Investigation of High Speed Friction Test for Aluminum Alloys

K Ooki[1] and S Takahashi[2]

[1] Graduate student, Nihon University, Narashino, Japan
[2] Professor, Nihon University, Narashino, Japan

E-mail:takahashi.susumu32@nihon.u.ac.jp

Abstract. To shorten the development stage of automobiles, FEM simulation has been applied. It was important to increase the accuracy of the sheet metal simulation results. The friction coefficient between the sheet metal and dies the greatly affected the simulation results. Therefore, apparatus for measuring the friction coefficient with a specific press forming speed (300 mm/s) has been developed. The materials of the sheet metals and dies were aluminum alloys and die steel respectively. It was found that the friction was affected by the difference between the velocity of the sheet metal and that of the dies.

1. Introduction
Automobile makers are reducing emissions from automobiles as a countermeasure against global warming. Therefore, the weight of the vehicle bodies has to be reduced. Although aluminum alloys and high tensile steel sheets are applied for this purpose, their formability is low. To shorten the development stage of sheet metal forming dies numerical simulation is applied. Accurate simulation results can be obtained by using accurate stress-strain curves, yield functions, friction coefficients, and so on. There are many investigation regarding biaxial tension and compression behavior for sheet metal [1-6]. One of the key parameters for obtaining accurate sheet metal forming simulation is friction coefficient. Friction is measured at the speed performed by conventional mechanical testing machine. The sliding speed of the blank on the die during sheet metal forming is about 300mm/s. The testing speed is not fast enough to investigate friction behavior at sheet metal forming speed. Therefore it is difficult to observe friction phenomena at high speed.
In this study, the friction behavior between the sheet metal and dies with respect to the sheet metal forming speed was investigated. A high speed friction test apparatus was developed. To perform the high speed friction test, a servo press was used. Aluminum alloy sheets was used as the blank material and tool material was used for the die. The wide range of testing speed was performed for investigating the influence of the testing speed on the friction.

High speed friction test method

1.1. Experimental apparatus
To perform friction tests at high speed, new apparatus was developed. A servo press (SDE-2025, 2000 kN, Amada Co., Ltd.) was used to move the dies for the friction test, because the slide of the servo press can be used to control the speed. Figure1 shows the movement of the experimental apparatus of the high speed friction test before and after the experiment. To increase the speed of the slide of the servo press, it needs to be moved some distance. Therefore, the minimum distance between the flange of the chuck

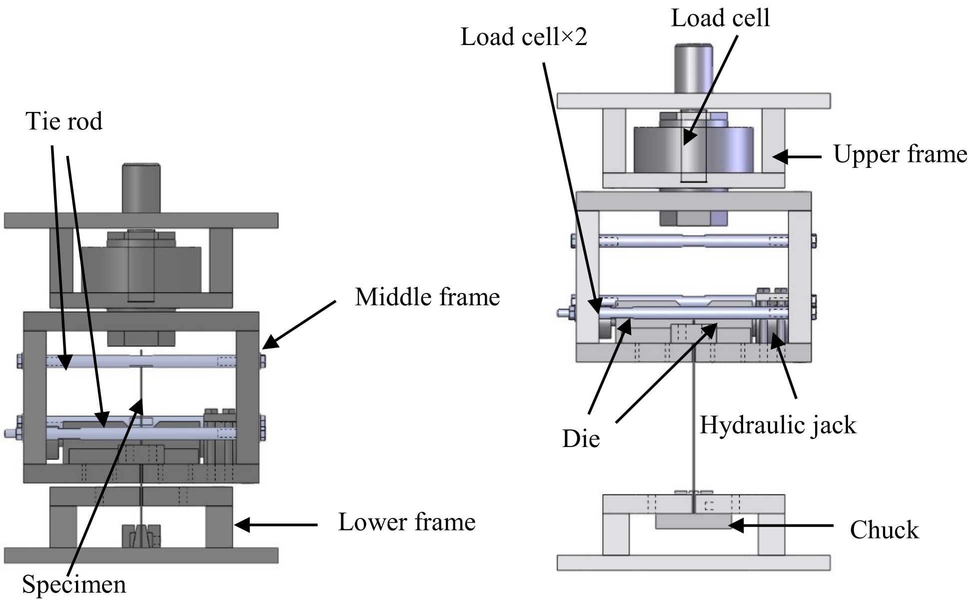
and the upper part of the lower flange to achieve test speed (500 mm/s), was 50 mm. Both sides of the specimen were in contact with the dies. To apply compression pressure to the specimen with the dies, a hydraulic hand pump and a jack (TWA - 0.3 Osaka Jack. Co., Ltd. and EF10S1.1 Osaka Jack . Co., Ltd.) were used. Two load cells (LUK-A 20kN Kyowa Electronic Instruments Co., Ltd.) were located on the other side of the hydraulic jack for measuring the compression pressure. The drawing (friction) force was measured by the load cell (LUK-A 100 kN Kyowa Electronic Instruments Co., Ltd.), which is located in the upper frame attached to the press slide. The material of the dies is SKD11. The hardness and surface roughness after heat treatment are Ra=0.30 - 0.55 μm and HRC59, respectively. The contact area between the dies and the specimen is 234 mm^2.

