the shearing process of the AZ31 sheet, many micro cracks parallel to the sheet plane are generated in the shearing zone. These micro cracks lead to the formation of loose particles during the shearing operation, which interfere with further processing of the part and incur additional costs by increasing the scrap rate.

It is found that the strong basal texture of this alloy is an important reason for the generation of such serrated cracks. In this paper a new method of selective texture modification is described to locally change the mechanical properties of the AZ31 sheet. Subsequent shearing experiments show a significant change in the material behavior, especially regarding the direction of crack propagation, which leads to a better shearing performance. The commonly observed serrated crack does not occur any more after this local treatment and the sheared edge is clearly improved.

Keywords: Shearing, Blanking, Sheared edge, Twinning, Texture, Magnesium, AZ31

1. Introduction

In the manufacturing process of sheet metal parts, the processes of shear cutting and blanking play an important role. The quality of the sheared edge is essential for ensuring sufficient adhesion of coating layers such as electrophoretic deposition (EPD) or organic lacquer. Therefore it is desired that the quality of the sheared edge be enhanced in order to reduce or omit costly post processing steps. However, unlike conventional construction materials such as aluminum, a commercial magnesium AZ31 sheet exhibits unfavorable characteristics at the sheared edge when processed at room temperature. The most notable characteristic is the presence of a serrated fracture surface when the sheet is blanked at room temperature, which was first described for AZ31 by Hilditch and Hodgson (2005). According to Bolurchi (2002), this undesirable material behavior also causes another problem - the formation of loose particles, which are generated in the shear zone by micro cracks parallel to the sheet plane. Bogon (2005) argues that these loose particles can lead to surface defects during further processing of the sheet and lower the corrosion resistance. Fig. 1 illustrates the difference between typical sheared edge profiles of Aluminum AA6016 and Magnesium AZ31 as well as the formation of micro cracks and loose particles, as observed by the authors during the present study.

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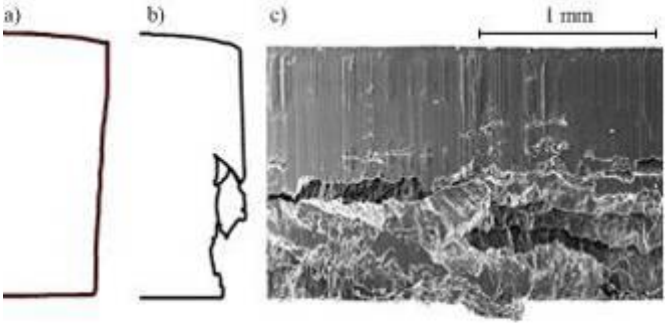

Fig. 1. Comparison of typical sheared edge profiles obtained at room temperature (die clearance 0.15 mm, tool radii sharp, punch speed 10 mm/s) a) Aluminum AA6016 T4 sheet material; b) Magnesium AZ31 sheet material; c) SEM micrograph of the same AZ31 profile

In order to understand the reasons for this characteristic, the deformation behavior of magnesium sheet during a shear cutting process is investigated in this work. Generally, wrought magnesium alloys show only a comparatively limited cold workability near room temperature which is understood by the low symmetry of its hcp (hexagonal close-packed) crystal structure and, related to this, the limited number of slip modes that are active in those materials. Plastic deformation near room temperature is mainly confined to basal or prismatic slip, both accommodating only slip in <a>-axis. This is discussed in-depth by Agnew (2002). As early as 1967, Patridge confirmed that there is a type of twins commonly observed in magnesium alloys, namely those with {10-12}-twin boundaries. Measurements and analyses of many authors confirm that these twins allow the magnesium crystal to accommodate plastic extension along the <c>-axis near room temperature (e.g. Barnett, 2007) under tensile stress along the <c>-axis (Wagoner et al., 2006). Above 200°C, additional slip systems are thermally activated and make a homogenous deformation of commercial AZ31 sheet in all directions possible (e.g. Friedrich and Mordike, 2006).

The specific deformation modes described which are activated at room temperature, lead to a strong anisotropy of its behavior under stress in different directions. For this reason, the crystallographic texture of polycrystalline magnesium sheets can influence its mechanical properties significantly. In 2005 it was understood by Agnew and Duygulu that there is typically a strong basal texture found for rolled AZ31 sheet, which leads to its strong anisotropic behavior. A strong basal texture means that the basal planes are mainly oriented parallel to the sheet plane. There are slight differences in the angular distribution of basal planes to the rolling direction (RD) and the transverse direction (TD), respectively, which was shown by Kaiser (2005). As reported e.g. by Rao and Prasad (1982), this typical basal texture is generated during the rolling process and affects the activity of deformation mechanisms in general (Brown et al., 2005) and especially twinning (Davies et al., 2005).

Consequently, the mechanical properties of rolled AZ31 sheet material in macro scale are influenced by the strong basal texture and therefore exhibit a significant anisotropy. Agnew and Duygulu (2005) show that AZ31 alloy has a significant anisotropy of yield and tensile strength in the rolling (RD), transverse (TD), and normal directions (ND). While strain is still relatively easy to accommodate in RD or TD, deformation along the ND, typically leads to premature failure of the material.

The blanking process itself can be seen in relation to the formability of the sheet as it requires a through-thickness shearing step on the sheet. Thus, blanking requires a good formability of the material, especially in the shearing zone, where the most critical deformation occurs. The poor formability of AZ31 in ND interrupts the shearing process and leads to the failure mode described above. In order to improve the shear cutting process for AZ31, the formability in this direction has to be improved.

A rather conventional approach to this is to raise the process temperature to above 200°C. At this temperature additional slip systems are thermally activated, which allows non-basal deformation mechanisms to become active and therefore improves the workability of the material. An appropriate tooling setup, suitable for shear cutting of Mg sheet at elevated temperatures, has been shown in an earlier paper by Nürnberg et al. (2009). However, in order to maintain the precision of the tooling alignment, complex solutions for heating, cooling and insulation have to be applied.

A more fundamental concept to improve the formability of magnesium sheets is to weaken the strong basal texture already during the production of the semi-finished product, as demonstrated by Iwanaga et al. (2004) where complex processing routes including extrusion and rolling were used to produce sheets with different texture strength of alloy AZ31. A similar principle has been shown Wagoner et al. (2006) basing on uniaxial compression of the specimen. Unfortunately, such types of processing cannot easily be applied to larger scale sheets. Another way to produce sheets with weaker textures is the usage of alloys that contain a certain amount of rare earth elements such as ZE10. This leads to improved ductility (Bohlen et al., 2007) and formability of the sheets (Yi et al., 2010). It is shown in these works that one of the important reasons for improved formability is the weaker texture of ZE10 which exhibits a broader angular distribution of basal planes. In the case of AZ31 this concept has not been carried out successfully yet.

In this paper, a method is shown to increase the shear cutting performance of AZ31 without adding much complexity to the process. The problem is solved by applying a local texture modification using a lattice reorientation mechanism based on the activation of tensile twinning. Results are compared to ZE10 sheets with a weaker texture in order to confirm the influence of texture on the shear cutting performance.

2. Experimental procedure

Magnesium sheets of alloys AZ31 and ZE10 were received from Salzgitter Magnesium-Technologie GmbH (SZMT), Salzgitter, Germany, in an O-temper annealed condition with a sheet thickness of 1.43 mm and used for this study. Microstructure analysis was carried out using standard metallographic procedures like elaborated by Kree et al. (2004).

The crystallographic texture was measured on polished sections on the sheet mid-planes. A Panalytical X-ray diffractometer setup using CuK_{α} radiation was employed and six pole figures, (0002), (10-10), (11-20), (10-11), (10-12) and (10-13) were measured. The calculation of the complete orientation distribution allows complete (0002)- and (10-10)- pole figures to be presented. Orientation imaging was performed on longitudinal sections of the sheets using electron backscatter diffraction (EBSD) in a field emission gun scanning electron microscope. Samples were prepared by mechanical polishing using alumina powder followed by electro-chemical polishing.

For performing the texture modification, a Kraftformer KF 30 Piccolo driving machine by Eckold AG, Germany, was employed (Fig. 2 a). The machine has a C-base frame and performs an oscillating tool movement with a constant number of strokes per minute. For this machine, a large set of specialized tool sets is available. Depending on the tool set, for example compressive (shrinking) or tensile (stretching) stresses can be induced parallel to the sheet plane by a special lamellae mechanism. During every forming stroke, i.e. every stroke when the tool jaw plates are in contact with the sheet, the tools clamp the sheet and transform the vertical strokes of the machine into horizontal movement (described by Scherer et al., 2007) (Fig. 2 b). In order to inhibit wrinkling of the sheet during the forming process, the jaw plates for shrinking are divided angularly, with the dividing angle having opposite directions for upper and lower tool. In this work, the shrinking tool set LFA 90 S by Eckold AG, Germany, is used. This tool set has polymer faces that protect the sheet surface.

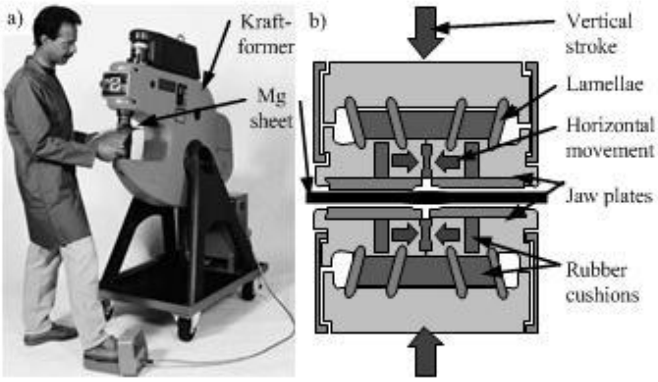

Fig. 2. a) Eckold Kraftformer KF 30 Piccolo driving machine; b) schematic representation of the mechanism inside the shrinking tool set (Scherer et al., 2007; Eckold AG, 2010)

Since the plastic deformation zone between jaw plates is only about 3 mm wide and about 50 mm long, the sheet was fed through the Kraftformer synchronously to the movement of the oscillating tool. The strokes were applied with small distances to one another that the compressive stresses could be uniformly applied to the sheet. As the strain achieved by each stroke strongly depends on the tribological conditions between tool and sheet surface and the sheet materials' deformation behavior, the effective strain for the material – and more important its effect on the texture - is hard to calculate. Therefore, different stroke intensities were tested by varying the infeed of the device, where an increasing infeed is related to increased vertical stroke and compressive load and strain.

The blanking experiments were conducted at room temperature in a stamping press BSTA 1600 – 181B by BRUDERER AG, Frasnacht, Switzerland, with the blanking tool described in an earlier paper (Nürnberg et al., 2009). During the blanking experiments, the radius of punch and die was set to 10 µm. The die clearance was set to 0.05 µm. The initial blanking velocity was 30 mm/s. The shear angle was 0°. The experiment was repeated separately several times and load/displacement curves were recorded.

3. Results & discussion

3.1 Characterization of magnesium sheets

Fig. 3 shows typical micrographs taken from longitudinal sections of the original O-tempered magnesium sheets of AZ31 and ZE10. Completely recrystallized homogeneous microstructures consisting of equiaxed grains are revealed. A very comparable average grain size of 10 – 11 µm is found for both sheets.

