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Improvements in productivity and formability by water and die quenching in hot stamping of ultra-high strength steel parts

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ABSTRACT

To improve the productivity in hot stamping of ultra-high strength steel parts, the parts are quenched not only with dies but also in water during holding at the bottom dead centre. Since the cooling speed for water quenching is higher than that for die quenching, the hold time for hardening is reduced. In hot stamping, water is kept in a lower die to increase the cooling rate during die quenching. In addition, local thinning around the punch corner was prevented by water and die quenching, and thus the drawablity increases.

1. Introduction

For the reduction in weight and improvement of crash safety for automobiles, hot stamping of quenchable steel sheets is increasingly employed for production of ultra-high strength steel parts. By heating the steel sheets, the forming load is remarkably reduced, the springback is prevented and the formability is improved [1,2]. In addition, the stamped parts are hardened by quenching with dies, and thus the ultra-high strength steel parts having a tensile strength of approximately 1.5 GPa are obtained under a low forming load [3].

In hot stamping, dies are held at the bottom dead centre of a press for about 10 s to harden stamped parts, and thus the productivity of hot stamping is considerably low, 2 and 3 shots per minute (see Fig. 1). The martensite transformation does not occur for insufficient holding, i.e. no hardening. The cooling speed of die quenching is lower than that of water quenching due to low heat transfer. In addition, the stamped parts have a non-uniform distribution of thickness, and thus are locally in contact with the dies during holding as shown in Fig. 2. Local thinning tends to occur due to a temperature distribution induced by local contact with dies during stamping [4]. Since the cooling speed of die quenching is influenced by the die pressure [5], large holding force is required to increase the cooling speed during die quenching. It is desirable in forming industry to reduce the holding time at the bottom dead centre because of productivity improvement.

In the present study, the productivity and formability in hot stamping of ultra-high strength steel parts were improved by water and die quenching. In addition, blankholding was delayed to improve hardening of a flange portion in hot stamping with water and die quenching.

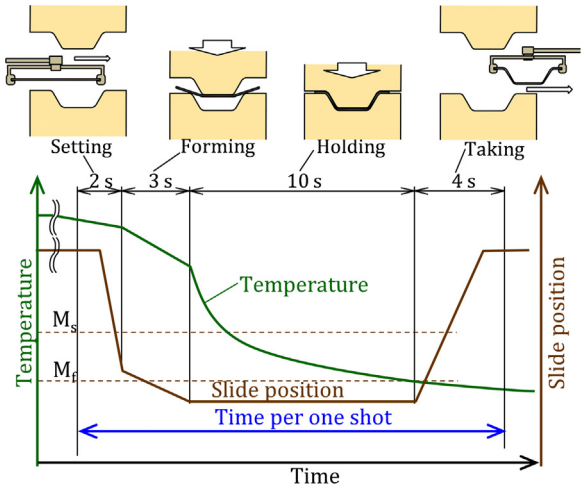

Fig. 1. Rough time for 1 shot in hot stamping and variation in temperature.

2. Shortening of holding time at bottom dead centre by water and die quenching

To improve the productivity in hot stamping of ultra-high strength steel parts, the holding time at the bottom dead centre was shortened by not only die quenching but also water quenching (see Fig. 3). Water is kept in the lower die in order to be in contact

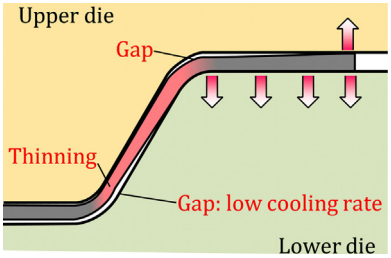

Fig. 2. Gaps between stamped part and die during holding at bottom dead centre for die quenching.

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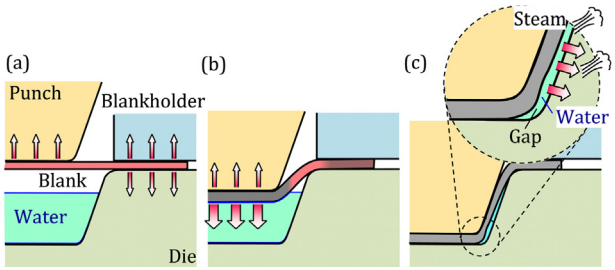

Fig. 3. Cooling of blank in hot stamping using water and die quenching. (a) Start, (b) stamping and (c) holding at bottom dead centre.

with the blank during stamping. The gaps between the blank and die are filled with the water during holding, and thus the portions without touching the dies are also rapidly cooled. The blank is cooled by high heat transfer and steam of the water.

