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Influence of wear on particle emission in aluminum blanking

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Abstract. The pollution of blanked parts with particles emitted by the blanking operation itself can be encountered in different cases of blanking, in particular aluminum blanking. The consequences of this pollution are a degradation of the quality of the parts produced (appearance, function) and, possibly, a degradation of the behavior of the blanking tool. In this context, we studied the effect of the wear of the punch in the case of AW5754 H111 blanking. Press tests were conducted with a complex part shape and with different press test configurations. The results highlighted two types of wear. The first one is called "run-in" (punch surface accommodation) and leads to a reduction of the emission of particles. On the contrary, the second type of wear, called "pick-up" (material transfer from the sheet), leads to increase particle emission. The mechanisms corresponding to the two particle emission modes are studied. The first mechanism is well known and results from the transition from a blanked edge geometry with secondary shear zone to a more conventional geometry without this secondary shear zone. The second mechanism is new, with sheet material being picked up by the punch and then the picked up material being scraped off, eventually leading to particles being deposited on the die and the part. The study also focuses on the effect of lubrication, clearance and punch shape on these mechanisms. The two mechanisms differ by the influence of lubrication: The second mechanism becomes preponderant as soon as lubrication becomes insufficient, and a solution must be found rapidly because of the larger particle emission and the risk of galling of the punch.

1. Introduction

Sheet metal forming firms are frequently faced with pollution caused by particles released by sheet blanking tools. The term "pollution" refers to debris or slivers resulting from the blanking operation and contaminates the tool and the manufactured part. These pollution problems should not be disregarded, as they lead to a degradation of the quality of the parts (marks, degraded appearance, distortions, etc.) and the quality of the tool (fracture, chipping, etc.). With the increasing use of aluminum as a solution for weight reduction, this problem is becoming more and more critical as these materials are a potential source of particle emission [1], [2]. The literature shows that particles can be emitted as a result of different mechanisms. Particles can result from burrs [3], these being related to the wear of the tool. In the specific case of aluminum, the particles may be related to the mode of propagation of the crack during the blanking operation, which may generate intermediate cutting zones [4] as a result of the convex shape of the cut edge [5], [6]. In this case, the wear of the tool seems to be a favorable factor for the reduction of particle emission [6]. Nevertheless, the wear which degrades the surface quality of the portions of the tool which rub against the cut edge, seems to contribute to the formation of slivers [4]. Therefore, it is challenging to understand the role played by the wear of the blanking tool. The study presented in this paper is a contribution to the study of the effect of blanking tool wear in the emission of particles for aluminum alloys.

2. Experimental aspects

We took an experimental approach to the problem. It consisted in performing aluminum sheet metal blanking tests with different test configurations. In this study, the blanked sheets are 0.8 mm thick and made of AW5754 H111 alloy, with the following characteristics: Rm = 211 MPa, Rp0.2 =111 MPa and A = 25%. The punching tool used (Figure 1) allows automatic press blanking operations. The punches and dies are made of X153CrMoV12 steel, heat treated to 58 HRC. The cutting shape (Figure 2) was proposed by the METALIS Company (France), which contributed to this study. This shape is complex, it is similar to a J and a K, with straight, concave (pointing to the outside) and convex (pointing to the inside) edges.

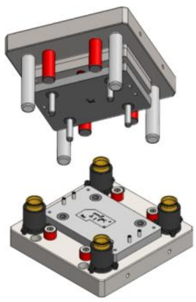

Figure 1. Tool used.

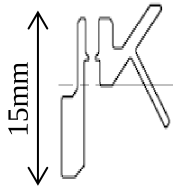

Figure 2. "JK" cut shape.

The tests were performed on a 200-ton mechanical press running at 80 strokes per minute. The test configurations are given in Table 1:

Table 1. Press test configuration.

Test configurations	Radial clearance (%)	Lubricant	Number of strokes
1	5	yes	20,000
2	5	no	500
3	7.5	no	500
4	10	no	500

When used, the lubricant was an evaporable oil, reference MARTOL EV 40 CF. The oil was applied to both faces of the metal sheet, in rather small quantities. For each test, the general condition of the tool and the strip was examined, then the tool was cleaned before starting a new series of blanking operations.

3. Results

3.1. Configuration 1

With configuration 1, during the first 500 press strokes, many particles were found in the tool (Figure 3). These particles were small and located on either side of the strip as shown in the figure. The center area was free of pollution. After this phase, and until 20,000 press strokes, there was almost no more pollution found (Figure 4). The examination of the sheared zone after 100 strokes (Figure 5) revealed a convex type rupture [5]. Usually, this rupture mode comes along with cut edges with an alternate type surface; this was actually observed in the blanked parts (Figure 6). Therefore, these results show that the mechanism which leads to particle generation is the recutting mechanism which takes place in the rupture (or fracture) zone as shown in the Figure 7. In this mechanism, the trajectory of the cutting blade meets the rupture zone of the cut edge due to the deviation of the crack path which passes under the face of the cutting blade.