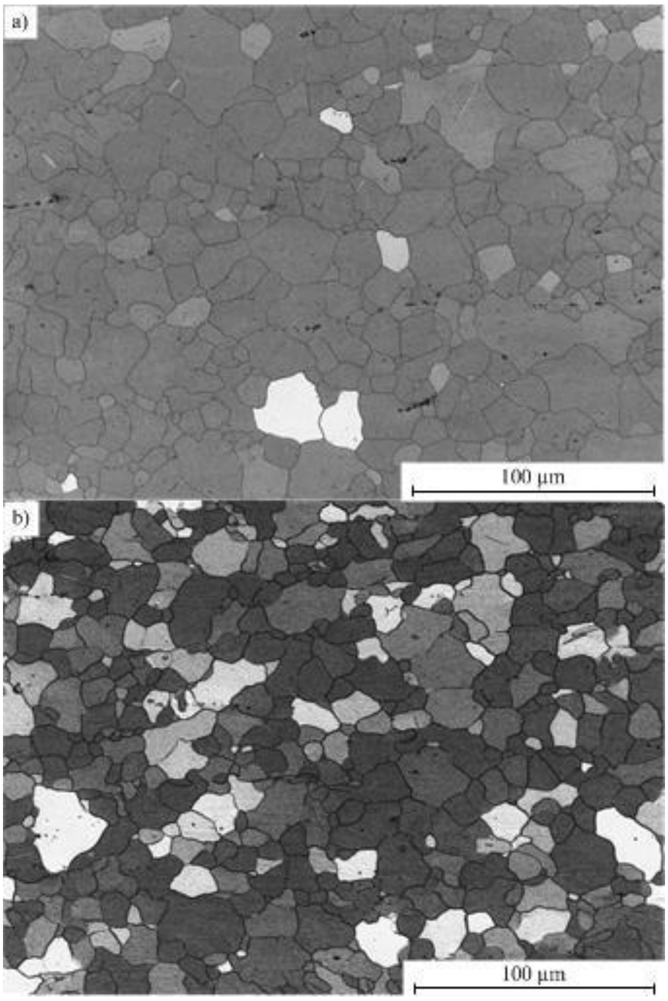

Fig. 3: Micrographs of a) AZ31 and b) ZE10

Fig. 4 shows the (0002) – and (10-10) pole figures to represent the texture of the two sheets. A strong basal texture is observed for AZ31 with a maximum intensity of 15.5 m.r.d. (multiple of random distribution) in the sheet normal direction. It shows that the majority of grains is oriented with the basal planes parallel to the sheet plane. Furthermore, the angular distribution of basal plane orientations is broader to the RD rather than to the TD. This is a very typical result for conventional magnesium sheets. For the ZE10 sheet a very different result is found. Generally, the texture is signifcantly weaker compared to AZ31 indicated by the maximum intensity of 4.0 m.r.d. The maximum intensity is found at a tilt angle of approx. 45° to the TD. Thus, no basal type texture with an alignment of basal planes in the sheet plane is found but basal planes are preferentially tilted to the TD of the sheet. This texture favours basal slip if plastic deformation is carried out in the sheet plane or perpendicular to it compared to the AZ31 sheet. It has been described in a related work that such a texture leads to an overall improvement of the formability of sheets (Stutz et al., 2011).

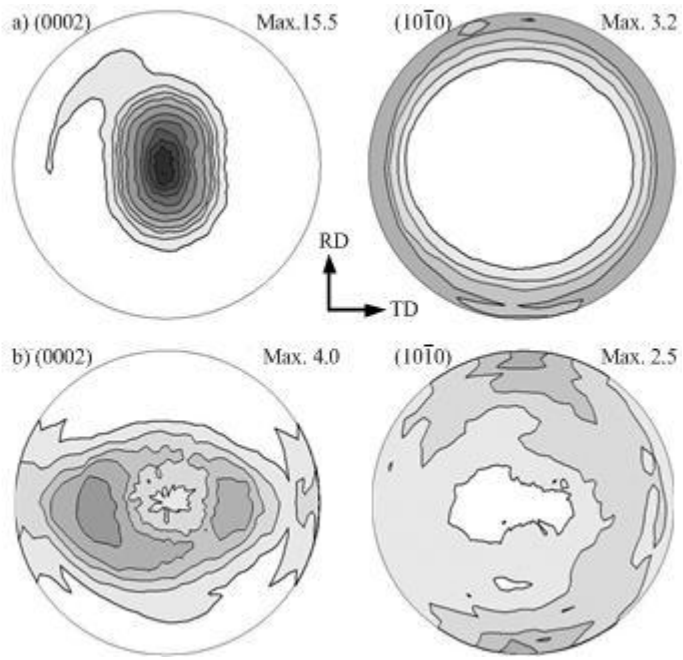

Fig. 4. (0002)- and (10-10) pole figures of the commercial sheet grades a) AZ31 and b) ZE10

3.2 Crack propagation in the original state AZ31

When blanking conventional sheet materials such as steel or aluminum grades, the flow behavior in the shear zone is dominated by shear stresses between the cut edges of the tools. Ductile materials have sufficient shear systems available, which together are sufficient for yielding to the stress fields exerted by the tool active elements and also preserving the yield compatibility with the neighboring grains.

While the deformation is advancing, due to cold work hardening, the agility of the slip systems is more and more constrained by barriers such as lattice defects, pile-up of dislocations as well as grain and phase boundaries. In those points stress concentration and the formation of micro cracks are the consequence. For conventional materials, the micro cracks always follow the direction of the greatest shear stress between the cut edges of the tool. After the two micro cracks evolving from the cut edges of punch and die have met, a clean cut surface has been formed.

However, when blanking the initial state, i.e. the original commercial AZ31 sheet at room temperature, a very unusual crack pattern evolves, which can significantly influence the shape of the part as well as the process stability, as described above. It is clearly visible in Fig. 5 a that already at a very early stage of the blanking process, the formability of the AZ31 material is exceeded at the sharp tool cut edges and micro cracks evolve. Cracks in an angle of approximately 75° to the front surface of stamp and die are already observed at a punch penetration depth of 0.1 mm. Obviously, at temperatures below 150°C, magnesium AZ31 exhibits a different failure mode compared to the described conventional sheet materials.

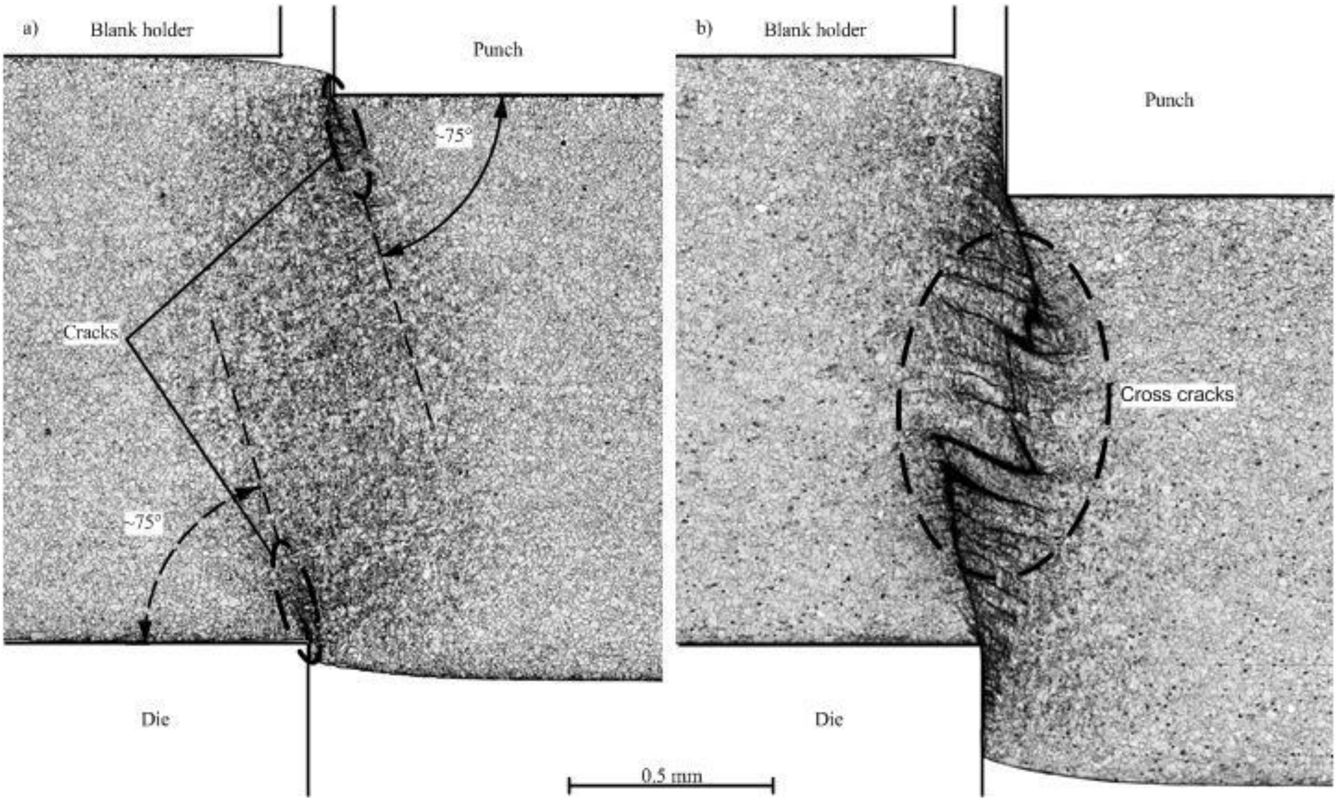

Fig. 5. Micrographs of partially blanked commercial AZ31 at room temperature: a) punch penetration 0.1 mm; b) punch penetration 0.4 mm

According to our investigations, this is due to its characteristic anisotropic microstructural deformation mechanisms: Both of the deformation mechanisms active at room temperature – basal slip and tensile twinning – in conjunction with the typical texture found in commercial AZ31 sheets contribute to the observed behavior. Basal slip as the first deformation mechanism has a very low critical shear stress, but due to the texture has an unfavorable orientation for the blanking process. Besides of the majority of basal planes being oriented parallel to the sheet plane there are also grains with greater angles to the sheet plane that contribute to the deformation with basal slip. However – the greater the angle towards the sheet plane the less grains are found that can activate basal slip in the shearing process. Therefore, basal slip is not sufficient for accommodating the large deformation during the blanking process.

The second mechanism, tensile twinning, needs compression parallel to the basal planes (i.e. tension along the c-axis) and therefore the grains with greater angles towards the sheet plane are favorably oriented for activating this mechanism during the blanking process. The EBSD maps shown in Fig. 6 clearly indicate that quite a large fraction of grains (6.5% of the measured area) already has formed tensile twins at a punch penetration depth of < 0.1 mm. The large extent of the measured twin volume fraction already at this early stage of the blanking process is equal to a major constraint for slip deformation, as the twin boundaries act as barriers for slip deformation just like grain boundaries.

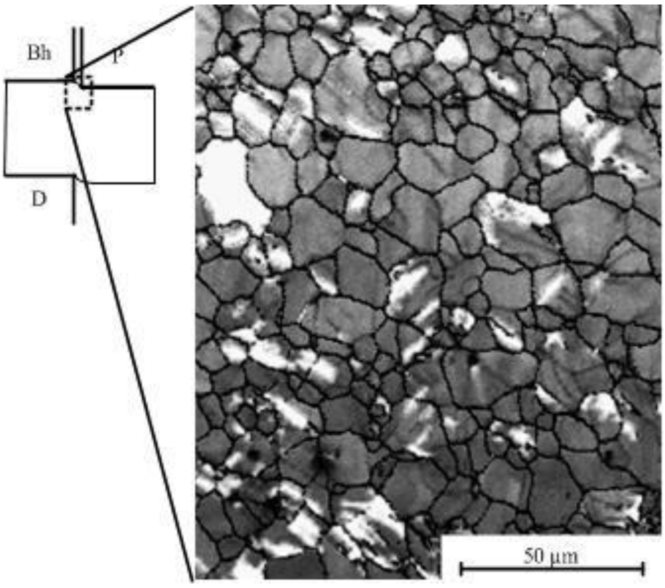

Fig. 6. Results of AZ31 EBSD measurements of cross sections in the shear zone in RD (punch penetration depth: 0.1 mm; grain fraction of tensile twins shown as white areas)

Because of the unfavorable orientation of the most important slip system, basal slip, and the additional constraint brought by the large number of twin boundaries in the lattice, deformation becomes more and more difficult and stress concentrations are quickly forming at the barriers. As a result, shear bands are formed across grain boundaries. Slip is largely confined to these shear bands, as the basal planes have a favorable orientation there. In this state, deformation is very localized. In accordance with the principal investigations described by Yang et al. (2004), the failure and crack propagation of magnesium can here also be observed parallel to or within the shear bands (Fig. 7).

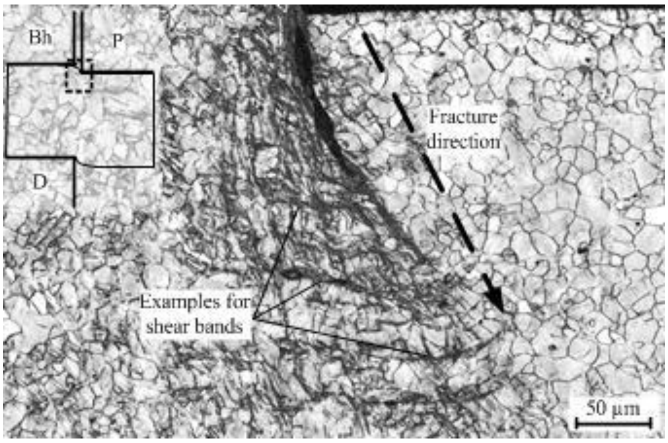

Fig. 7. Formation of shear bands in 75°and parallel to the sheet plane and cross cracks forming within the shear bands

This material behavior, in an overall view, is the reason for the early failure in the blanking process observed in the experiments. Based on the described mechanisms, the effective slip direction and the formation of shear bands is in the area of around 75° to the front surface of stamp and die. In this way the primary cracks evolving from the cut edges of punch and die cannot meet each other. Therefore, additional shear bands and cross-cracks parallel to the sheet plane are initiated at further punch penetration resulting in the typical cleft sheared edge (Fig. 5 b). Clearly, the described cross cracks are the origin of the loose particles typically generated during blanking of basal textured, commercial AZ31 sheet (cf. Fig. 1 c).

