Hot Stamping of Zn-Coated PHS Steel Using Atomization Precooling Technology

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Abstract. In this paper, hot stamping of Zn-coated PHS was introduced. Targeting to control or eliminate the liquid metal induced embrittlement phenomenon, a self-make atomization precooling apparatus was developed to solidification the melted coating during the former heating process. The key role of the apparatus was to provide foggy environment around the heated blank to lower its temperature both rapidly and homogeneously. The relationship between atomization intensity and properties of the hot stamping parts was studied. Low medium flow condition of 50 L/h and high medium flow condition of 100L/h were adopted with the same other test parameters. Mechanical properties and microstructure as well as LME were detected. The results show that under low medium flow condition, no qualified products can be deserved while with high medium flow condition, qualified products can be achieved.

Keywords: Zn-coated PHS · Liquid metal induced embrittlement · Atomization · Hot stamping

1 Introduction

The safety performance of a vehicle in its service life has attracted more and more attention in recent years. As it is known that hot stamping parts using advanced high strength steel are widely used not only for higher safety level but also for lightweight purpose. Therefore, how to insure the effectiveness in service life has become a hot issue. One of the fatal damages to the hot stamping parts is corrosion which may induce microcrack and subsequent crack growth, even fracture of a part. Lower body hot stamping parts such as floor middle channel and door sill are exposed to the humid environment. These parts need to have even higher corrosion resistance properties. Compared to the traditional used hot stamping parts with no coating and Al-Si coating, Zn based coating including pure Zn coating (GI), Zn-Fe coating (GA) and Zn-Ni coating (GA) has been investigated both theoretically and practically. These coatings have the advantage of anti-oxidation during the hot forming, as well as providing additional cathodic protection for the hot stamped parts [1]. However due to low melting point of the Γ phase, hot stamping of the Zn-coated steel has been limited due to liquid metal-induced embrittlement (LME)

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[2]. An effective way to solve LME problem is indirect hot stamping which is adopted and patented by Voestalpine. But the cost of this method is quite high for at least two processes before finished product.

In this paper, a lower cost experiment of direct hot stamping of GI with high pressure atomization is carried out with a self-developed automatically controlled fixture. The relationship between atomization intensity and properties of the hot stamping parts was studied.

2 Materials and Experiments

The as received cold rolled and then hot dip galvanized 22MnB5 steel with thickness of 1.4 mm was used. The yield stress and the ultimate tensile stress are 427 MPa and 621 MPa respectively. The elongation is 27%. Its chemical composition is listed in Table 1.

The materials are laser cut into the door sill shape. Then these door sill blanks are transferred into the multi-layer drawer furnace to be heated from ambient temperature to around 900 °C and the in furnace time is 300 s. In order to ensure that the internal structure of the material is full austenite, blanks are required to stay in the furnace when their temperature reach the preset value. After austenitization, the heated blanks are transferred out of the furnace to the hot stamping die. During this process, high pressure atomization precooling is applied to the heated blanks to fast solidification of the melted coating during the former heating process. The target temperature at the end of the cooling is around 600 °C. At the end of precooling process, the die is going to be closed. The subsequent process is similar to the conventional hot stamping process, that is press hardening process. The main process of the adopted approach to hot stamping of Zn-coated PHS steels is shown in Fig. 1.

Table 1. Chemical composition of the as received steel (wt. %).

