

Evaluation of Prog-Die Wear Properties on Bare DP1180 Steel

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ABSTRACT

The die wear up to 80,800 hits on a prog-die setup for bare DP1180 steel was investigated in real production condition. In total, 31 die inserts with the combination of 11 die materials and 9 coatings were evaluated. The analytical results of die service life for each insert were provided by examining the evolution of surface wear on inserts and formed parts. The moments of appearance of die defects, propagation of die defects, and catastrophic failure were determined. Moreover, the surface roughness of the formed parts for each die insert was characterized using Wyko NT110 machine. The objectives of the current study are to evaluate the die durability of various tooling materials and coatings for flange operations on bare DP 1180 steel and update OEM tooling standards based on the experimental results. The current study provides the guidance for the die material and coating selections in large volume production for next generation AHSSs.

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INTRODUCTION

In order to meet the requirement of weight reduction and in the same time maintain and even improve the crash performance, the demand for advanced high strength steels (AHSS) and ultra-high strength steels (UHSS) are developed rapidly in automobile industry worldwide. The structure component manufactured by AHSSs provides the optimal performance due to their excellent combined strength and ductility. However, the die wear problem becomes more and more severe, because the sheet metals become harder and traditional die materials and surface treatments (coatings) are not sufficient for AHSSs stamping [1, 2, 3, 4]. It leads to the significant cost increase due to the die maintenance and interruption in manufacturing. In the sheet metal stamping industry, there is a pressing demand to understand die wear behavior in next generation AHSSs forming. The special die materials and coating are worth the efforts to develop for forming AHSSs in large volume production.

In the present research, the die wear properties were evaluated in real production environment for in total 31 die inserts with the combination of 11 die materials and 9 coatings when flanging bare

DP 1180 steels. The computer simulation was conducted to simulate the strain distribution and sliding energy density during the forming. The scanning electron microscopy (SEM) was adopted to measure the wear area in the inserts after forming. The energy-dispersive X-ray spectroscopy (EDS) mapping was provided to distinguish the elements distribution around the fracture surface. The final panel surface roughness was examined by Wyko NT1100. The objectives of the current study are to evaluate the die durability of various tooling materials and coatings for flange operations on DP 1180 steel and update OEM tooling standards based on the experimental results. The current study provides the guidance for the die material and coating selections in large volume production for next generation AHSSs.

EXPERIMENTAL PROCEDURES

The die wear experiment was conducted at Richard Tool & Die Corporation in real production condition. The upper and lower progress die (prog-die) setup is shown in Fig. 1(a) and (b), respectively. It is worth to mention that beside the flange the hole piercing with different

shape and geometry was also investigated during the experiment. The current study only focuses on the flange operations to assess the die wear. In prog-die, in total 14 stations were included. The details for each station are listed in Fig. 1(c). The flange die insert is displayed in Fig. 1(d). The die insert located in upper prog-die. It is demonstrated that there are two “noses” [red circled on Fig. 1(d)] on each side of the insert. The simulated and real final formed parts are illustrated in Fig. 1(e) and (f), respectively. The sample labeling of 1-12 in Fig. 1(f) corresponds to inserts # 1-12. The left and right fingers are marked on Fig. 1(f) as letter “L” and “R”, which will be used throughout the present paper. The project was separated in two phases, 2015 and 2016. In 2015 project, in total 8 die materials and 7 coatings were evaluated up to 15,000 hits. In 2016 project, in total 6 die materials and 4 coatings were tested until 65,800 hits. The detailed test matrix with die material hardness and roughness after coating for both 2015 and 2016 projects was listed in Table 1 and 2, respectively.