3.3 Crack Propagation in weakly textured magnesium sheet - ZE10

In order to prove the viability of the arguments, Magnesium ZE10 is also investigated for its material behavior in the blanking process. ZE10 is an alloy that typically exhibits weak textures, which means a relatively homogeneous distribution of the basal planes in the sheet (see Fig. 4 b). Although the same deformation mechanisms are active at room temperature, due to the fundamentally different basal texture, there is almost no tensile twinning during the blanking process (Fig. 8). Also the more homogeneously distributed basal planes improve the slip conditions, as the basal slip can be activated in many directions.

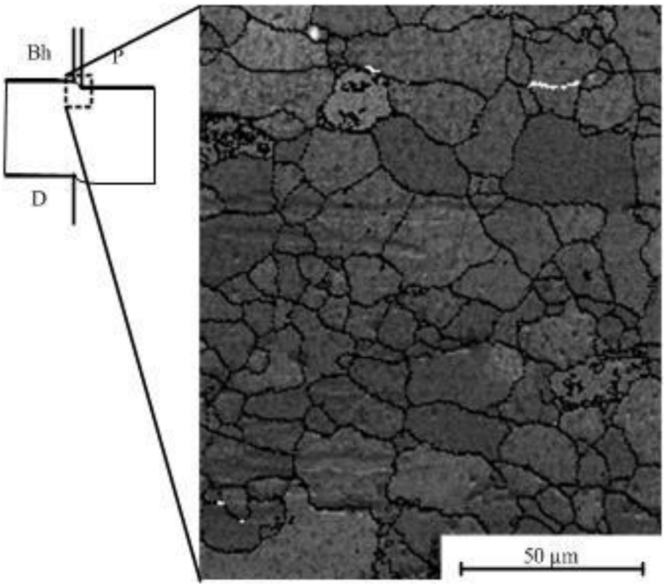

Fig. 8. Results of ZE10 EBSD measurements of cross sections in the shear zone in RD (punch penetration depth: 0.1 mm; grain fraction of tensile twins shown as white areas)

At a punch penetration depth of 0.2 mm, micro cracks are forming at the cut edge (Fig. 9 a). As there is almost no deformation visible in the microstructure, it can be assumed that shear bands were formed, that can follow the direction of the greatest shear stresses between the cut edges, because the deformation mechanisms can be activated more uniformly and no tensile twins were inhibiting the deformation. This leads to a completely different crack propagation behavior. As displayed in Fig. 9 b, this localized deformation starting at the cut edges of punch and die can form a linear crack connecting the cut edges of punch and die directly.

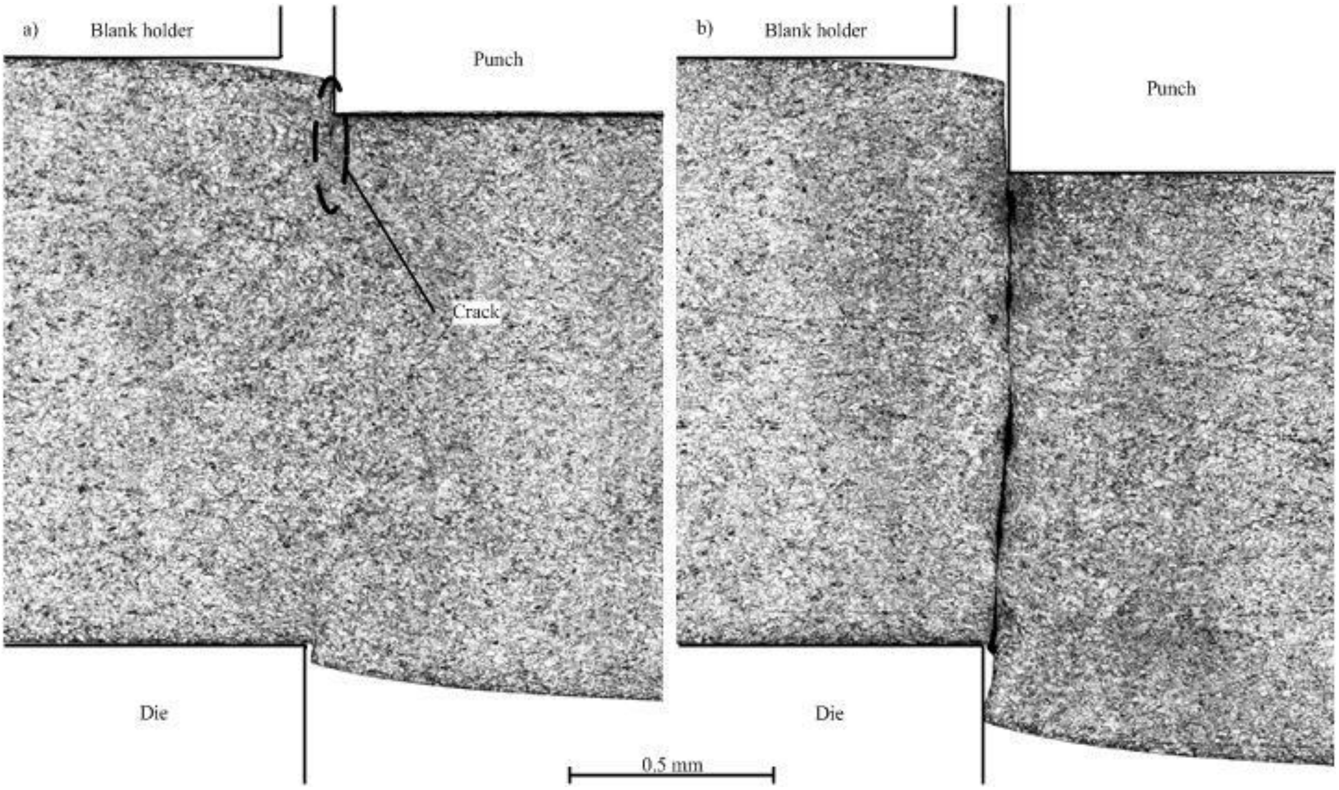

Fig. 9. Micrographs of partially blanked ZE10 at room temperature: a) punch penetration 0.2 mm; b) punch penetration 0.3 mm

The fact that using a magnesium alloy with weaker texture is able to lead to such a fundamentally different crack propagation behavior supports the argument, that texture has a significant influence on the crack propagation of magnesium alloys, which is not known to that extent for other conventional sheet materials. This demonstrates the potential of weak textures for the blanking process of magnesium sheet. Expensive tool setups for performing heated blanking at a process temperature of above 230°C could be avoided if it were possible to optimize the texture and thereby achieve a similar improvement of formability. This shall be shown in the following experiment.

3.4 **Modifying the texture of commercial AZ31**

The formability of AZ31 at room temperature could be significantly improved, if it were possible to achieve a more favorable distribution of lattice orientation. As described above, the formability in ND to the sheet plane is important for shear cutting. However, the texture presented in Fig. 4 a is very unfavorable for this. A re-orientation of the grains' basal planes 90° to ND, i.e. parallel to RD or TD would be preferred. The uniform orientation of the grains in the basal texture of AZ31 makes it possible to activate the {10-12}<10-11> tensile twinning mechanism: According to Barnett (2007) this twinning mechanism is activated by an extension of the c-axis and reorients the matrix by 86° around <1-210> following the direction of the greatest stresses. This can be done by either applying tensile stresses in ND to the sheet plane, which is rather difficult to realize technically, or compressive stresses parallel to the sheet plane. The change of the crystallographic texture generated by this twinning mechanism can be visualized using texture measurements, as the lattice inside the twin boundaries has an orientation of 86° to the parent lattice.

Wagoner et al. (2006) achieved such a reorientation of a AZ31 basal texture using the effect of tensile twinning. They show that within a compression specimen the preferred (0002)-pole shifts towards greater angles in the direction of the compressive stresses. Under tension, as expected, the basal pole stays still compared to the initial sheet.

However, Wagoner et al. (2006) use a specially stabilized compression specimen in a hydraulic material testing facility for conducting their experiments. This study aims for transferring the principle shown by Wagoner et al. (2006) to industrial scale by using a universal tooling setup with the goal of improving the blanking process of such modified sheet material.

In order to generate compressive stresses parallel to the sheet plane, the described Kraftformer driving machine was employed using several infeeds. See Table 1 for details about the infeed settings used and the strains achieved.

Table 1. Resulting sheet thicknesses and strains at different infeed settings (initial sheet thickness: 1.43 mm)

Infeed [-]	Thickness sample 1 [mm]	Thickness sample 2 [mm]	Thickness sample 3 [mm]	Average thickness [mm]	Resulting strain ε [%]
4.0	1.43	1.44	1.43	1.43	0.5
4.5	1.47	1.48	1.52	1.49	3.7
5.0	1.50	1.52	1.53	1.52	6.3
5.5	1.51	1.52	1.54	1.52	6.8

Fig. 10 illustrates the evolution of the crystallographic texture after the process. The compressive load activated tensile twinning in preferentially oriented grains. The lowest infeed (4.0) does not change the overall texture of the sheet although the corresponding micrograph reveals a partly twinned microstructure. However, twinning appears to be a local phenomenon in this condition. Infeed 4.5 leads to a partially twinned microstructure and the development of a new texture component approx. 90° tilted to the TD compared to the original basal fibre. This texture change is a typical result of twinning. The (0002) pole intensity decreases as a certain volume fraction is taken from the original fibre orientation during twinning. On the other hand, the (10-10) pole figure intensity increases due to a concentration of orientations as a result of twin activation.

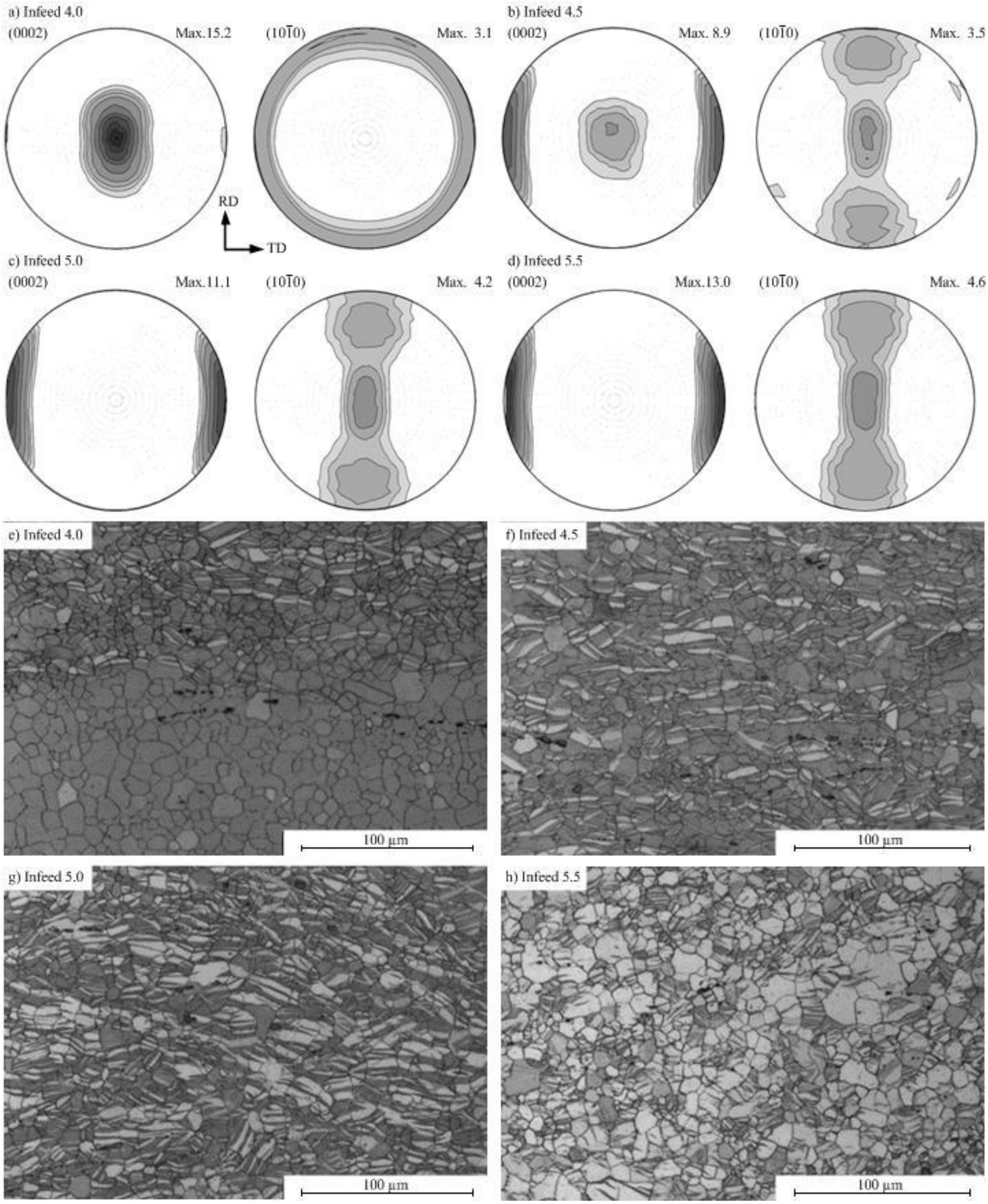

Fig. 10. Influence of applied compressive stress in the sheet plane on a) the texture and b) the microstructure of the AZ31 sheet

With increasing compressive stress at infeed 5 the original basal fibre disappears and the strength of the new twin orientation dominates the microstructure which now consists of two "phases", one being the old mother grains and one being the twins. A further increase of the stress (infeed 5.5) leads to a microstructure which consists mostly of re-oriented grains where the new texture is almost as significant as the original sheet texture, but with a different preferred orientation which orients the basal planes perpendicular to the sheet plane. It can be assumed that the twin boundaries expanded through the parent lattice until the whole grain was shifted to its new orientation.

