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Technical Data

Effect of Punch Coating on Pierced Surface Properties

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1. Preface

Reducing weight of automotive parts is required due to restraining the emission of carbon dioxide to prevent global warming recently. High strength automotive parts are also required from the perspective of collision safety. Therefore the high strength steel sheets for automotive parts have spread through market to achieve both lightweight and high strength. The maximum tensile strength of steel sheets made by cold roll process for automotive parts reached 1180 MPa now.

However, some issues were pointed out on the forming of high strength steel sheets. Decrease of die service lives is one of them. Therefore improving die service lives in shearing process has become a serious challenge.[2)3)]

In the shearing process, evaluating the degradation of sheared surface quality, not galling on shearing dies as die tool service lives is necessary. Actually, the evaluation of shearing process tool service lives depends on burr heights on sheared surface and the amount of distortion on the product[4)~6)]. Therefore, if these evaluated points are within the acceptable range, tools can be worked even if galling occurred. This is different from other processes that tool service lives are evaluated by tool galling such as drawing, bulging and bending processes.

In case of high strength steel sheets shearing, not only burr heights on sheared surface and the amount of distortion on the product are required for sheared surface quality, but also stretch flangeability[7)~11)], fatigue property[11)~13)] and hydrogen embrittlement resistance[14)15)]. These properties are affected by surface roughness, hardness and residual stress of sheared surface. Thus, it is important to understand how these sheared qualities change whether tools are coated or not.

Based on above background, in this study the effect of punch coating on roughness, work hardening, and residual tensile stress of pierced surface with 1180MPa class high tensile strength steel sheets were investigated.

2. Test conditions

2.1 Piercing test

Figure 1 shows the schematic image of piercing tools. Test was performed by ϕ 10.0mm piercing punch with conditions without lubricant and with 5%t clearance. %t means the percentage of clearance against work sheet thickness. Work sheets were 1180MPa class high tensile strength cold-rolled steel sheets with the thickness of 1.6mm.

As the same way reported in the reference paper[16)], 0.3mm chamfered punches to prevent chipping of the edge were used. Punches were made from DC53, 8%Cr-2%Mo type JIS SKD11 modified cold work die steel made by Daido Steel, Co., Ltd. Three surface treatment conditions, HT-CERAC, nitriding+HT-CERAC and non-coating, have been evaluated. HT-CERAC is the original PVD coating produced by Daido Die & Mold Solutions.

Dies were changed every new punch test to eliminate an effect of the quality of pierced sections by die wearing with long run.

2.2 Observation of the pierced surface

The confocal laser scanning microscope was used to observe pierced surfaces. The observation areas were 4 positions, which are every 90 degrees of inside holes circumference surface. (See Figure 2)

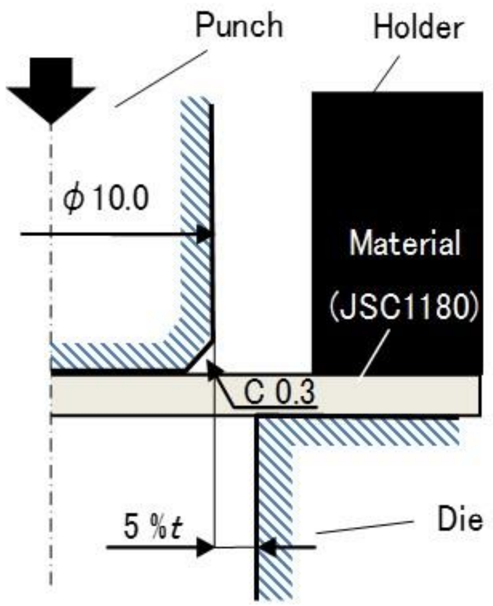

Fig. 1. Schematic image of piercing tools.

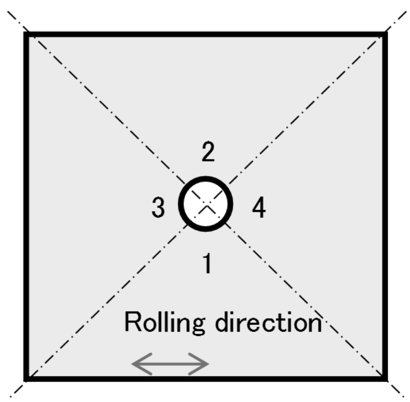

Fig. 2. Positions for observation of pierced surface.

2.3 Hardness test on pierced surface

As shown in Figure 3, hardness was tested along with the line of 0.04mm depth from the surface on the cross section of the hole. The indentation load was 25gf, and the measurement interval was 0.08mm pitch along with the sheet thickness direction. Two positions were measured for each punch condition.

2.4 Residual stress measurement on pierced surface

Residual stresses of circumferential directions and sheet thickness directions were measured by X-ray method. Specimens were cut along lines through center of holes for easy X-ray irradiation for measurements. Beam diameters were ϕ 0.5mm, and measurement positions were three points that divide the sheet thickness into four equal parts.