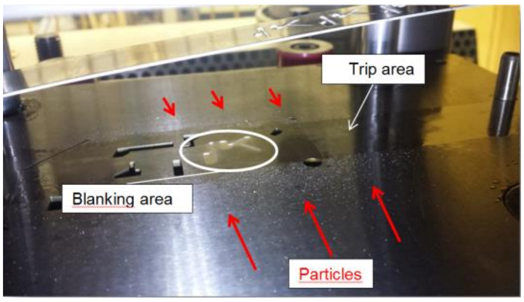

Figure 3. Presence of tool pollution after 500 press strokes - Configuration 1.

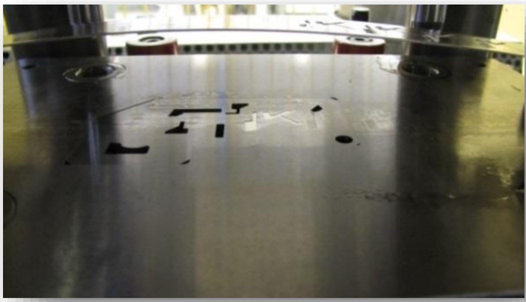

Figure 4. Absence of tool pollution between 500 and 20,000 press strokes - Configuration 1.

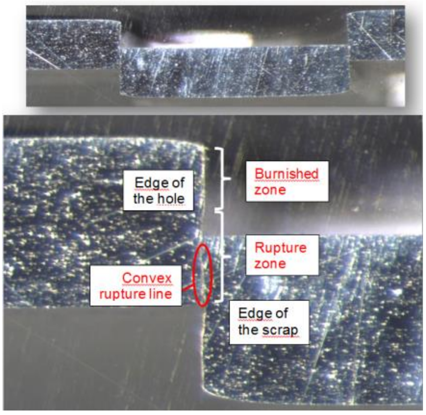

Figure 5. Cut edge with convex shape – Configuration 1 – 100 press strokes.

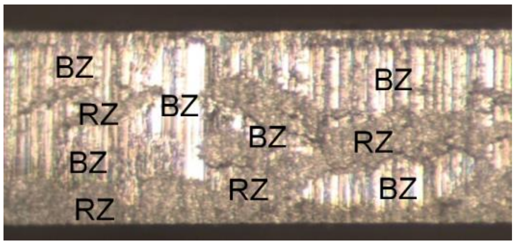

Figure 6. Cut edge with alternate type profile – Configuration 1 – 500 strokes (BZ: Burnished Zone, RZ: Rupture Zone).

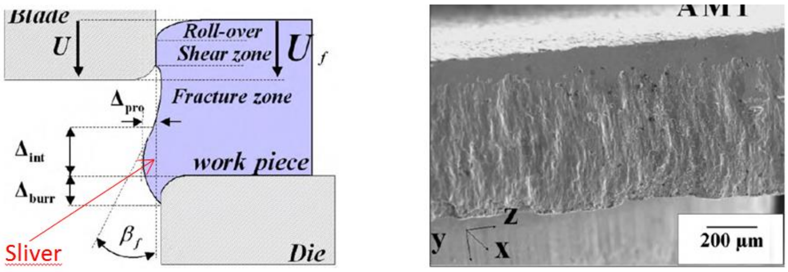

Figure 7. Sliver creation due to recutting phenomenon in the rupture (or fracture) zone, related to the convex shape of the rupture zone [6].

After 500 press strokes, as shown by Figure 8, the profile of the cut edge changes and becomes conventional, without alternating zones. From that moment, the particle generation phenomenon stops. This phase of the test (up to 500 press strokes) is called “run-in”. As a matter of fact, this is a well-known phase in the sheet metal blanking sector, a phase during which the wear of the punch increases rapidly and then stabilizes. This particular wearing out over a rather short operating period of the tool is difficult to assess by measurements on the tool, but it is undoubtedly beneficial in order to limit the pollution in the tool in the case of the particle generation mechanism presented here.