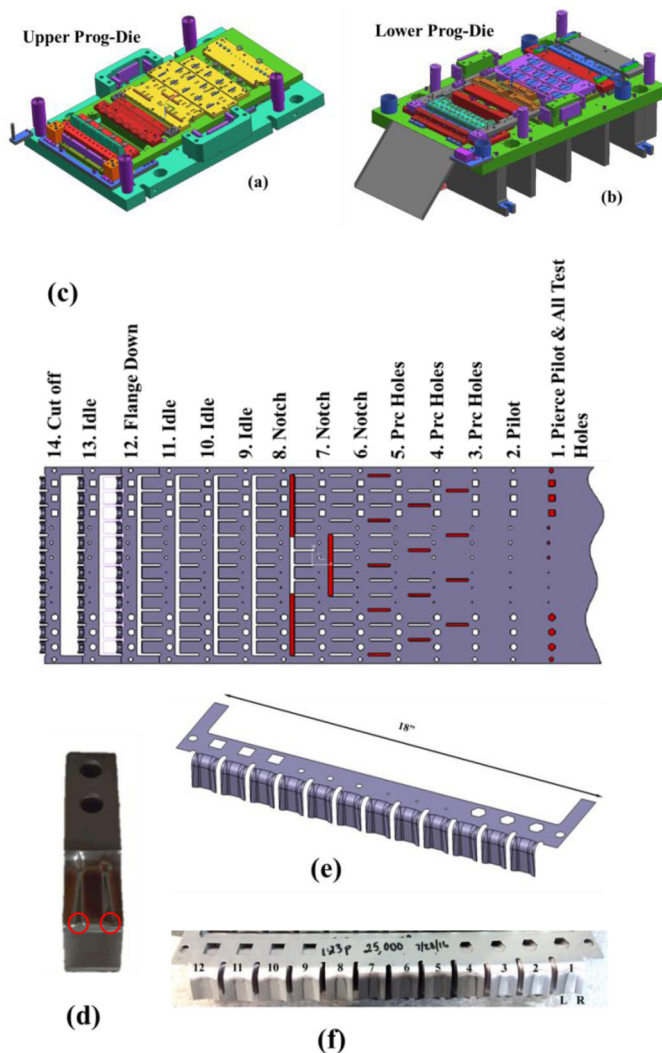


Figure 1. (a) and (b) Upper and lower prog-die, respectively. (c) The detailed information for each station in prog-die. (d) The die insert for flange operation. (e) and (f) The simulated and real final formed parts, respectively.

The bare DP1180 steel was selected. Because of the high strength and no zinc coating applied on the surface of steel, it will create the worst case scenario for die wear during forming. It makes this steel a good

candidate to evaluate the die wear properties in the current study. The stress-strain curve and tensile properties of bare DP1180 steel along longitudinal (L), transverse (T), and diagonal (D) are shown in Fig. 2 and Table 3, respectively. The yield strength and ultimate tensile strength of bare DP 1180 steel were approximately 920 and 1197 MPa, respectively. The uniform and total elongations were about 5.3 % and 9.9 %, respectively.

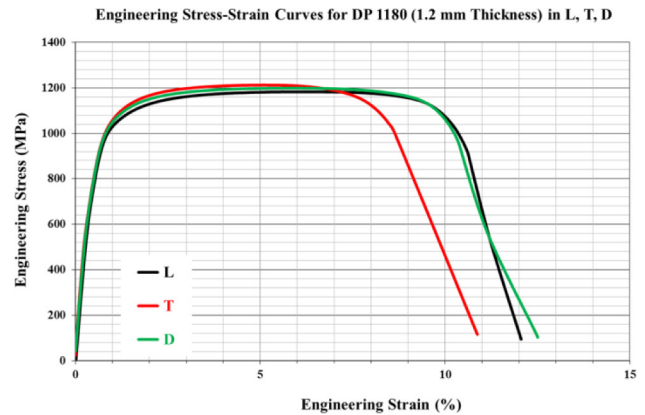


Figure 2. The engineering stress-strain curves of bare DP1180 steel along L, T, and D directions.

The microstructure of as-received bare DP1180 steel was characterized by optical microscopy (OM) along L and T directions for both top and center of the sheet, as displayed in Fig. 3. It was found that approximately 70 % volume fraction of martensite and 30% ferrite evenly distributed in the bare DP1180 steel.