1.2. Specimen

The material of the specimen was A5023-O with a dull finish. The dimensions are 300 × 30 ×1 mm. The specimens were machined in the rolling and transverse directions.

2.3 Experimental conditions

Wash oil (R303P, Sugimura Chemical Industrial Co., Ltd) was used as lubricant. The oil was applied to both sides of the specimen prior to testing. The coating amount was 0.1 - 0.15 g. The compression load applied to the dies was changed in the range 1.1 - 1.9 kN. The pressure was 5 -10 MPa. The drawing speed of the specimen was changed in the range 5 - 500 mm/s.



a)Before experiment b) After experiment

Figure 1. Movement of experimental apparatus of high speed friction test.

2. Test results and discussion

3.1 Drawing force

The drawing force during the experiment is shown in figure 2. The test conditions were 5 MPa (compression pressure), and 500 mm/s (drawing speed). It was found that there was electrical noise when measuring the force, so it was difficult to evaluate the friction coefficient from the result.

To reduce the noise, the location of ground for the measuring devices was investigated. The most appropriate location of ground was the bolster of the press. Figure 3 shows the results after reducing noise. The range of noise before and after changing the location of ground is ±250 N and ±15 N, respectively. The reduction rate of the noise is about 95%. In the subsequent test, the appropriate location of ground was used.

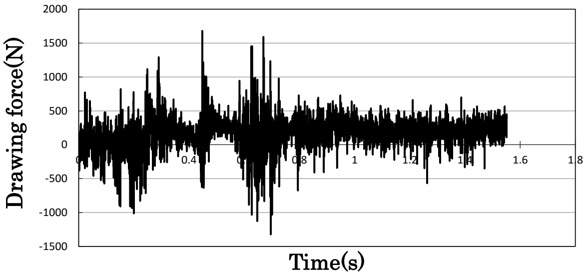


Figure 2. Drawing force during experiment with noise.

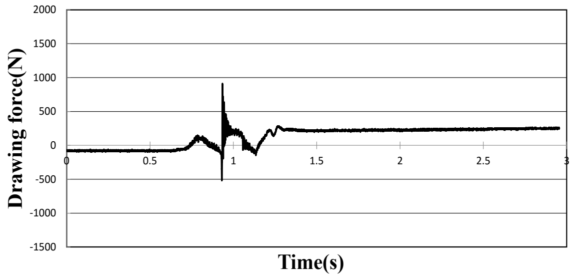


Figure 3. Drawing force during experiment without noise.