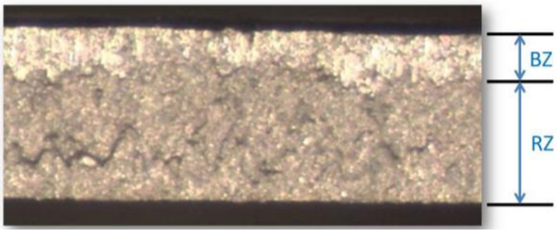

Figure 8. Conventional surface of the cut edge after 20,000 press strokes (BZ: Burnished Zone, RZ: Rupture Zone).

3.2. Configuration 2, 3 and 4

In configurations 2, 3 and 4, the lubrication was removed in order to accelerate the wear of the tool. The tests carried out until 500 press strokes for the three configurations revealed the presence of large numbers of particles built up on the tool (Figures 9a, 9b and 9c). The distribution of the particles on the tool is very different from that of configuration 1. As a matter of fact, the particles gathered in the travel area of the strip and not outside the latter, distinctly forming the letters JK on three feed steps on the strip. Therefore, it seems that a mechanism different from that of configuration 1 is the root cause of the emission of these particles. The examination of the punches after the tests revealed a significant amount of pick up on the surface of the tools (Figure 10). This punch damaging phenomenon suggests the following particle generation process (Figure 11):

- Significant friction between the metal sheet and the punch, due to the absence of lubrication during the blanking operation.
- Pick-up of metal sheet material onto the flanks of the punch. The dimension of the punch in its active portion increases.
- During the stripping of the punch, the blank holder guide, which is adjusted to the dimension of the punch, touches the upset material which built up on the flanks of the punch. Therefore, it acts as a metal file and scrapes off the excess material at each press stroke.
- This excess material builds up on the surface of the metal sheet on the side which features the inlet of the blanking hole (space left by the rollover of the edge of the hole), then it is carried by the strip and finally settles at the next steps due to the vertical shock generated by the blanking operation and the horizontal jerky movements resulting from the feed of the strip.

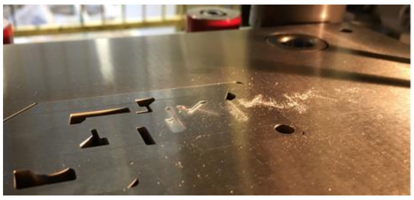

Figure 9a. Configuration 2 – 500 strokes.

Figure 9b. Configuration 3 – 500 strokes.

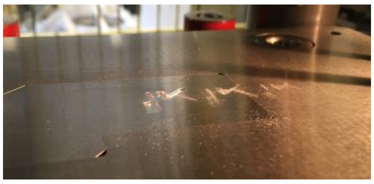

Figure 9c. Configuration 4 – 500 strokes.

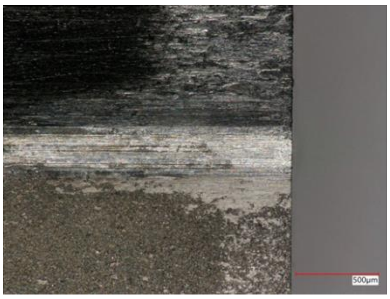

Figure 10. Appearance of the punches after 500 press strokes – Example of configuration 4.

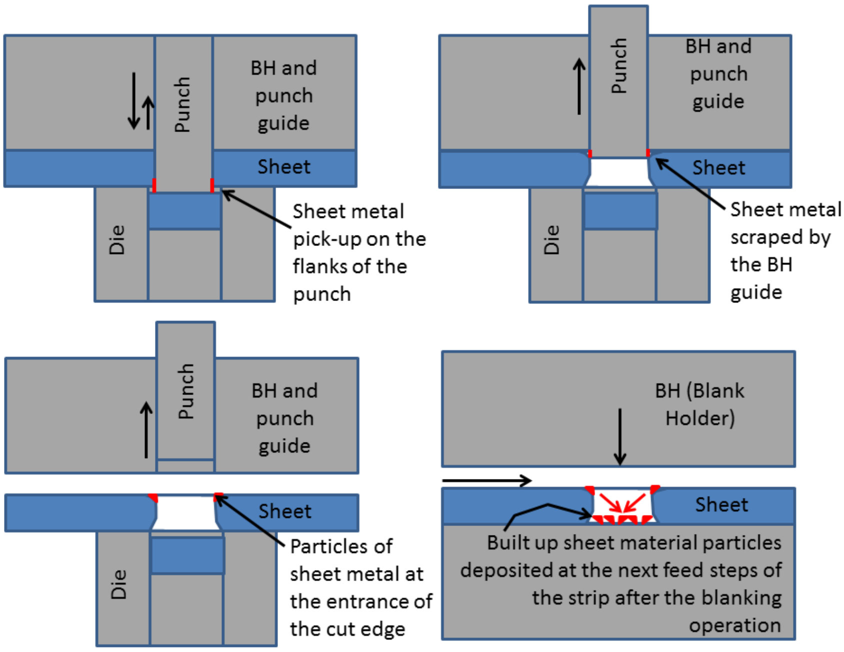

Figure 11. New tool pollution generation mechanism: pick-up, scraping, transport, settling.