Any infeed higher than infeed 5.5 leads to macro-cracking of the sheet. The obtained texture is expected to facilitate slip in ND of the sheet material and therefore improves the formability of the sheet in blanking direction. It is unclear though, which extent of reorientation is necessary and helpful to improve the sheared edge quality. Therefore, blanking experiments were conducted with samples 4.5, 5.0 and 5.5.

3.5 **Crack Propagation in the modified state AZ31**

When blanking such modified AZ31 sheet, the cut surface is significantly improved throughout all samples. The fracture pattern seen before at the initial state material is no longer observed. Fig. 11 shows the sheared edge profiles of sheets treated with the described different infeed settings. The infeed 4.0 sample was not blanked because there are too little changes in texture and microstructure. The sheared edge of the sample with infeed 4.5, however, already shows significant improvement, although several undesirable cross-cracks, are still observed. Starting from infeed 5.0 almost no cross-cracks are visible and the infeed 5.5 sample exhibits an almost perfect cut surface. Infeed 5.5 is therefore chosen for further experiments.

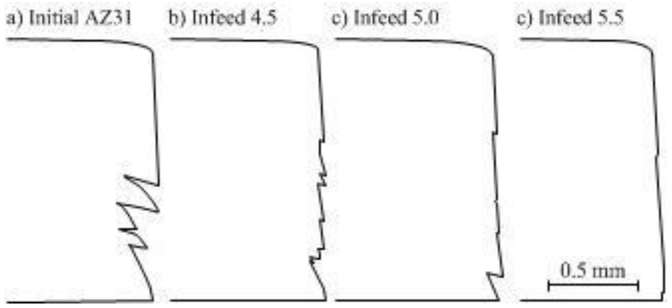

Fig. 11. Sheared edge profiles of the different sheet samples

Because of the improved slip conditions in ND to the sheet plane, at this setting the primary cracks are formed almost perpendicular to the front surfaces of stamp and die. This can be shown by looking at partially blanked sheet samples, where the direction of crack propagation becomes visible (Fig. 12 a). There are no additional cross-cracks observed and therefore the generation of loose particles is inhibited. During further punch penetration the cracks meet directly and merge into a perfect cut surface (Fig. 12 b). Because of the sharp cut edges, there is no burr observed.

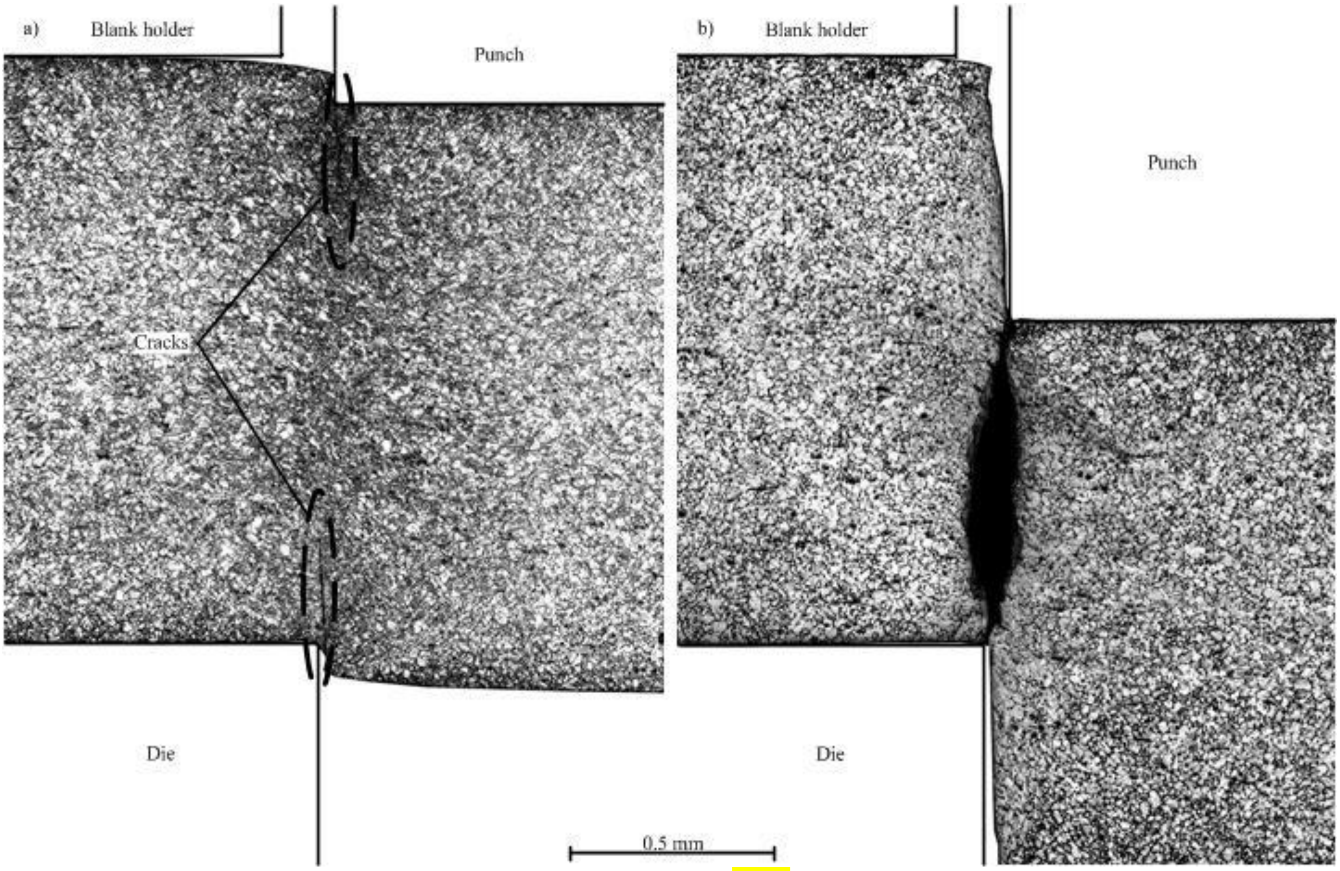

Fig. 12. Micrographs of modified state (infeed 5.5) partially blanked AZ31 at room temperature: a) punch penetration 0.1 mm; b) punch penetration 0.7 mm

The differences in blanking performance can also be observed in the punch-force vs. displacement diagram. The most significant difference between both cutting force progressions is visible in the cracking and part separation stages. Following the curve progression of the unmodified sheet (grey curve in Fig. 13), obviously there is a small second peak following the initial one, where the cutting force rises again by about 10%. After this second peak it continuously decreases. Since the punch penetration is still only about 30% of the sheet thickness at this time, the friction on the sheared edge cannot play an important role here. The first drop of the cutting force curve originates from the main cracks in the shearing zone, which have missed each other. With further punch penetration, cross cracks are formed in the parts which are still connected, while the punch force rises again. The disrupted particles are pushed against the sheared edge and cause a lot of friction. After ejection of the scrap part, the force declines to zero. Additionally there is no vibration after the cutting stage during blanking of commercial AZ31 sheet, which is different from the regular phenomenon during blanking of aluminum and most steels. This is also a sign for an unclean cutting process because the primary cracks miss each other.

The cutting force progression of the modified sheet is much more similar to that of regular materials such as aluminum and most steels. The stage of elastic deformation, plastic shearing, crack formation, release of elastic energy (vibration) and the scrap ejection force caused by friction can be clearly identified in the diagram. Again it becomes visible that the cross crack is suppressed during the blanking process with modified texture AZ31.

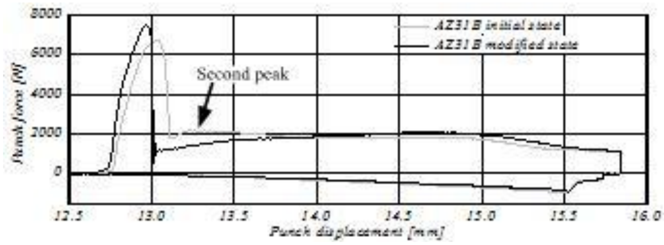

Fig. 13. Punch force vs. displacement diagram

As mentioned before, one way to improve the sheared edge of AZ31 magnesium sheet is to raise the process temperature to above 250°C. Through this approach the serrated crack pattern causing the formation of loose particles can be fully avoided (Fig. 14 a, b). However, the sheared edge obtained in the AZ31 sheet with modified texture has an equally favorable appearance to the one of the initial condition alloy cut at 250°C (Fig. 14 b, c). After modifying the texture of the sheet, the formability and simultaneously the direction of crack propagation is visibly improved in terms of the blanking operation.

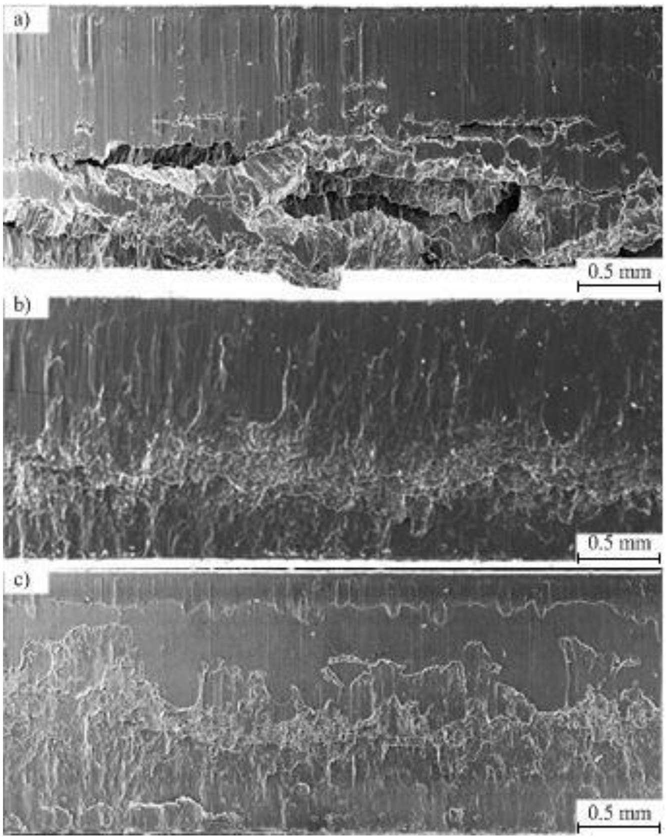

Fig. 14. SEM micrographs of sheared edges a) initial condition AZ31 O at RT; b) initial condition AZ31 at 250°C; c) modified state AZ31 at RT (infeed 5.5)

Therefore, it can be concluded that not only the stress state in the shear zone, but also the direction of the lattice orientation i.e. the texture, has a significant influence on the direction of crack propagation. The change of texture, based on the above-mentioned process, has two very significant impacts on the sheet material. First, as described above, the activation of tensile twins leads to a re-orientation of grains or grain fractions, which are now favorably oriented to directly accommodate shear along the ND of the sheet. Secondly, it has still to be seen that this holds for a mechanically deformed section of the sample which would give support for assuming that work hardening had taken place during preparation of the sample. Thus, it is expected that in the beginning of the process higher forces are required for deformation compared to the original sheet condition as a result of work hardening (also visible in the progression of the force-displacement diagram Fig. 13).

