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Hot Stamping Die Steel "DHA™-HS1"

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Preface：

In recent years, demands for ultra-high strength automotive parts made by hot stamping methods are increasing due to lightweight and collision safety requirements. Hot stamping methods are known as a production method of parts with higher tensile strength compared with current cold stamped parts. The process is to heat a steel sheet above the austenitizing temperature, then the heated steel sheet is quenched and formed by die pressing.

One of the challenges of hot stamping methods is a low production efficiency. The reason is because the process needs a holding time at bottom dead center for heat transfer from heated steel sheets to dies. Therefore, in order to reduce the holding time by improving the heat transfer efficiency, dies with high thermal conductivity are required.

Moreover, hot stamping die damages have become an issue. Wear and adhesion of plating are known as failure mode. The wear is caused by the complex factor such as deformation resistances during forming and oxide contamination generated during heating. Therefore, dies with high hardness and high wear resistance are required. On the other hand, adhesion of plating takes place when alloyed layers, which tend to generate when plating to prevent steel sheets from oxidation is heated, adhere and stick to die surfaces, resulting in unplanned die maintenances. This phenomenon brings about low productivity or high defective rate.

Additionally, tailored tempering method[2] has been suggested for making highly-functional parts. This is a method to create low strength area partially on the ultra-high tensile strength parts by heating dies partially by electrical heater to prevent that part from hardening. In this case, since heated dies are exposed to high temperatures for a long time, wears progress by softening issue. Therefore, the high softening resistance is also required for those dies.

In this paper, the properties and applications of hot stamping die steel "DHA-HS1" is explained. DHA-HS1 is designed for high thermal conductivity, high hardness and high softening resistance to correspond to hot stamping die requirements.

Features of DHA-HS1：

Figure 1 shows the positioning of DHA-HS1 in comparison to hot and cold work die steel grades. DHA-HS1 is alloy-designed based on our study that the effect of each chemical component to thermal conductivity. It is a new concept steel grade that has both high thermal conductivity and high hardness[3].

Thermal conductivity of DHA-HS1 is shown in Figure 2. DHA-HS1 has higher thermal conductivity than

JIS SKD61 (AISI H13 and 1.2344 eq.) and DH31-EX (AISI 1.2367 mod.) in the temperature range between room temperature and 700 ℃. It contributes to increase of product efficiency of hot stamping and decrease of die damage, wear and adhesion of plating, because of its capability of suppression of the rise in die temperature.

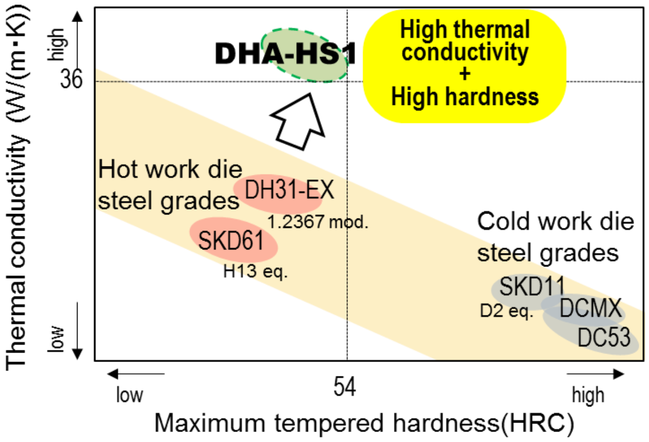

Figure 1. Positioning diagram.