The pick-up mechanism was studied based on the examination of the punches with a confocal microscope, for the various configurations, after 500 press strokes. The four examined zones are presented on Figure 12 and correspond to protruding radii (zones A and C) or recess radii (zones B and D). Figure 13a illustrates some pick-up on the protruding radius of zone A, which is extremely high (approximately 1.5 mm). This height is much higher than the length of friction between the flanks of the punch and the cut edge of the sheet (1 mm). This result seems to be explained by a pick-up mechanism which also affects the inside of the blank holder guide, as illustrated on Figure 14. This mechanism starts with the pick-up of material onto the flanks on the punch, then continues with the transfer of the pick-up material to the inside of the punch guide (when the punch rises) and finally ends with the transfer of the material from the punch guide to the flanks of the punch, thereby contributing to increasing the pick-up height.

The effect of the blanking clearance is low since, for the three configurations, the emission of particles remains significant. Nevertheless, the protruding shapes of the punch should increase the emission of particles due to the increased pick-up in these areas (Figure 15). A relationship can be established between the significance of the pick-up, depending on the shape of the punch (protruding or not), and the height of the smooth area on the corresponding cut edge (Figure 16).

Therefore, in these tests, lubrication seems to play a major role in the generation of particles and its effect becomes prominent in relation to the other parameters of the process in the event of galling.

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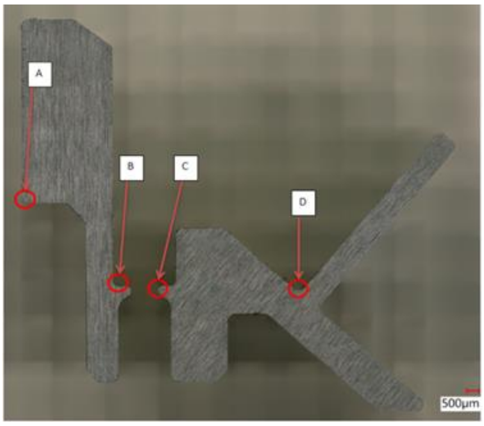

Figure 12. Zones examined on the blanking punch.

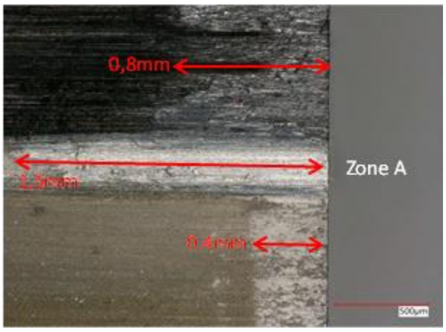

Figure 13a. Zone A after 500 press strokes – Configuration 3.

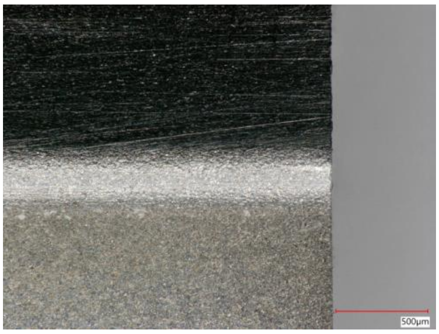

Figure 13b. Zone A, new tool – Configuration 3.