Furthermore, if the change in the texture allows basal slip to take the major role during shearing, lower forces are likely to occur compared to the original condition.

4. Conclusions

A significant improvement of the sheared edge quality is achieved in this study through modification of the local texture of a commercial AZ31-O-temper sheet. For blanking, grains with basal planes oriented perpendicular to the sheet plane are favorable. Texture modification could be obtained by applying compressive stresses parallel to the sheet plane and thereby activating the tensile twinning mechanism. The following conclusions can be drawn:

1. The limited formability in ND of the commercial AZ31 sheet causes the generation of cross cracks and loose particles in the sheet plane because of the highly oriented basal texture after the rolling process;
2. The high degree of orientation of the basal texture allows activation of tensile twinning in almost all the grains. Therefore the texture experiences an extensive reorientation in the direction perpendicular to the sheet plane by compression in the sheet plane. The reoriented texture exhibits a beneficial slip potential during the blanking process.
3. When blanking the modified sheet material with reoriented texture at room temperature, the sheared edge is significantly improved and has a similar appearance to the sheared edge of unmodified AZ31 sheet material at 300°C. The typical cleft fracture surface is completely suppressed after the modification of the texture.
4. By modifying the texture of AZ31 sheet, its formability and simultaneously the direction of crack propagation is positively changed in terms of the blanking process. Therefore it can be concluded that not only the stress state in the shear zone, but also the direction of the lattice orientation i.e. the texture, has an influence on the direction of crack propagation.

Using the method described in this paper, magnesium AZ31 sheet blanking can be conducted with conventional tooling setups near room temperature without generating the undesired loose particles and micro cracks.

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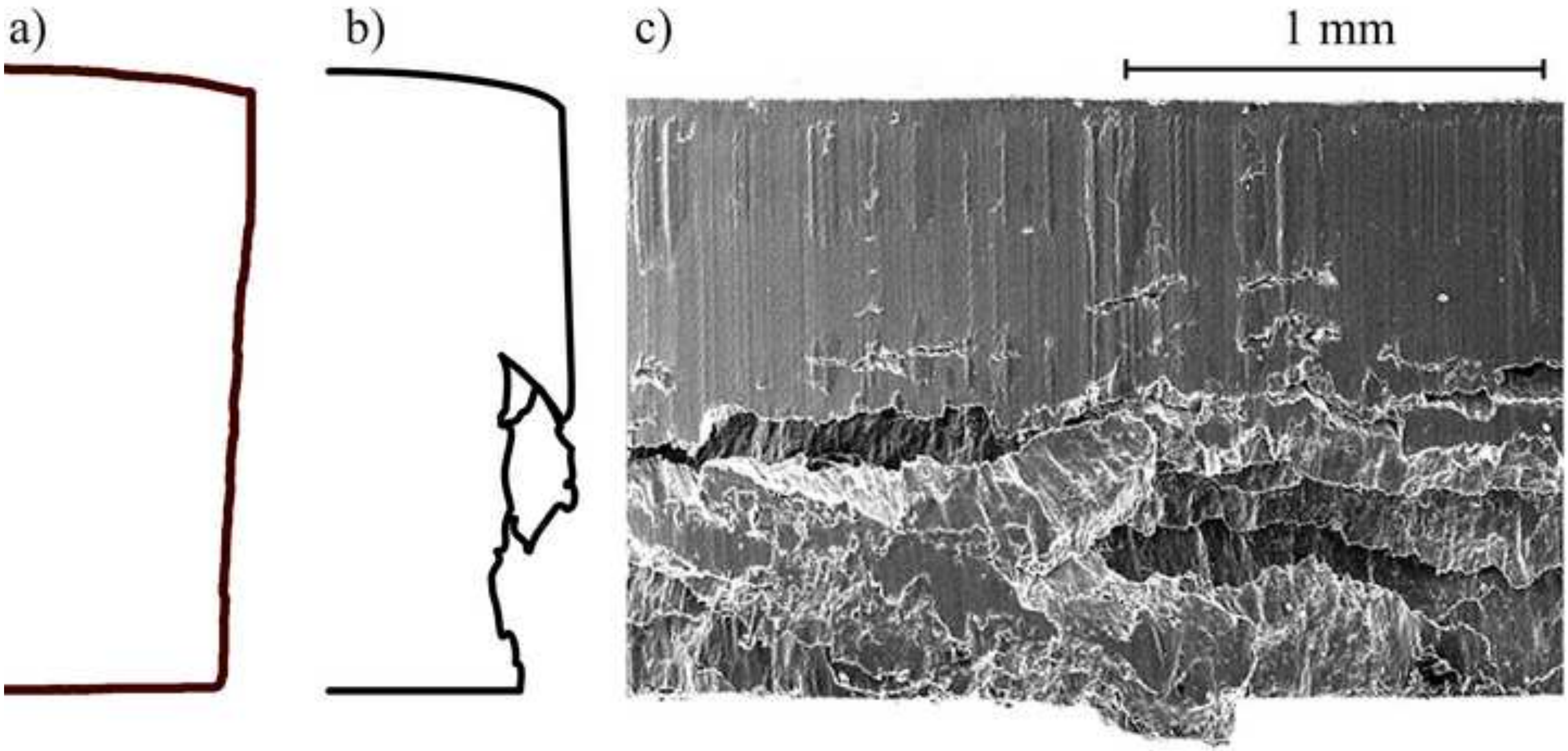

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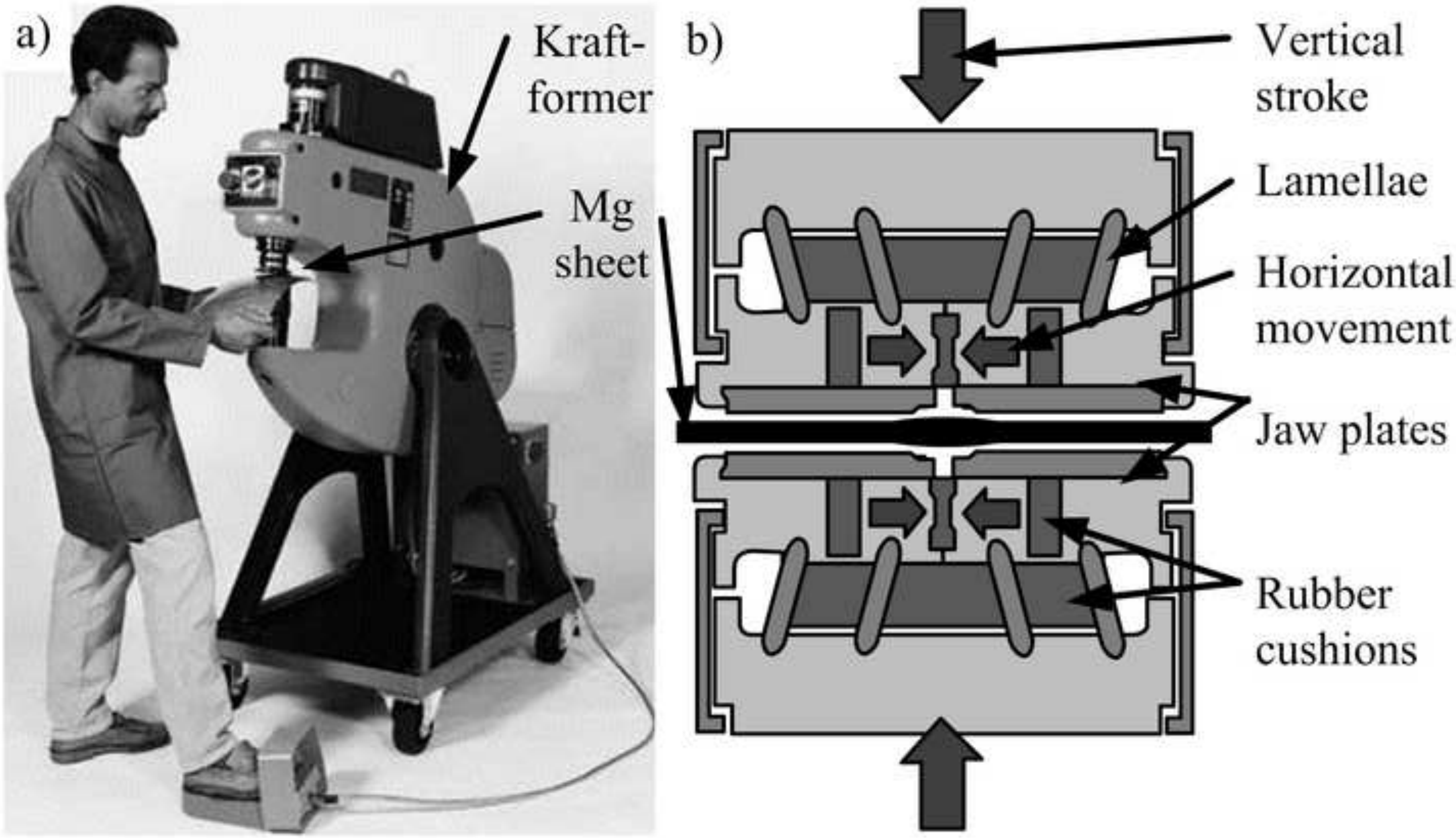

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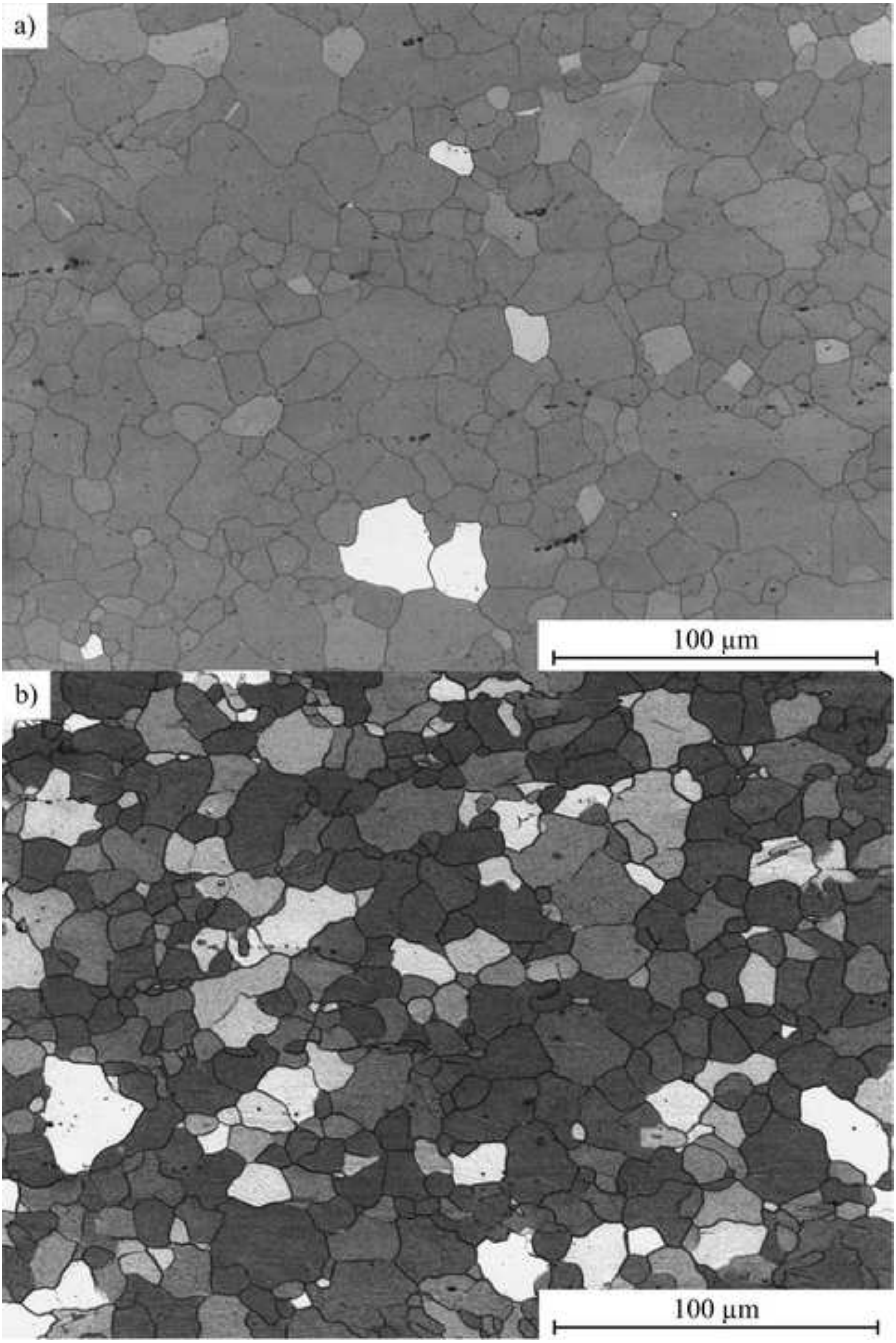