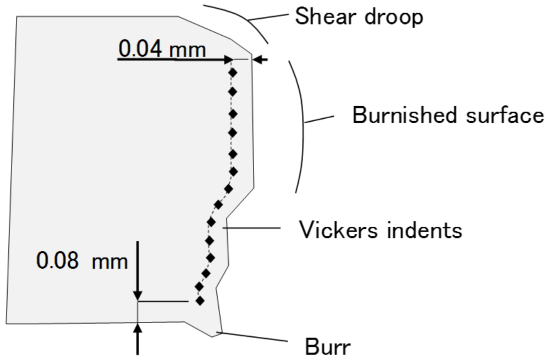

Fig. 3. Measurement positions for Vickers hardness.

3. Results and discussion

3.1 Pierced surface observed by microscope

Figure 4 shows observations of the pierced surfaces. As shown in Fig.4, every boundary area between burnished surface and fracture surface was greatly rough. The boundary roughness did not depend on punch conditions and observation positions.

Non-coated punch was different from other conditions from the view point of burnished surface. It had a strong hairline mark along with sheet thickness direction. This hairline mark affects the surface roughness. The surface roughness on the burnished surface area is shown in Figure 5. These were the arithmetic mean roughness, Ra measured 0.5mm length by laser method. The non-coating condition roughness is 7 times larger than other conditions.

From the previous report16) result, the strong hairline mark on the pierced surface of the non-coating condition may be generated by die galling. Therefore the roughness on the coating condition was smaller than non-coating one because coating prevented die galling.

The boundary of HT-CERAC on the nitride surface condition (See Fig.4 (C)) appeared to have smaller surface undulation compared to HT-CERAC condition (See Fig.4 (b)). However, quantitative difference between both two conditions could not be determined because pierced surfaces were very variable depending on observation positions. The cause of this surface quality variation was assumed to be affected by slight off-center holes by piercing.

Fig. 4. Pierced surface observed by micro-scope.

3.2 Work hardening

Figure 6 shows the hardness. Hardness distributions at every two positions are plotted separately, as ○ and ■. Hardness on coating conditions were clearly higher compared with the non-coating condition. The maximum hardness of the non-coating condition was about 460 HV (See Fig.6 (a)), but coating conditions (See Fig.6 (b) and (c)) were over 500 HV. This reason can be thought that the coating punch edge made a larger work material flow than non-coating one due to the small friction coefficient of the coating surface. Work-hardening is considered to depend on work material flow volume.

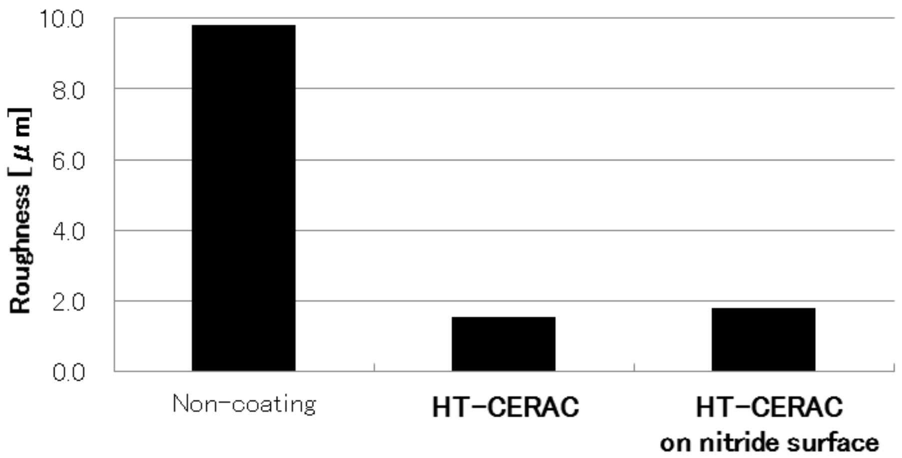

Fig. 5. Roughness (Ra) on burnished surface.