3. Hot stamping of cup having non-hardened flange using tool detachment

3.1. Procedure of hot stamping using water and die quenching

The hot stamping process using water and die quenching is shown in Fig. 4. The heated circular blank was drawn into a cup having a flange with the punch and die. Because the flange of the drawn cup is often cut as products, the flange was not hardened by detaching the blankholder from the flange just after reaching at the bottom dead centre. This enables cold shearing of the non-hardened flange [6,7]. To improve the drawability, the resistance to drawing of the flange was reduced by inserting the spacers thicker than the blank between the die and blankholder [4]. The temperature drop of the flange during forming becomes small, because a gap is generated between the blank and the blankholder by the spacers. The water was kept in the lower die just before stamping, and the overflowed one was drained from the holes in the side wall of the die during stamping.

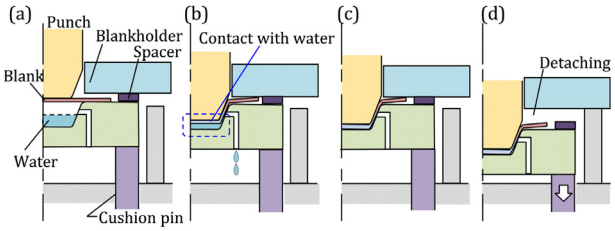

Fig. 4. Hot stamping process using water and die quenching with tool detachment. (a) Start, (b) drawing, (c) bottom dead centre and (d) holding.

The tools used for the hot stamping process using water and die quenching are shown in Fig. 5. A non-coated quenchable steel sheet 22MnB5 (C: 0.21, Si: 0.25, Mn: 1.2, B: 0.001 mass%) was employed for the stamping experiment. The blank having 1.6 mm in thickness and 170 mm in diameter was heated at 910 °C in 240 s in an electrical furnace, and the temperature just before stamping was about 870 °C. The blank was formed into a taper cup having

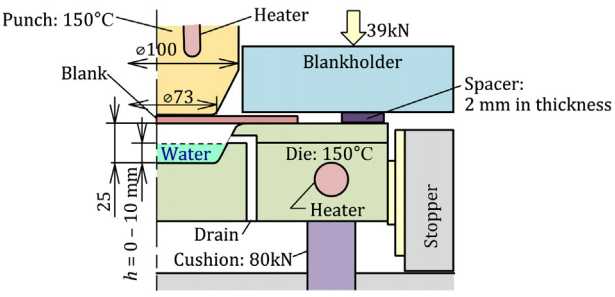

Fig. 5. Tools used for hot stamping using water and die quenching.

25 mm in height. Since the temperature of tools raises for repeated stamping, the punch and die were heated at about 150 °C by the heaters. A 1500 kN mechanical servo press was used, and no lubricant was applied to the blank and tools. The average speed of the press slide during stamping was 200 mm/s.

3.2. Results of hot stamping using water and die quenching

The cup by hot stamping using water and die quenching is shown in Fig. 6, where t is the holding time at the bottom dead centre. The degrees of oxidation on the surface of the cup with and without the water were almost similar. The wrinkles in the flange were comparatively small even with the spacers. The water hardly splashed even for the maximum ram speed of the servo press, and gave off steam for rapidly cooling the blank. Since the water was poured into the lower die just before stamping, almost no steam was generated up to stamping.

Fig. 6. Hot-stamped cup with water for $t = 3$ s.

The distributions of temperature in the stamped cup after 1.6 s from the end of holding at the bottom dead centre with and without the water are shown in Fig. 7. The temperature was measured with an infrared thermograph by moving the die upward. The temperature distribution with the water for $t = 3$ s is similar to the distribution without the water for $t = 5$ s. On the other hand, the temperature drop of the flange is prevented by the tool detachment from the flange just after reaching at the bottom dead centre.

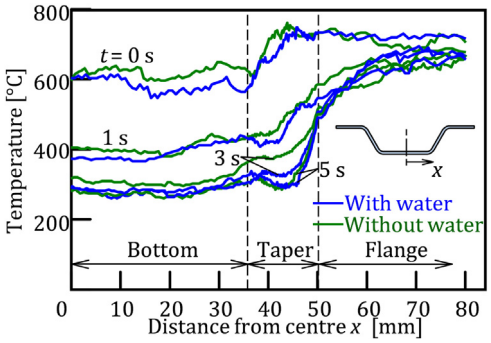

Fig. 7. Distributions of temperature in stamped cup after 1.6 s from end of holding at bottom dead centre with and without water.

The distributions of Vickers hardness in the stamped cup with and without the water are shown in Fig. 8, where that with the water without the tool detachment is added as a comparison. The hardness distribution with the water for $t = 3$ s is similar to the distribution

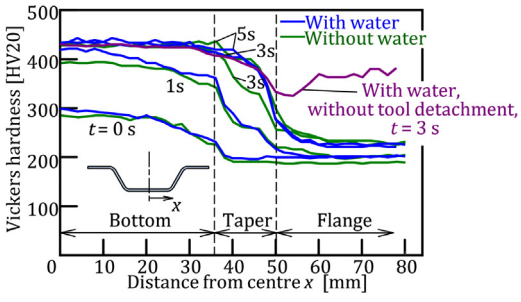

Fig. 8. Distributions of Vickers hardness in stamped cups with and without water and without tool detachment.