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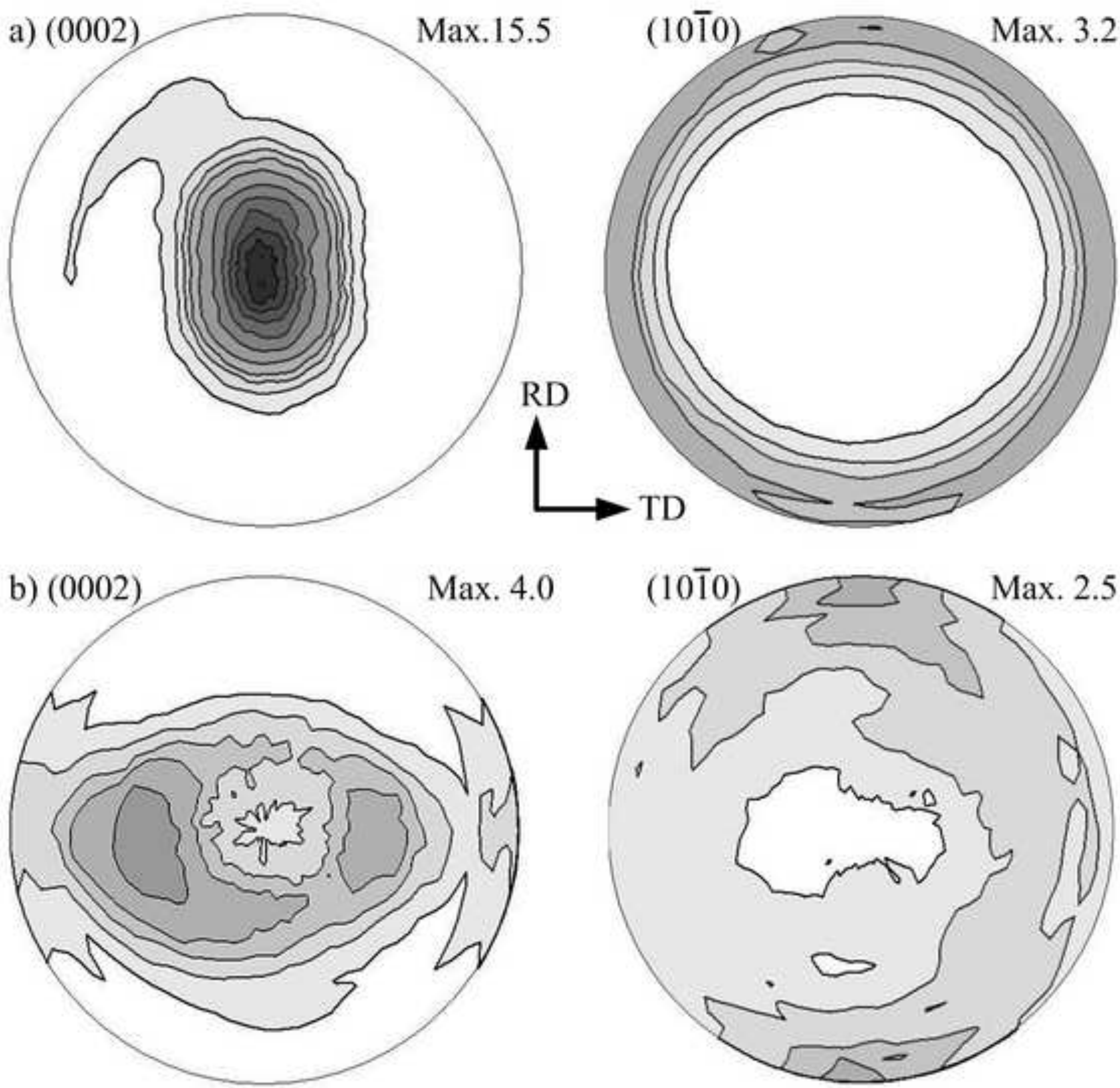

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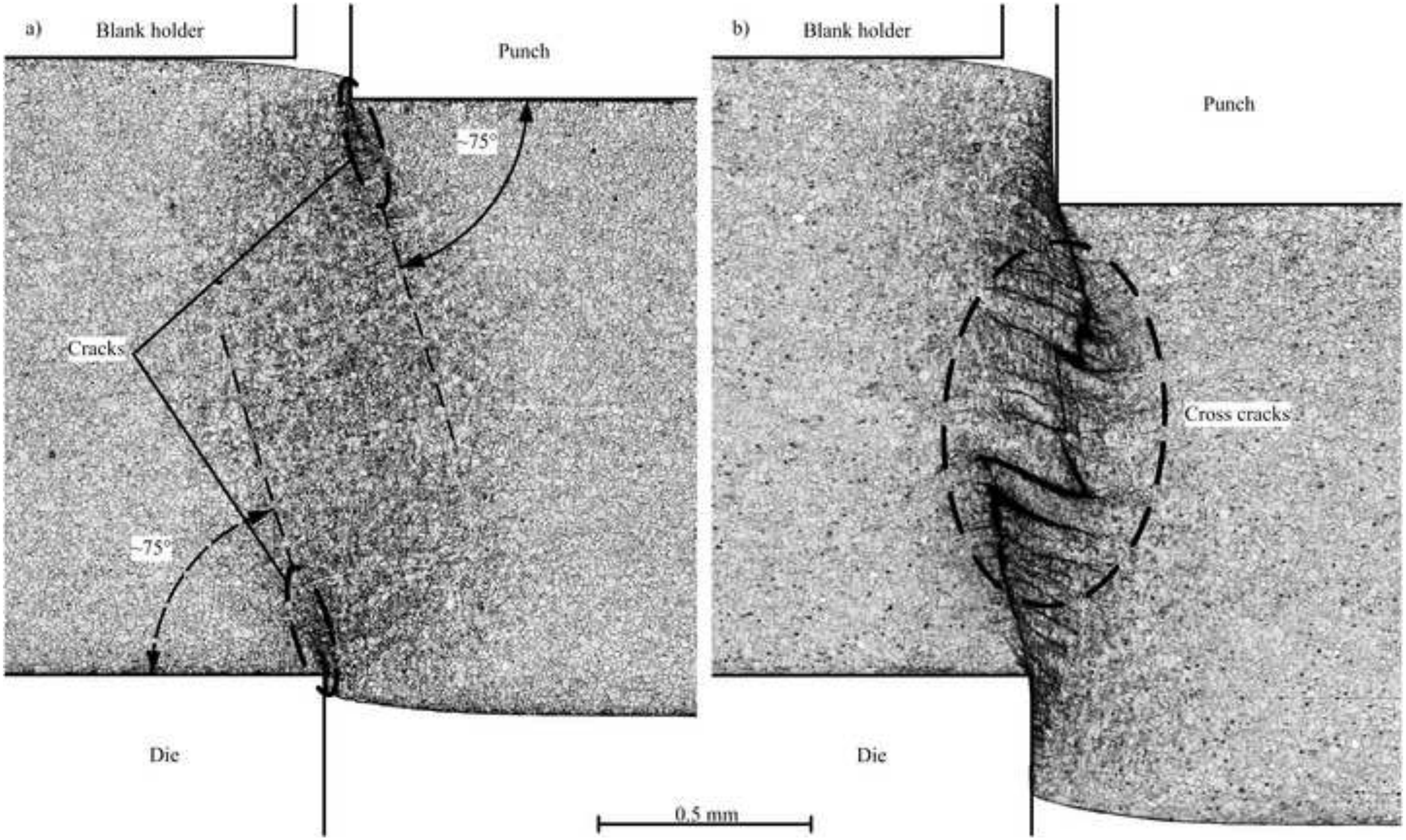

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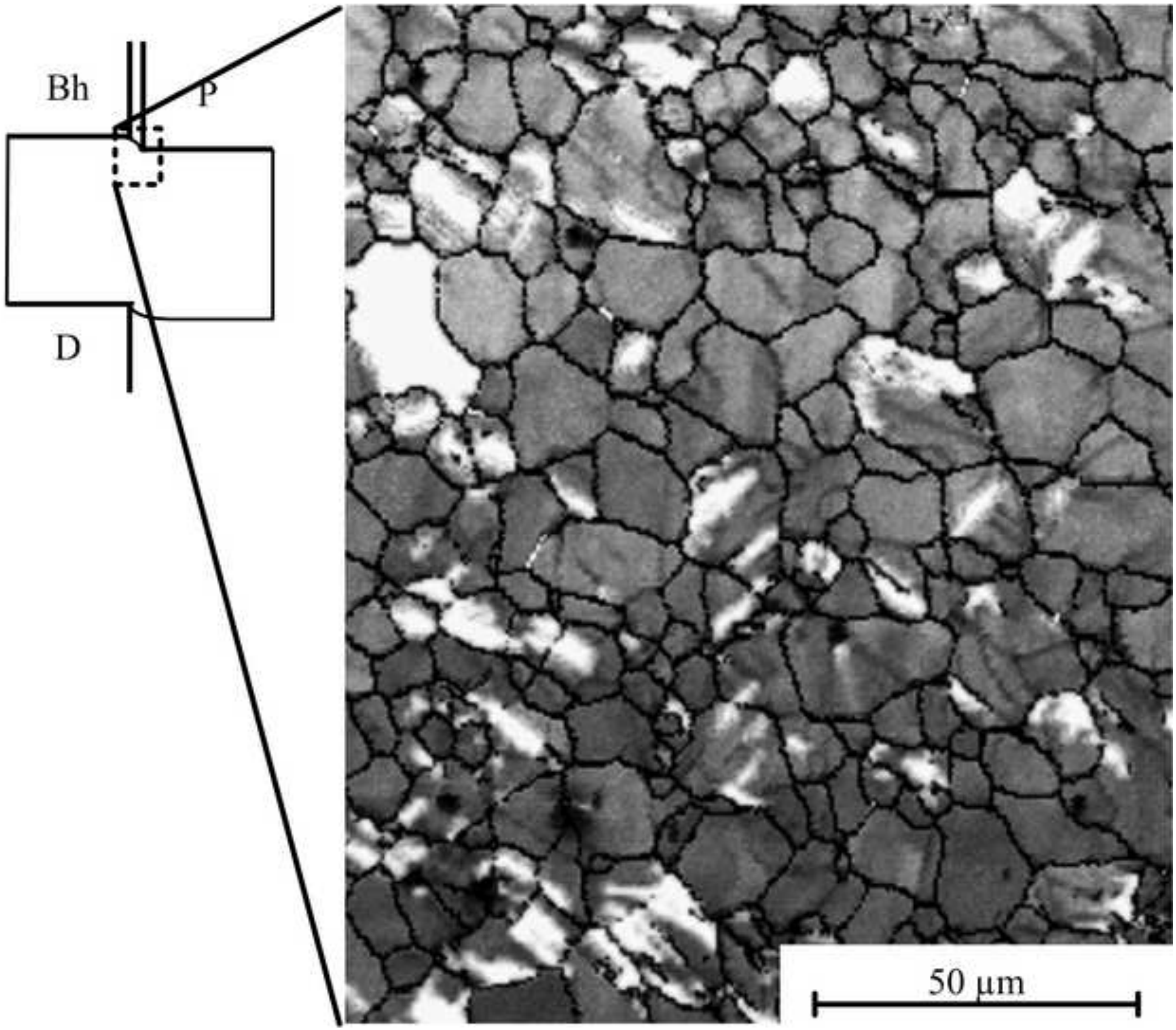