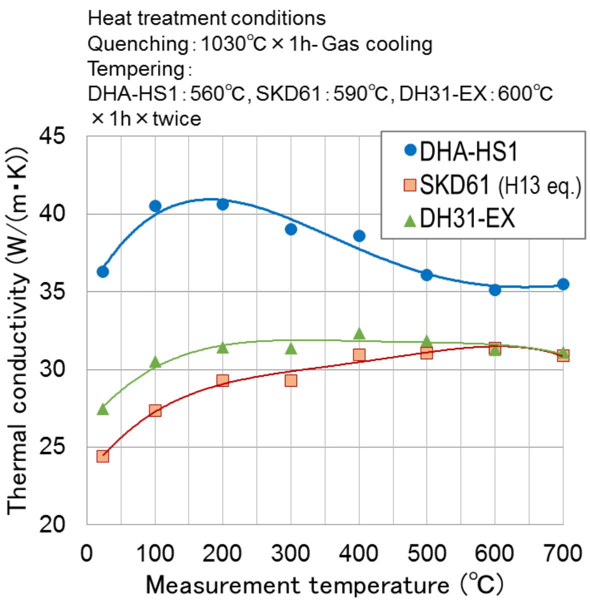

Figure 2. Thermal conductivity.

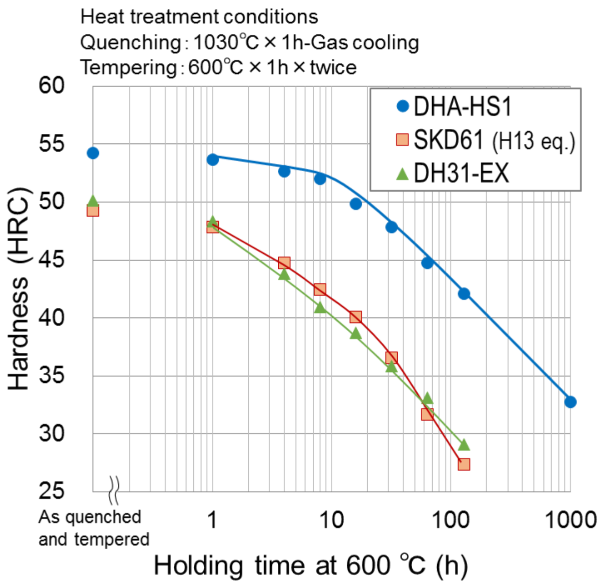

Figure 3. Softening resistance.

Figure 3 shows the softening resistance of DHA-HS1. Hardness was tested at room temperature after 600 ℃ holding at the furnace. The initial hardness of specimens were the 600 ℃ tempered hardness, DHA-HS1 = 54 HRC, SKD61 = 49 HRC, DH31-EX = 50 HRC. The DHA-HS1 specimen was kept over 40 HRC after 200 hours of holding, but, SKD61 was softened to under 40 HRC after 20 hours of holding. Therefore, the time of DHA-HS1 for softening to 40 HRC was ten times longer than that of SKD61. DHA-HS1 will be contributed to prevent the die damage with softening problem because die inserts of tailored tempering parts and high stress parts were sometimes heated at high temperature in hot stamping methods.

Case study of DHA-HS1：

1. Cycle time reduction

(1) Evaluation of die and product surface temperature by hot stamping machine.

Die temperature was evaluated by actual hot stamping equipment with 2 mm thickness aluminized steel sheet plates[4]. The test dies with DHA-HS1 and SKD61 insert blocks were installed side by side as shown in Figure 4, then the both two steel grades were evaluated at the same time. Figure 5 shows the die temperature measured by the thermocouple installed at 5 mm depth from the die surface. The die temperatures of DHA-HS1 during hot stamping were about 30 ℃ lower than SKD61 ones.

And, Figure 6 shows the product surface temperatures immediately after opening the dies. The temperatures of contacted part with the DHA-HS1 insert were 25 ℃ lower than SKD61 ones.

Considering these test results, applying the high thermal conductivity steel grade DHA-HS1 is surely contributed to decrease of the temperatures of dies and products.