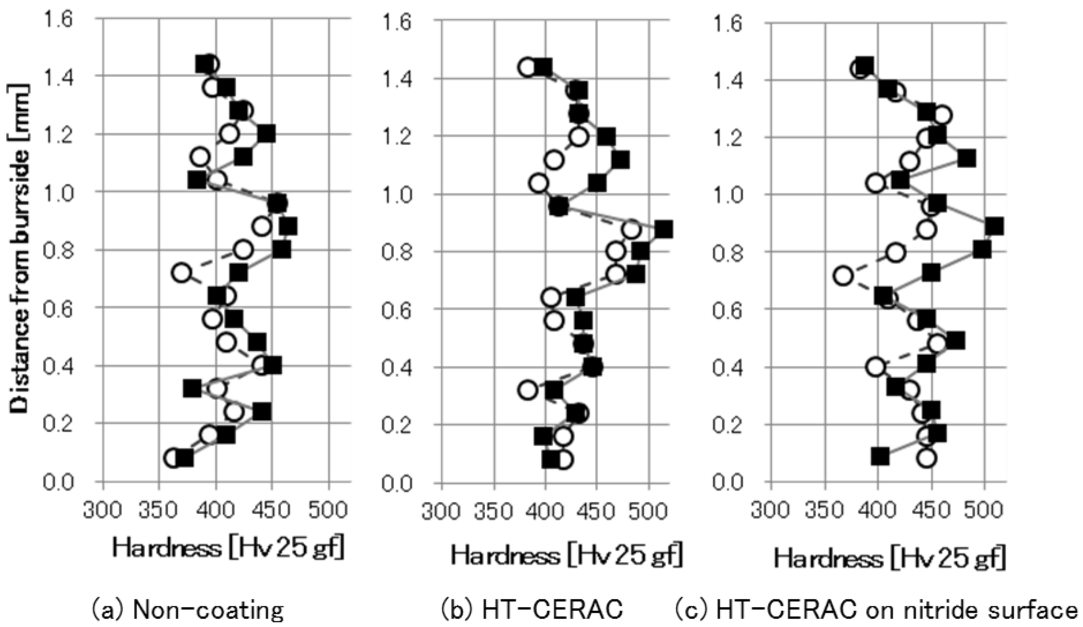

Fig. 6. Hardness measurement on cross section of pierced surface.

3.3 Residual stress

Results of residual stress measurement on pierced surfaces are shown in Figure7. Fig. 7 (a) shows residual stresses on the circumferential direction, and Fig.7 (b) shows thickness direction ones. Both two results have the difference between the coating or non-coating conditions. The results of the non-coating condition measured at the upper side of the thickness (burnished surface area) except for the middle of thickness result were 750MPa tensile stress or higher, while both two coating conditions results were compressive stress or under 100 MPa tensile stress. On the other hand, results on the lower side of the thickness (fracture surface area) were all tensile stress and values are almost the same.

The cause of high residual tensile stress that were measured on the burnished surface of the non-coating condition was considered to be affected by galling between work and punch. Therefore, galling and adhesions of work material on the punch, have added tensile stress on fracture surfaces. In the case of the coating punch, prevention of die galling may reduce the tensile stress. Therefore coating conditions seemed to generate compressive or low tensile residual stresses on pierced surfaces.

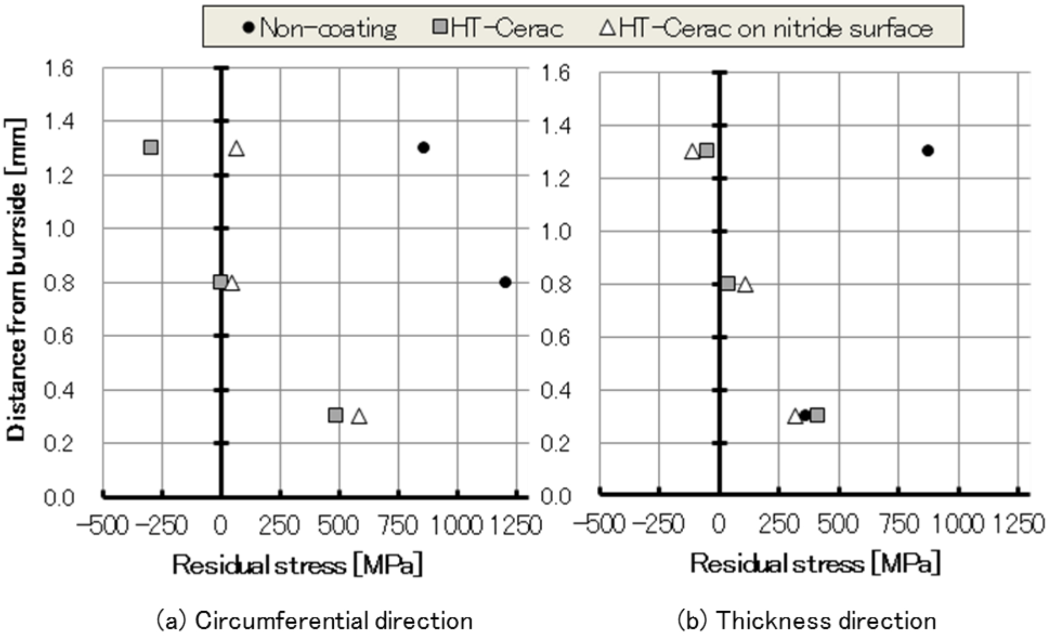

Fig. 7. Residual tensile stress on pierced surface.

4. Summary

The effect of punch coating on pierced surface qualities with 1180MPa class high tensile strength steel sheets were investigated in this study. Findings of this study are summarized as follows:

1. The punch coating reduces the roughness on the burnished surface because the coating prevents the galling.

2. The punch coating increases the work hardness near the pierced surface. This reason is the coating punch edges generate large work material flows.

3. The punch coatings reduce residual stresses on burnished surfaces. However residual stresses on fracture surfaces are almost the same whether punches are coated or not. It is considered to be the effect of preventing galling by coating.

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