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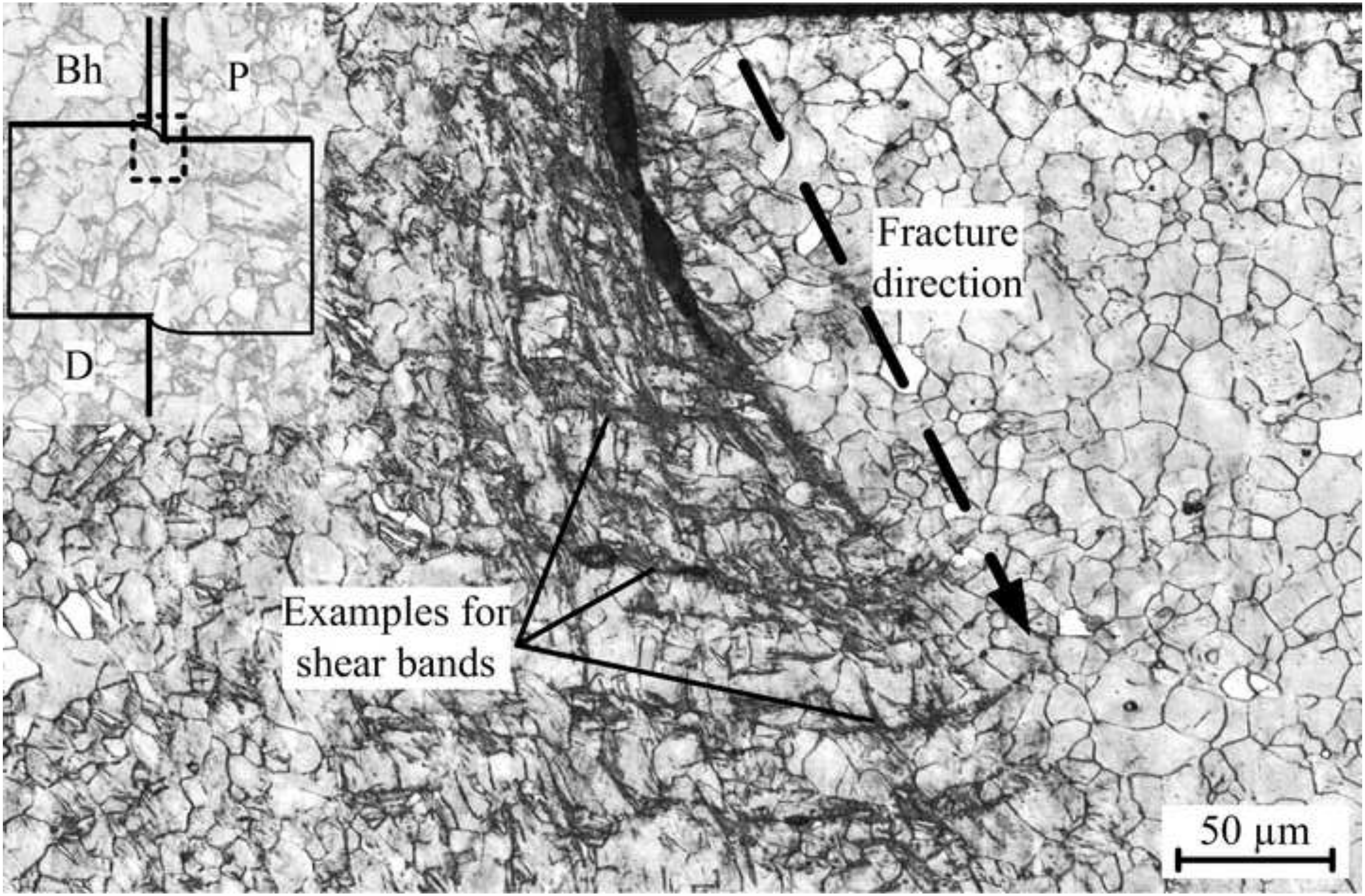

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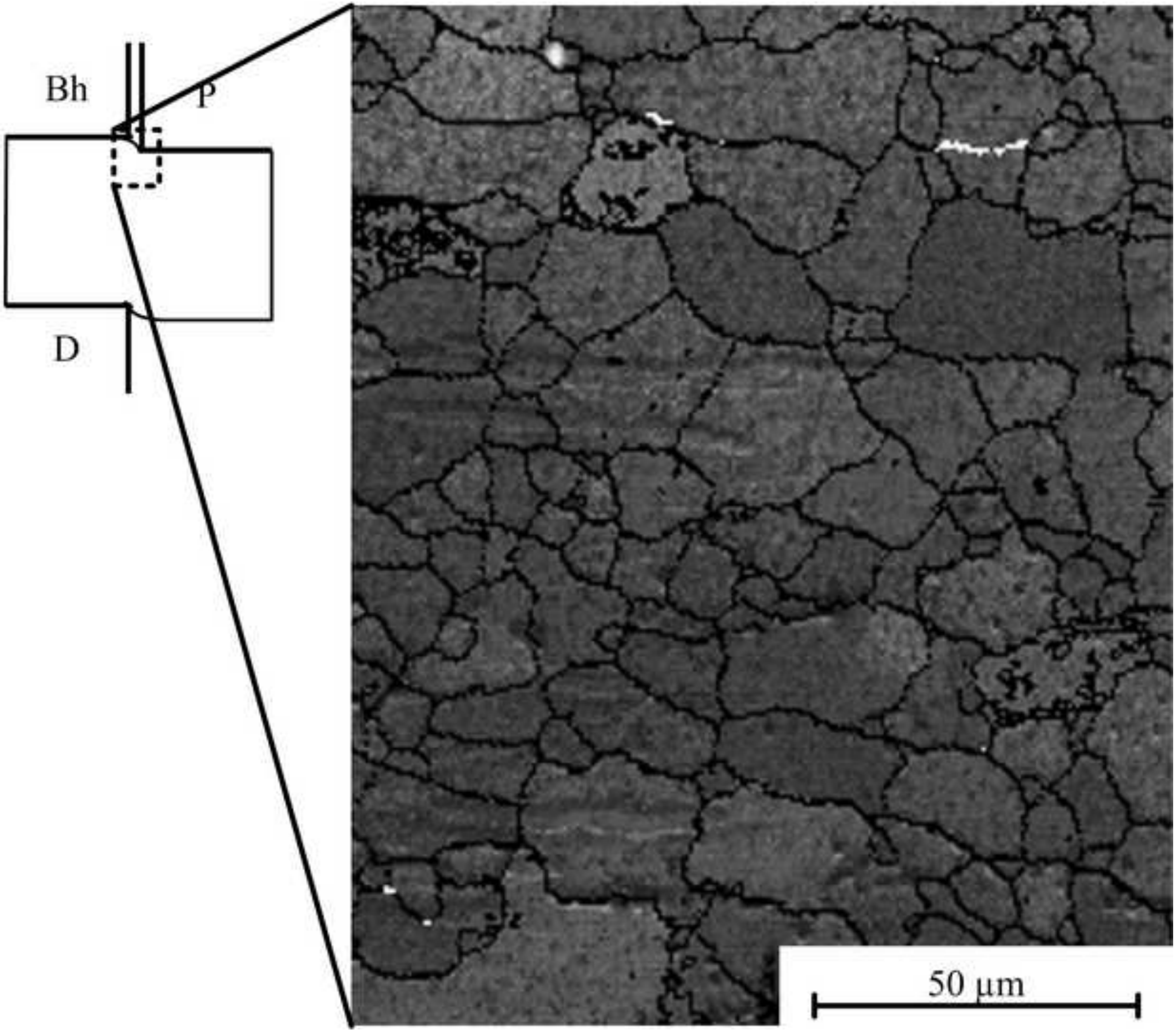

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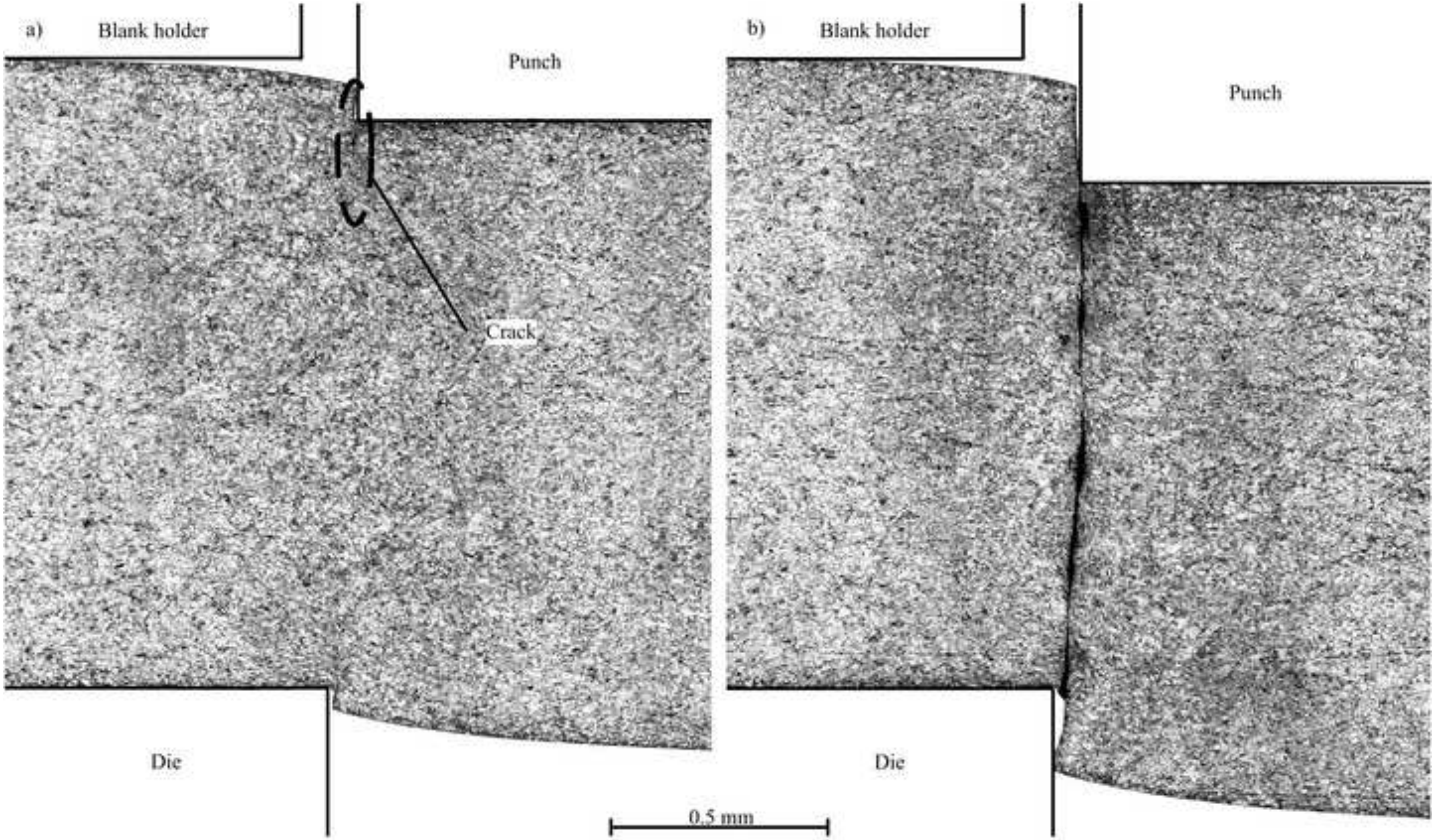

