



Development of new lubricants for hot stamping of Al-coated 22MnB5 steel



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ABSTRACT

The use of lubricants is effective for decreasing the forming load in hot stamping of Al-coated 22MnB5 steel. It is desired that new lubricants for hot stamping are developed. In this study, first, the coefficients of friction were measured using commercial lubricants for hot forging with the hot flat drawing simulator. The coefficient of friction of a commercial lubricant that consisted of a hydrophilic polymer and a mineral salt was the lowest. Second, lubricants with added different solid lubricants were newly developed and their coefficients of friction were measured. The coefficient of friction of the lubricant with added swellable mica was the lowest. Third, the formability of Al-coated 22MnB5 steel using the newly developed lubricant was examined with the hot deep drawing test machine and its formability was superior. A new high-performance lubricant for hot stamping was developed.

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1. Introduction

In hot stamping, Al-coated 22MnB5 steels are widely used as the sheet material (Karbasiyan and Tekkaya, 2010). When the coated steels were used, Yanagida and Azushima (2009) reported that the aluminum on the sheet surface severely adhered on the die surface and the coefficient of friction became higher than 0.5 in hot stamping under dry condition using a hot flat drawing test machine, which was newly developed in order to examine the coefficient of friction in hot stamping (Yanagida et al., 2007). Moreover, Hardell et al. (2008a) measured the coefficient of friction of Al-coated 22MnB5 steel under dry condition using a special hot-sheet-forming test rig at the University of Kassel/Metakus, and the values became around 0.4.

The coefficients of friction of Al-coated 22MnB5 steels at elevated temperature under dry condition reported in these papers are high, and it is desired that the coefficient of friction is reduced in order to decrease the stamping load. Hardell et al. (2008b) examined the effect of die surface coating on the coefficient of friction of Al-coated 22MnB5 steel at elevated temperature under dry condition using a fundamental tribosimulator, and they reported that the die surface coating was not expected to reduce the coefficient

of friction. Uda and Azushima (2014) also examined the effect of die surface coating on the coefficient of friction of Al-coated 22MnB5 steel under dry condition using a hot flat drawing test machine. They reported that the coefficients of friction were high, similar to those of the noncoated dies. From these results, it is estimated that others methods must be developed in order to decrease the coefficient of friction and the aluminum layer adhered on the die surface. As a way to decrease the coefficient of friction and the aluminum layer in hot stamping, it is conceivable to use lubricants. In regard to the report on the use of lubricant, Bariani et al. (2008) examined the formability in the hot stamping of HSS using graphite foil as lubricant at the interface between specimen and punch and Kusumi et al. (2012) evaluated the effect of lubricant for hot forging on the draw-bend formability in hot press. On the other hand, Azushima et al. (2012) measured the coefficient of friction of Al-coated 22MnB5 steel at elevated temperature under lubricated condition using a commercial lubricant for hot forging with the hot drawing test machine, and the values decreased from 0.5 under dry condition to about 0.3 under lubricated condition at 720 °C. They reported that the use of lubricants in hot stamping process was highly effective.

In this study, first, the coefficients of friction of Al-coated 22MnB5 steel were measured using 5 types of commercial lubricant for hot forging using a hot flat drawing tribosimulator. Second, from the results, the coefficient of friction were measured using 5 types of lubricant with added different solid lubricants which were newly developed. Third, the formability of Al-coated 22MnB5 steel

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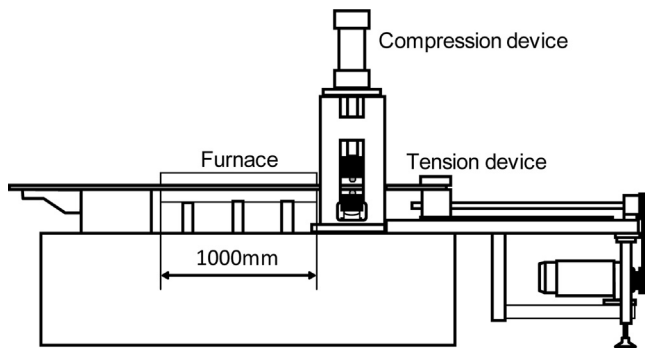


Fig. 1. Schematic representation of hot flat drawing test machine.

was examined using the newly developed lubricant using the hot deep drawing test machine.

2. Development of lubricants for hot stamping

2.1. Experimental procedure

2.1.1. Hot flat drawing test machine

Fig. 1 shows a schematic representation of the hot flat drawing test machine used to measure the coefficient of friction at elevated temperatures. This test machine consists of a compression device using a hydraulic actuator, a furnace, and a drawing device controlled with a ball screw using a 2.2 kW vector control AC motor. The maximum compression load is 200 kN and the maximum tension load is 20 kN. The maximum drawing speed is 30 mm/s. An infrared image furnace is placed in front of the compression device. The maximum furnace temperature is 1100 °C.