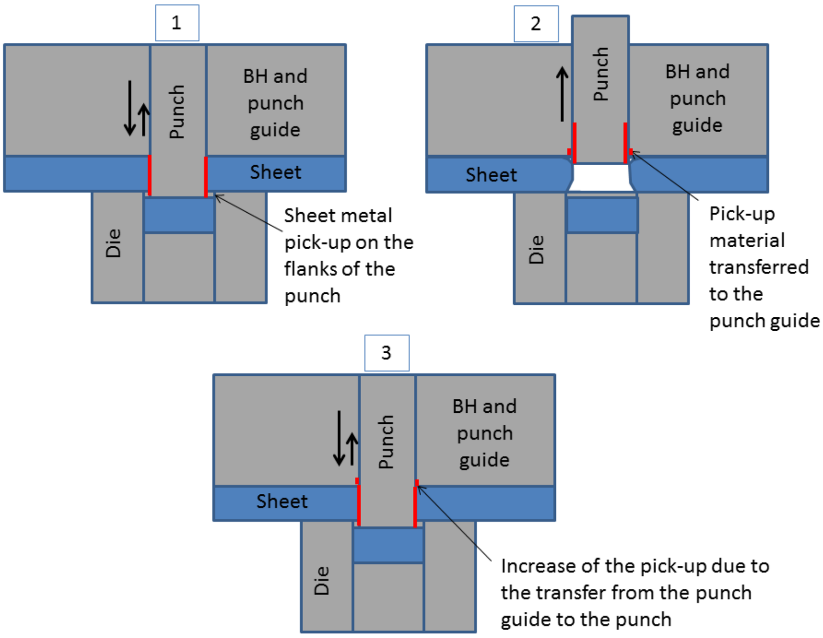

Figure 14. Pick-up mechanism on the protruding portions of the punch.

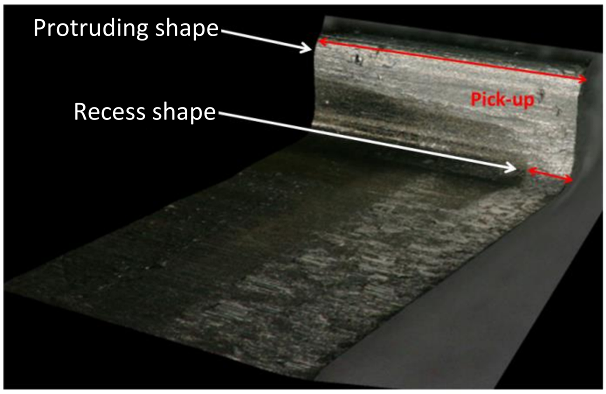

Figure 15. Influence of the protruding and recess shapes on pick-up.

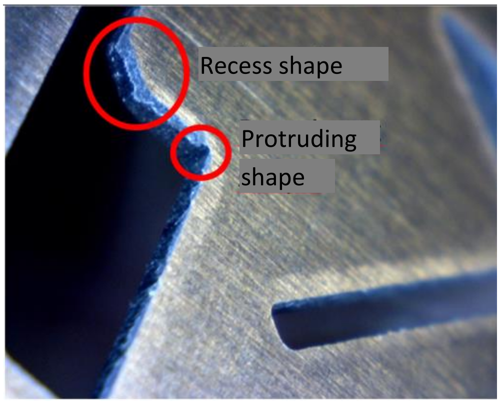

Figure 16. Influence of the protruding and recess shapes on the smooth area height.

4. Conclusion

The study of particles generated by the aluminum alloy sheet blanking operation revealed that the wear of the tool, when it was of the "run-in" type and did not cause any material pick-up onto the tool, could help to lessen the emission of particles. However, when pick-up occurred due to insufficient lubrication of the tool, the wear led to the emission of a very significant quantity of particles generated by a mechanism different from the recutting mechanism. In severe working conditions without lubricant, the blanking clearance does not seem to be able to reduce the pick-up phenomenon which, on the contrary, seems to be affected by the protruding or recess shape of the tool. Therefore, for the problems of particle emissions during the blanking operation, proper control of the wear induced by pick-up should be given priority, through sufficient application of lubricant and/or by the use of suitable surface coatings. This is all the more important since pick-up is often an early warning sign of tool galling. For the remaining part of this study, we plan to assess the influence of the blanking clearance in the case of a lubricated blanking operation. Indeed, it is a known fact that the alternate cutting surface is directly influenced by this parameter, which therefore may have a direct influence on the emission of particles by recutting

References

[1] Daniel D, Shahani R, Baldo R, Hoffmann J 1999 Development of 6xxx Alloy Aluminum Sheet for Autobody Outer Panels: Bake Hardening, Formability and Trimming Performance *SAE Technical Paper* 3195
[2] Li M 2000 An experimental investigation on cut surface and burr in trimming aluminum autobody *sheet International Journal of Mechanical Sciences* pp 889-906
[3] Selvaraj R, Quagliato L, Jang S, Kim N 2017 Numerical model for a quantitative estimation of sliver formation in shearing process *IDDRG* July 3-5 *(Munich)*
[4] Li M, Fata G 1999 Sliver Reduction in trimming aluminum *Autobody sheet SAE Technical Paper Series*, 1999-01-0661
[5] Golovashchenko SF 1999 A study on trimming of Al alloy Proceedings *6th ICTP Advanced Technology of plasticity* pp 2261-2266
[6] Bacha A, Daniel D, Klöcker H 2010 Crack deviation during trimming of aluminum automotive sheets *Journal of Materials Processing Technology* Elsevier 210 (14) pp1885-1897