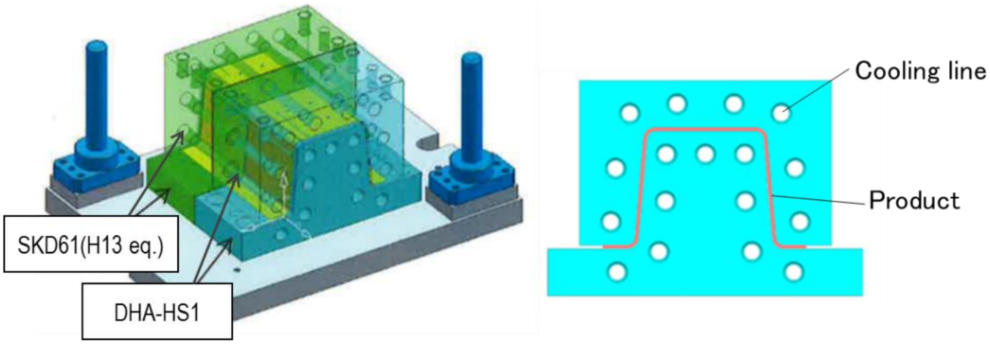

Figure 4. Test die design of the actual hot stamping equipment.

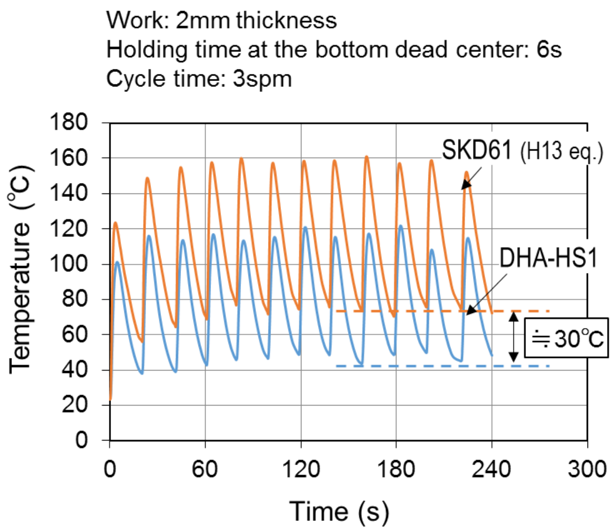

Figure 5. Die temperature during hot stamping.

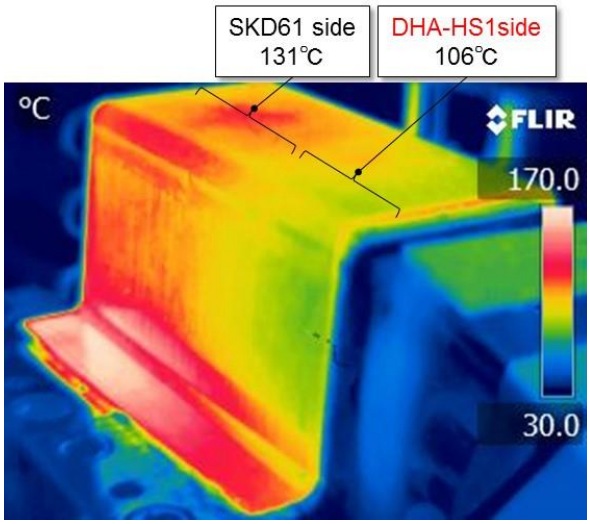

Figure 6. The product surface temperatures immediately after opening the dies.

(2) Trial for reduced the holding time at bottom dead center

In this trial, product surface temperatures when the bottom dead center holding time is changed from 1 to 10 sec were evaluated to clarify the effect of DHA-HS1 to cycle times. It was tested by the actual hot stamping equipment installed to simulate the die performance[5]. The test product was hat-shaped bended products simulated the center pillar part. For this test, DHA-HS1 and SKD61 were used separately to whole die blocks, then the each steel grade was tested one by one.

Figure 7 shows the relationship between maximum temperature of 20th products surface immediately after opening the die and the holding time. The maximum temperature of product surface was saturated in 20 shots. The temperature of DHA-HS1 die was maximum 60 ℃ lower than SKD61 die, and the result of 6 seconds holding time condition was the same as the SKD61 result of 8 seconds holding time condition. From this result, applying DHA-HS1 has an effect on the cycle time reduction because of shortening the holding time at bottom dead center.