The method for measuring the coefficient of friction is as follows. The strip is first set on the table and then the strip edge is clamped to the chuck part of the tension device. The strip is heated to a given temperature using the infrared image furnace. Second, the strip is moved to the entrance of the die by the tension device, and then the heated strip is compressed at a given compression load by the upper die and is simultaneously moved at a constant drawing speed. Under these conditions, the compression load P and the tension load T are measured. The coefficient of friction can be calculated from P and T using the following equation:

$$\mu = \frac{T}{2P} \quad (1)$$

The repeatability of the coefficient of friction measured by the hot flat drawing test machine was examined in former paper (Yanagida et al., 2007,2009). Then, the mean value is defined by integrating the following equation:

$$\mu_m = \frac{1}{L_s - L_0} \int_{L_0}^{L_s} \mu dL \quad (2)$$

where $L_0 = 20$ mm and $L_s = 40$ mm.

2.1.2. Material and die

Al-coated boron steel (0.22% C, 1.2% Mn, 0.002% B) is used as a test material. The dimensions of the specimen are 2 mm thickness, 20 mm width, and 2000 mm length. The coating layer of steel is a layer of aluminum containing 10% Si (Suehiro et al., 2003). The thickness of the coating layer of the Al-coated boron steel is about 35 μ m and the surface roughness is R_a 0.6 μ m. The die material is SKD61 (X40CrMoV5-1) and the heat treatment allows a hardness of 45HRC in the hot flat drawing test. The chemical compositions of die material are listed in Table 1. The dimensions of the die are 60 mm length, 30 mm width, and 12 mm height. The flat length of

Table 1

Chemical composition in (wt%) of die material.

Material	C	Si	Mn	Ni	Cr	Mo	W	V	Co
	0.37	1.00	0.5	–	5.00	1.25	–	1.00	–

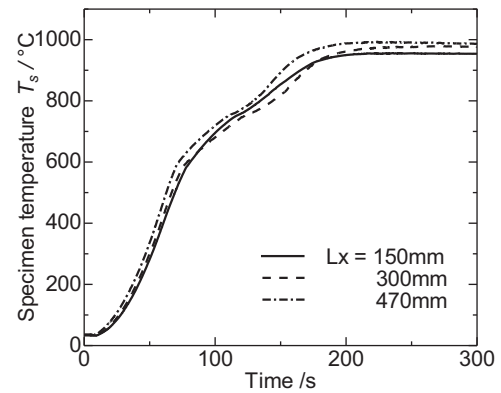


Fig. 2. Temperature profiles of specimen.

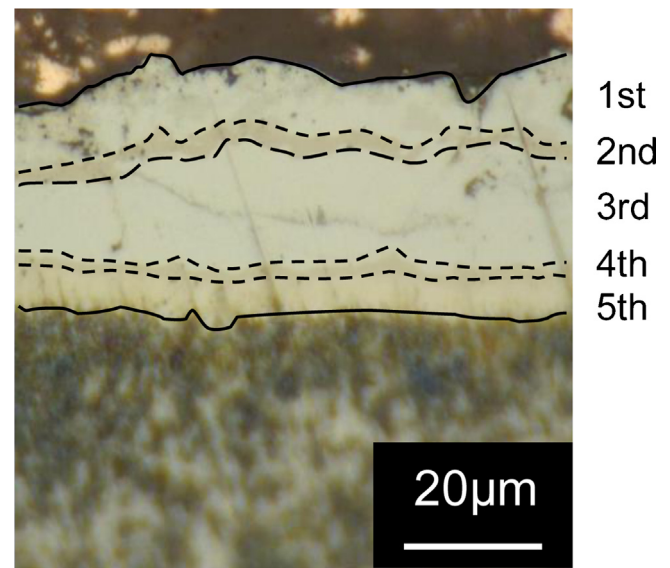


Fig. 3. Cross-sectional image of specimen after heating.

the die is 20 mm and the corner radius is 5 mm. The die surface is without surface treatment such as hard coating.

2.1.3. Heating conditions of drawing test

The temperature profiles of the specimen obtained in a previous study (Yanagida and Azushima, 2009) at three points, i.e., 150, 300, and 470 mm from the exit of the furnace during heating, are plotted in Fig. 2. The specimens are heated in a furnace and after heating for 240 s, the temperature of the specimen surface exceeded 950 °C. Consequently, it is considered that the 22MnB5 steel was austenized. After heating, the surface roughness of the Al-coated high-strength steel is R_a 2.81 μ m. Then, as shown in Fig. 3, a five-layered structure is observed in the coated aluminum layer, and it can be understood that the film does not melt during heating (Suehiro et al., 2003).

2.1.4. Experimental conditions of hot flat drawing test

The hot flat drawing tests are carried out over a sliding distance of 60 mm at a constant compression load of 3.5 kN and a constant drawing speed of 10 mm/s using 5 types of commercial lubricant

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