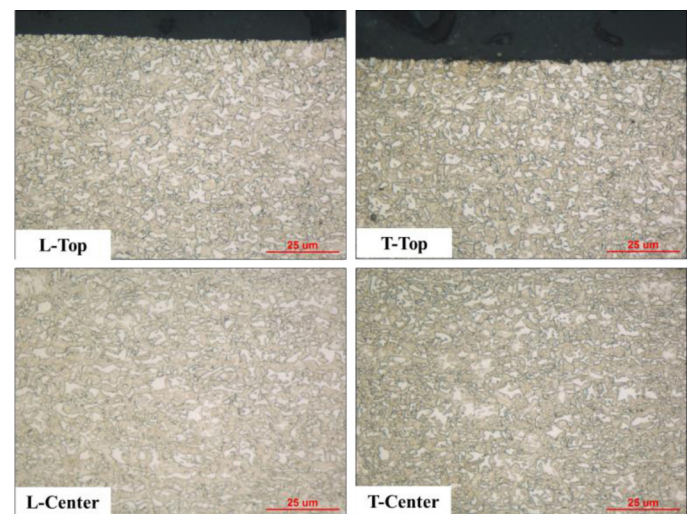


Figure 3. The microstructure of bare DP1180 steel in L and T direction for top and center of sheet metal.

The computer simulation was performed using LS-DYNA to simulate the sliding energy density, thinning strain, and effective strain distribution, as displayed in Fig. 4(a)-(c), respectively. The performance of the insert with softened nose design (left side) and the real die insert with sharp nose (right side) employed in the current study was examined. It was noticed that modifying the die insert design resulted in the decrease of sliding energy density, thinning strain, and effective strain, indicating that the die wear could be significantly

reduced by optimizing the die design. However, the major objective in the present research was the die durability evaluation. It was intentionally to generate the worst case scenario by using the die insert design which will cause issues. Then, the AUTODFORM was utilized

to examine the possible wrinkle and failure after flanging, as illustrated in Fig. 4(d). It was obvious that the formability issues would not occur. Therefore, the current experiment setup is suitable for evaluating the die wear behavior for bare DP1180 steel.

Table 1. The experiment matrix of 2015 project.

Die ID	Die Material	Coating	Hardness (Re)	Roughness, Ra (μm)
1	D6510	PVD Duplex CrN	54-58	0.94
2	CC1	PVD Duplex CrN	38-42	0.68
3	T44	PVD Duplex CrN	44-46	0.42
4	TD2	PVD Duplex CrN	55-58	0.35
5	TD2	PVD Duplex CrN	55-57	0.39
6	DC53	PVD Duplex CrN	55-60	0.42
7	TD2	Cool Sheet	55-57	0.26
8	TD2	Concept	55-60	0.42
9	S2333	PVD Duplex CrN	40-45	0.48
10	S0050A	Cr Plate	54-58	0.17
11	S0050A	Cr Plate over Ion Nitride	38-43	0.20
12	CC1	HVOF	54-58	0.22
N1 (replace 1 after 15k hits)	D2 (NEW)	PVD Duplex CrN	58-60	-
N2 (replace 2 after 15k hits)	D2 (NEW)	PVD Duplex CrN	58-60	-
N8 (replace 8 after 15k hits)	TD2 (NEW)	Concept + Most	58-60	-
N10 (replace 10 after 15k hits)	D2 (NEW)	PVD Duplex CrN	58-60	-
N11 (replace 11 after 15k hits)	D2 (NEW)	PVD Duplex CrN	58-60	-
N12 (replace 12 after 15k hits)	D2 (NEW)	PVD Duplex CrN	58-60	-

Table 2. The experiment matrix of 2016 project.

Die ID	Die Material	Coating	Hardness (Re)	Roughness, Ra (μm)
1	S2333	Cool sheet	40-45	0.15
2	S2333	Cool sheet	50-54	0.22
3	Cast Caldie	Cool sheet	58-62	0.17
4	Toolox 44	Cool sheet	No heat-treatment	0.10
5	SLD-i	Cool sheet	58-62	0.24
6	TD2	Concept + most	55-58	0.16
7	TD2	Cool sheet	55-57	0.17
8	TD2	Duplex CrN + most	55-58	0.12
9	Cast Caldie	Concept + most	58-62	0.11
10	DC53	Concept + most	62-64	0.23
11	TD2	Duplex Variantic (TiAlCN)	55-58	0.10
12	SLD-i	Concept + most	58-62	0.18
14 (replace 8 after 4k hits)	TD2	Concept + most	58-62	0.19