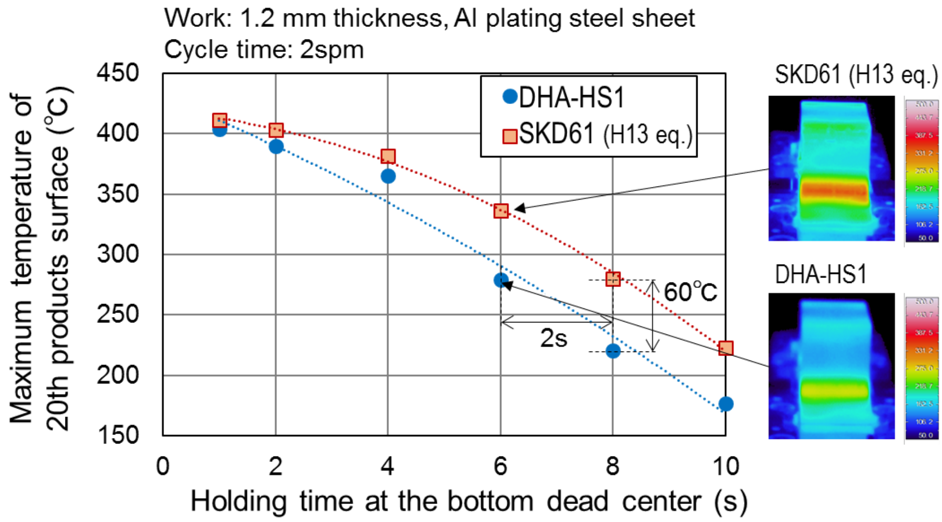

Figure 7. The relationship between maximum temperature of 20th products surface immediately after opening the die and the holding time.

2. Improvement of wear resistance

The wear amount was evaluated on the upper punch of 8 seconds holding time condition that was used for the trial with changed the holding time at bottom dead center in (2) above. DHA-HS1 (54 HRC), SKD61 (49 HRC), and DH31-EX (53 HRC) were selected as the die materials. Surface profiles of wear part on the upper punches were measured by a non-contact 3D dimension measuring machine, and the total volume of dent area from original shape line was defined as the wear amount. It was measured at every 1,000 shots[5].

Figure 8 shows the changes in the wear amount of upper punches during continuous stamping. The amount of wear increased as the number of shots increased, but the DHA-HS1 punch was about 66% smaller than SKD61. The reason why the DHA-HS1 punch wears less is that it has higher hardness than SKD61, so it has higher strength at high temperature[6]. And the high thermal conductivity affects to prevent the die temperature heating during stamping, so DHA-HS1 helped to keep its strength.

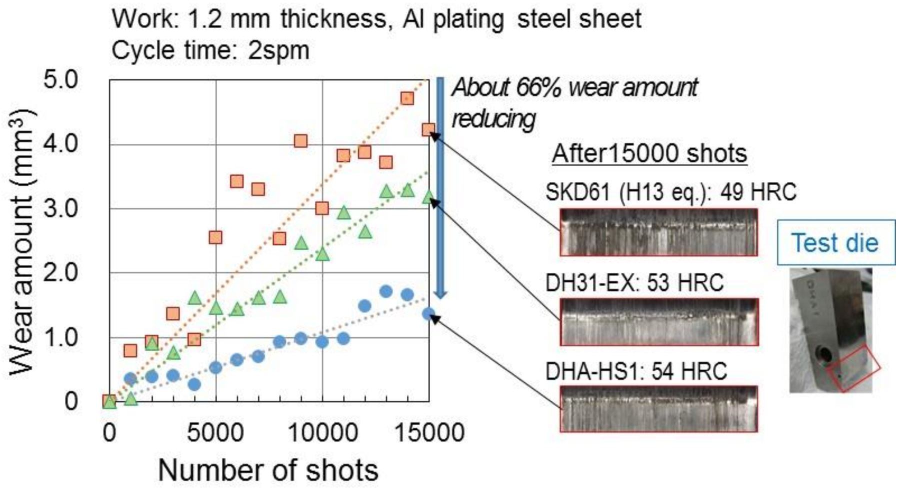

Figure 8. The changes in wear amount of upper punches during continuous stamping.