C	Si	Mn	P	S	Cr	Al	B	Fe
0.22	0.23	1.2	0.012	0.0023	0.1–0.3	0.037	0.0021–0.0079	balance

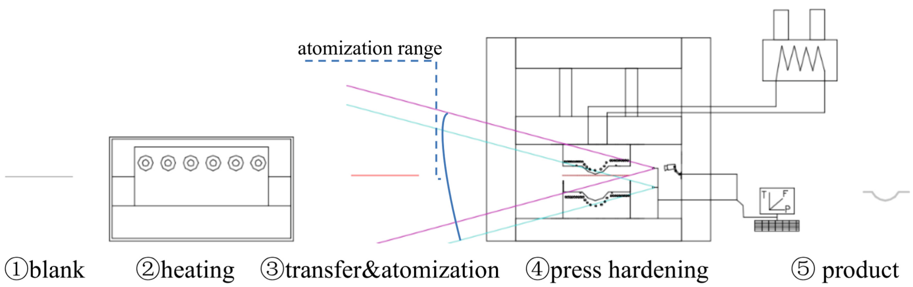

Fig. 1. Hot stamping process of Zn-coated blanks.

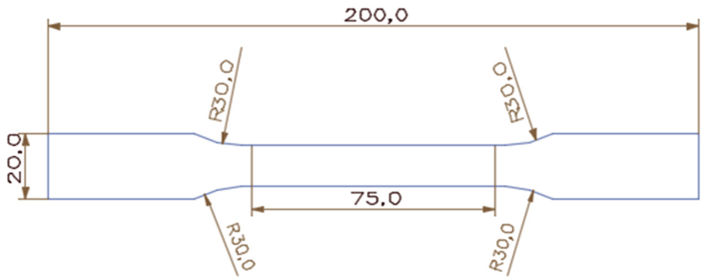

Fig. 2. A50 tensile sample.

The key of the process is to control the blank temperature after they leaving the furnace. It can be seen from Fig. 1 that atomizing nozzle is located in the working plate of the press and the distance between the nozzles and hot stamping die as well as the spray angle can be adjusted according to atomization effect. Colored solid straight lines except red indicate the atomization range. Atomizing medium is mixed with compressed air to ensure that the atomization does not form droplets. To monitor the temperature value and distribution of the blank, an infrared thermal imager is used. In order to compensate for the temperature fluctuation of the sheet, temperature collected by thermal imager and atomizing medium flow as well as pressure of the compressed gas are integrated in the control system. Through this control system, the atomization process can be controlled automatically. Based on the former study [3], medium flow and air pressure are two key factors which influence the atomization precooling effect. However, due to the workload, this paper only changes the medium flow as a variable. The experiments are carried out with medium flow of 50 and100 L/h with air pressure of 7 bar. According to the sheet transfer time 8s, atomization precooling time is a little shorter, that is 6 s.

To ensure repeatability, each process parameter is repeated three times. After hot stamping, mechanical properties, microstructure and LME testing are carried out to evaluate the feasibility of the atomization precooling process. A50 tensile sample is shown in Fig. 2.

3 Results and Discussion

The press hardened parts are shown in Fig. 3.

3.1 Mechanical Properties

Uniaxial tensile samples are laser cut from almost flat surface of the press hardened parts: top surface, wall area and flange area. Results of uniaxial tensile test are listed in Table 2.

It can be seen evidently from Table 1 that both under low medium flow and higher medium flow, almost all good mechanical properties can be achieved. The main reason for good mechanical properties is sheet temperature control during whole process. It is well known for almost common hot stamping used press hardening steels.

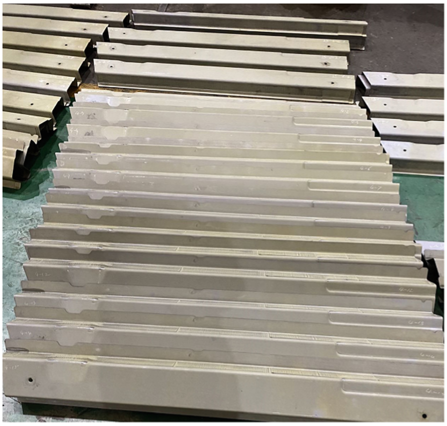

Fig. 3. Press hardened parts.

Table 2. Mechanical properties after hot stamping.