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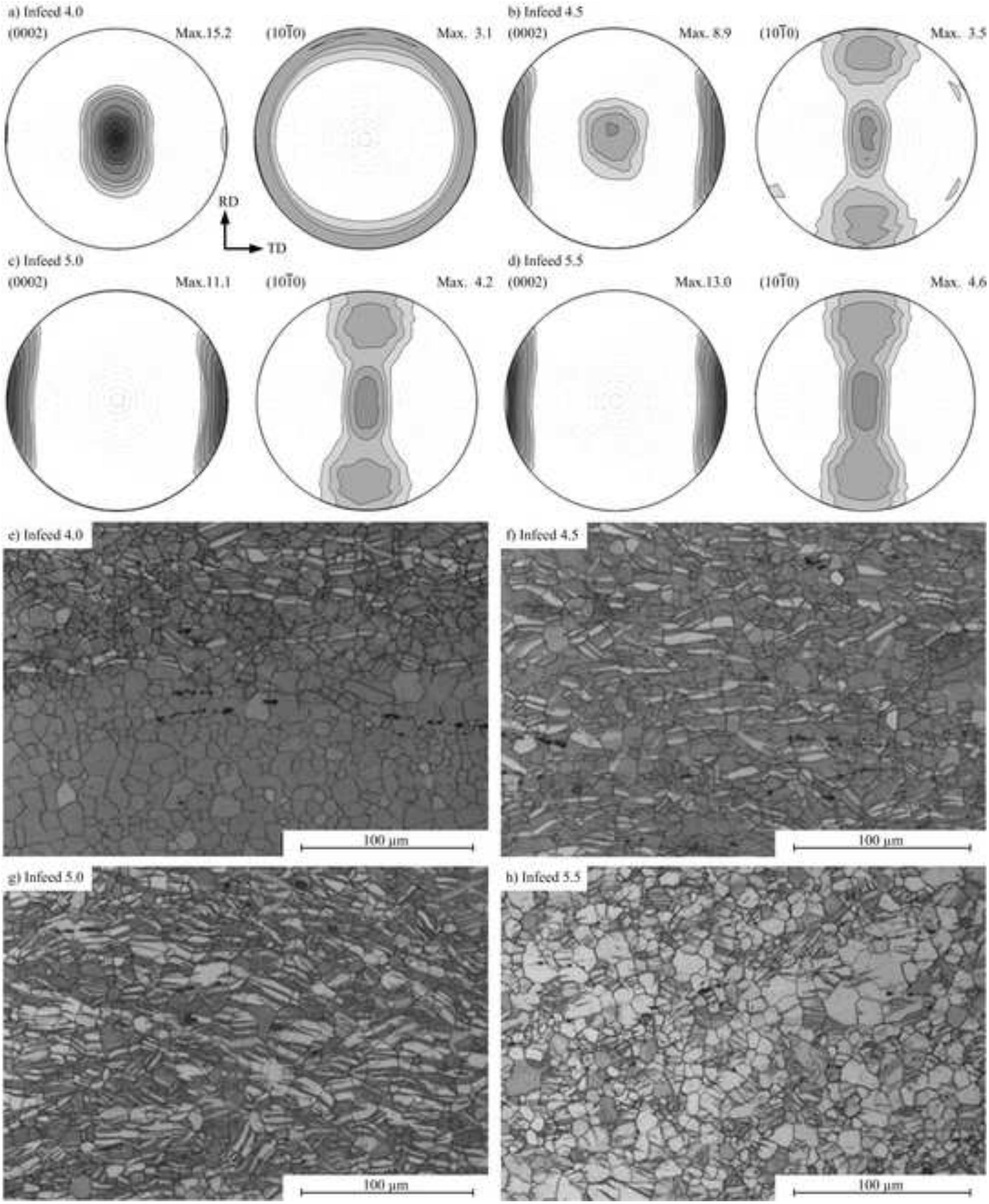

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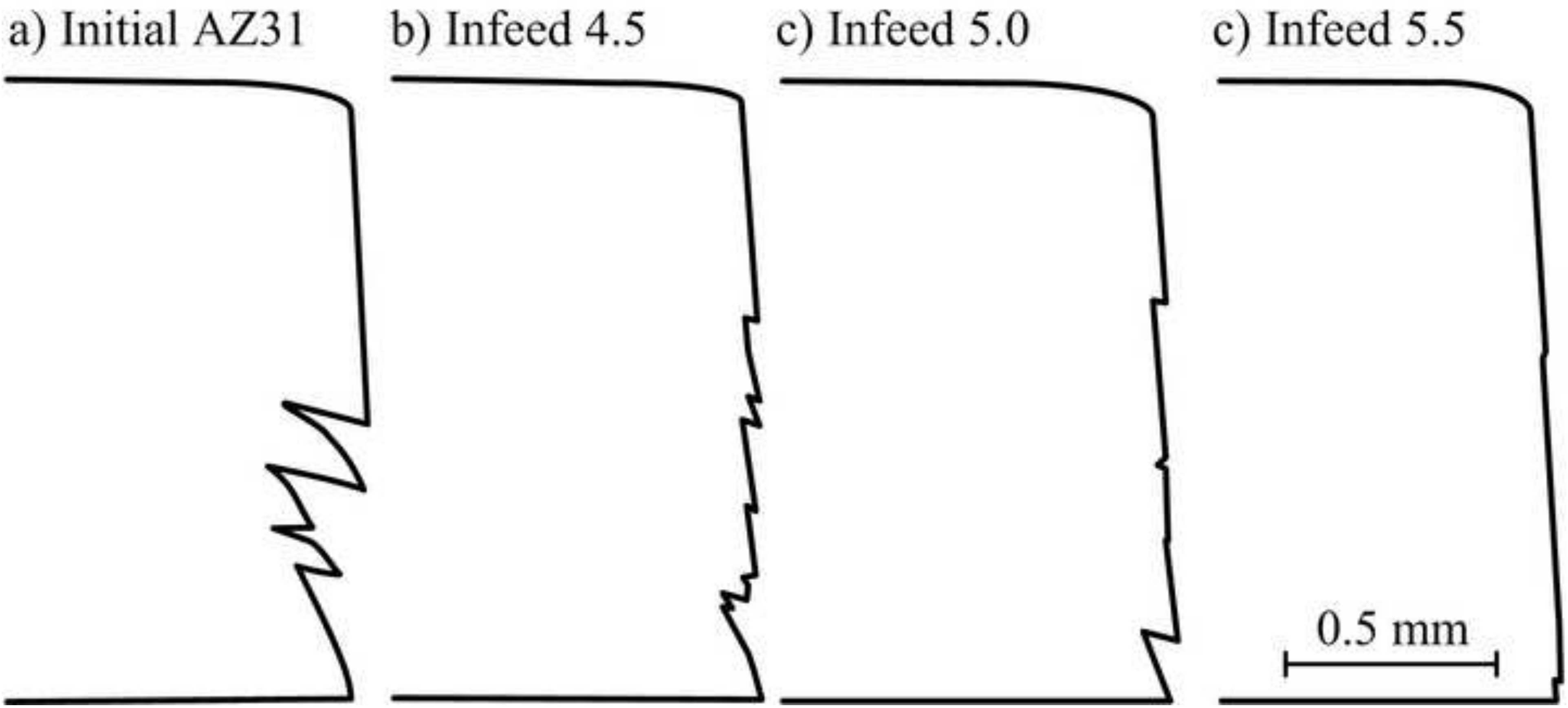

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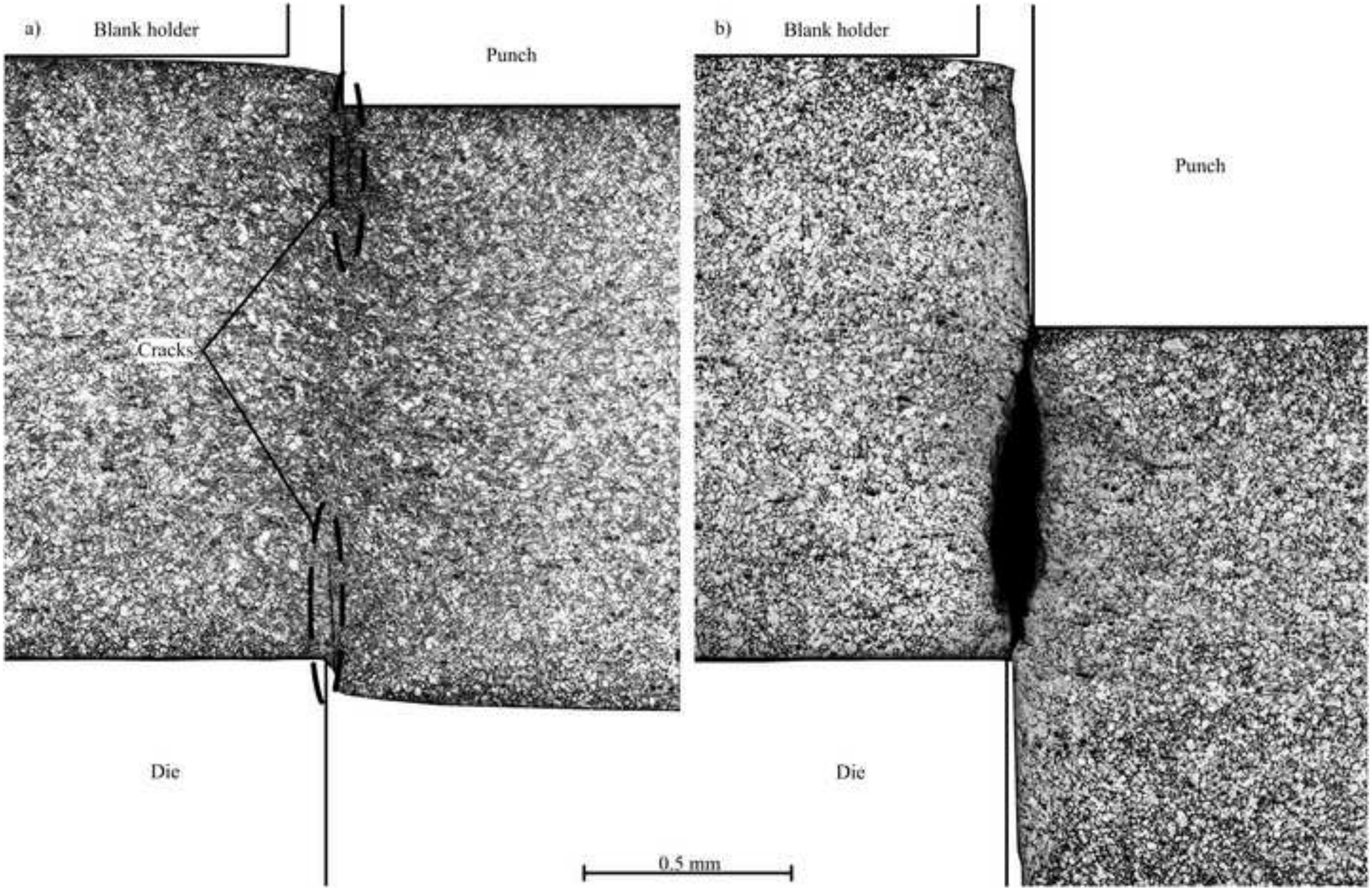

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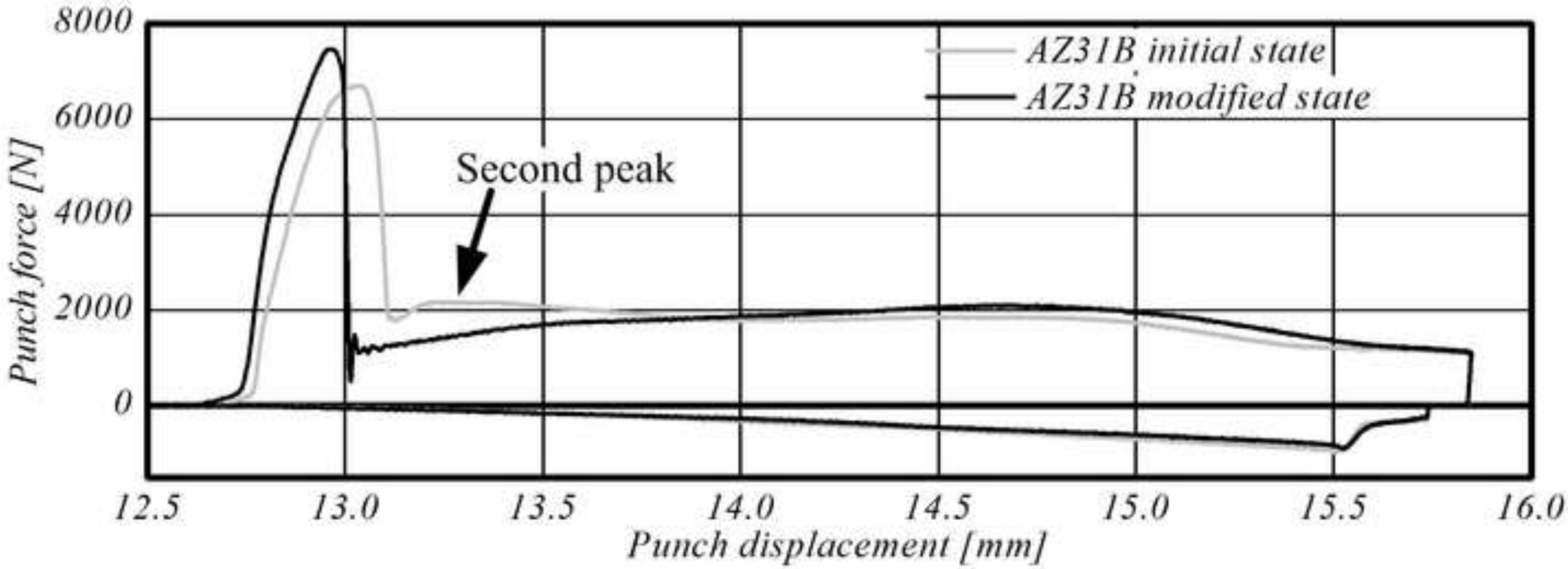

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