3. Prevention of the adhesion of plating

Adhesion amount of plating was evaluated when the die surface temperatures are changed by the amount of water on the upper punches. DHA-HS1 (54 HRC) and SKD61 (49 HRC) were selected as the die materials, and the adhesion amount of plating on the die surface was evaluated after 2,000 shots. The adhesion amount of plating on the R part of the upper punches was evaluated by the non-contact 3D dimension measuring machine, and the total volume of the convex area from original shape line was defined as the adhesion amount[7]. The die temperatures were measured at 2 mm depth from the die surfaces of the upper punches, and it was defined as the maximum temperature when the dies were heated.

Legends	Amount of cooling water (L/min)		
	0	0.5	2.5
SKD61	□	△	○
DHA-HS1	■	▲	●

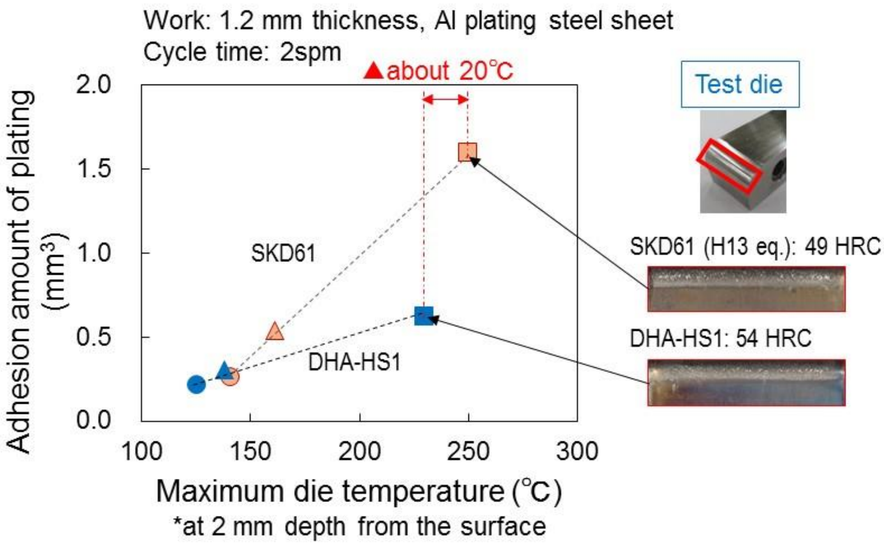

Figure 9. The relationship between the maximum die temperature and the adhesion amount of plating on the upper punch after 2000 shots.

Figure 9 shows the relationship between the maximum die temperature and the adhesion amount of plating. The adhesion amount of plating increased as the maximum die temperature increased. When the condition of amount of cooling water was the same, the maximum die temperature of DHA-HS1 was about 20 ℃ lower than SKD61, and the DHA-HS1 adhesion amount of plating was smaller than SKD61.

According the result of this trial, the relationship between the maximum die temperature and adhesion amount of plating was found out. And, applying DHA-HS1 has an effect on the prevention of plating adhesion. On the other hand, to lower the die temperature, it is also effective to cool strongly by design change such as the position and the number of cooling lines.

Additionally, Figure 9 shows that the increase rate in the adhesion amount with increasing the maximum die temperature of DHA-HS1 was smaller than SKD61, it indicates DHA-HS1 has a better adhesion resistance based on its chemical property than SKD61. It is necessary to do factor analysis of DHA-HS1 on the adhesion resistance in the future.

Conclusion：

This paper has introduced the case study of high thermal conductivity and high hardness grade, DHA-HS1 developed for hot-stamping die material, and has shown its features such as improvement of internal cooling efficiency, wear resistance, and prevention of plating adhesion. Daido will continue to research the hot stamping die damaged mechanism and the effect of die material properties to improve die service life by using the actual hot-stamping equipment. And, we will develop new die steel grade to improve the die service life and productive efficiency as DHA-HS1 has done.

(Reference)

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