	Medium flow: 50 L/h			Medium flow: 100 L/h		
Part No.	Yield stress/ MPa	Tensile stress/ MPa	Fracture elongation/ %	Yield stress/ MPa	Tensile stress/ MPa	Fracture elongation/ %
1	1028	1370	5.1	1206	1438	5.8
	1042	1365	5.3	1060	1378	4.1
	1051	1401	4.9	1030	1439	7.2
2	1102	1355	5.6	1244	1422	5.2
	1039	1402	5.8	1313	1439	4.8
	1099	1443	5.1	1274	1460	4.2
3	1122	1405	5.0	1033	1395	6.7
	1098	1392	5.3	1044	1431	7.1
	1066	1386	6.0	1133	1482	7.9

3.2 Microstructure and LME

Microstructure and LME can be tested using the same sample by optical microscope. Samples are laser cut from fillet area of the press hardened parts. Microstructure after low medium flow and high medium flow is shown in Figs. 4 and 5 respectively.

The phase of the base material is almost Martensite mixed with a small amount of ferrite. A transition layer can be clearly seen between surface layer and base material as shown in both Fig. 4 and Fig. 5. However, with low medium flow condition, LME crack that more than 10 μm penetrated through the transition layer into base material is observed which is not permitted according to the requirements of some car makers such as BMW and BENZ [4, 5]. While with high medium flow, a continuous transition layer

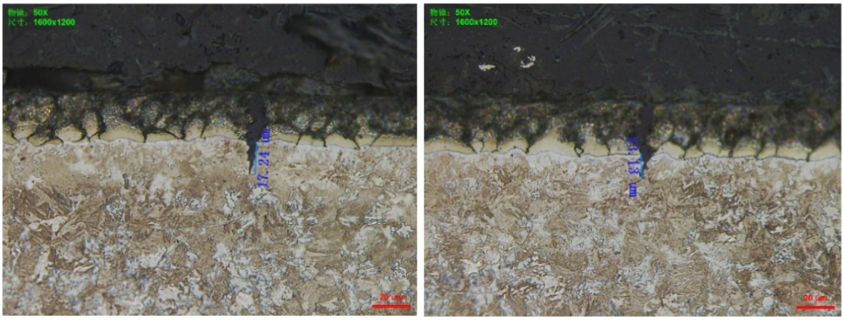

Fig. 4. Microstructure after low medium flow.

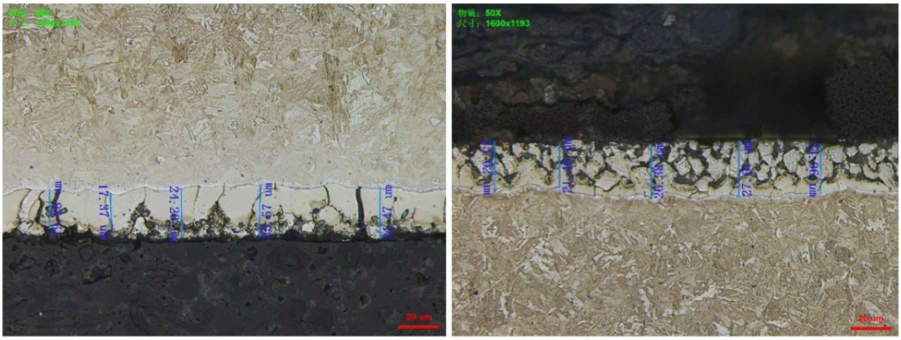

Fig. 5. Microstructure after high medium flow.

is deserved. The results demonstrate that higher medium flow exerted on the surface of the heated blank can solidify the melted Zn-coating to greatly reduce or even restrain LME.

4 Conclusions

This paper experimentally studied the feasibility of direct hot stamping of Zn-coating boron steel through atomization precooling method. Low medium flow condition of 50 L/h and high medium flow condition of 100 L/h were adopted with the same other test parameters. Mechanical properties and microstructure as well as LME were detected. The results show that under low medium flow condition, no qualified products can be deserved while with high medium flow condition, qualified products can be achieved.

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