3.2 Friction coefficient

The relationship between the friction coefficient and time in the case of a pressure of 5 MPa and drawing speed of 500 mm/s during the evaluation stage in figure 3 is shown in figure 4. To reduce the oscillation of the results, a moving average method was applied. The friction coefficient calculated using the average of the values in figure 4 is 0.09.

Figure 5 indicates the relationship between the friction coefficient and pressure. Figure 5 shows the relationship between friction coefficient and pressure under the influence of drawing speed. It indicates that a faster drawing speed leads to a lower friction coefficient. It can be said that if the viscosity of the lubricant is high enough, the faster drawing speed can reduce the movement of lubricant between specimen and dies towards the outside of the specimen. That helps to decrease the friction coefficient. Figure 5 b) shows the relationship between friction coefficient and pressure under the influence of machining direction of specimen. It indicates that the friction coefficient in the transverse direction is lower than that in the rolling direction, and the direction of scratch in the rolling direction coincided with the drawing direction. In this case, lubricant could easily flow out of the specimen. This makes causes a larger friction coefficient than that of the case in the transverse direction.

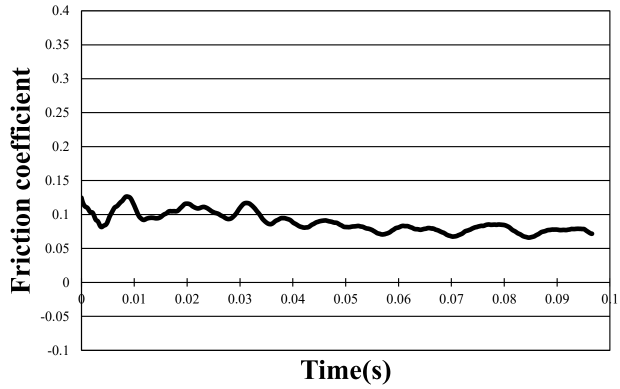
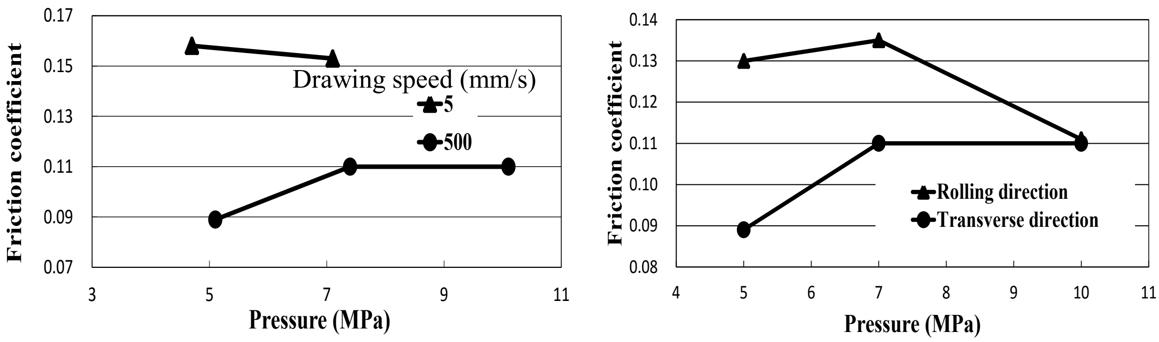


Figure 4. Friction coefficient during experiment (Pressure 5MPa Drawing speed 500mm/s).



a) Changing drawing speed (Rolling direction) b) Changing machining direction (Drawing speed 500mm/s)

Figure 5. Relationship between friction coefficient and pressure.

3. Conclusions

1) To reduce the electrical noise of the measured results, the location of ground of the measurement device is important.

2) A faster drawing speed can result in a lower friction coefficient.

3) The friction coefficient of the specimen in the rolling direction is greater than that of the specimen in the transverse direction. It can be said that a more accurate sheet metal forming simulation can be obtained by taking into account the changing friction and moving direction of the material.

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