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Frictional properties of new developed cold work tool steel for high tensile strength steel forming die

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ABSTRACT

Currently developed tool steel SLD-MAGIC^{TM} was examined and compared with other SKD11 (corresponding to AISI D2) type tool steels from the view point of machinability, friction property and anti-galling property. The experimental results indicated the SLD-MAGIC shows very low kinetic friction coefficient and shows excellent machinability. The anti-galling property of the alloy was studied and compared with typical SKD11 and model alloys eliminating characteristic elements from the newly developed steel. The anti-galling property of the alloy was discussed with a role of elements included.

1. Introduction

The application of high tensile strength steel (hereafter abbreviated as HTSS) is being abruptly increased to produce the more rigid automobiles without increasing body weights in the worldwide automobile industry. This trend comes from that automobile manufacturers are required for higher global environment protection and improvement of collision safety while they suppress costs through improving fuel consumption of automobiles.

However, HTSS is much more difficult material to be formed due to higher strength compared to current used materials such as plain structural steels. The above requires automobile manufacturers to get new die materials to ensure durability in terms of wear resistance and seizure resistance for press forming operation of HTSS.

Moreover, requirement for mold steel materials is to improve machinability and easy heat treatment and good surface treatment. According to this requirement, the current materials such as conventional D2 (equivalent to JIS SKD11) and its improved type materials are impossible to attain good wear resistance and machinability simultaneously, however, the new alloy design method could accomplish the breakthrough based on 11 alloying elements addition. SLD-MAGIC^{TM} (hereafter abbreviated as S-MAGIC^{TM}), the name of the new alloy, can attain better wear resistance and machinability as well as showing excellent performance in wide various applications such as forming, pressing and other cold working applications. Recently, S-MAGIC has been accepted in various application fields of cold forming processes as so-called an eco-material and especially, has an excellent reputation in large size molds for automobile body industries.

The method of developing alloy design is reported elsewhere [13]. In this report, roles of alloying elements of newly developed S-MAGIC are investigated based on the self-lubrication without coating Fig. 1.

2. Materials and methods

Applied materials for experiments are cold work tool steels based on developed steel S-MAGIC. Table 1 shows the chemical composition of each cold work tool steels. Fig. 2 shows the calculated phase diagram of SKD11 and S-MAGIC. Phase diagram of other conventional steels is almost same to SKD11. Because even conventional steel is high C and high Cr one, the phase diagram is more complex than the simple Fe–C steel because of existence of two types of carbides which are M_7C_3 and $M_{23}C_6$.

Machinability has been estimated by two ways; face mill and end mill tests. Machinability with both milling were estimated by vertical type machine center (Matsuura BT40) shown in Fig. 2 with cutting speed of 120 and 100 m/min. ASTM E618 is well known as standard evaluation of machinability, however, these two types

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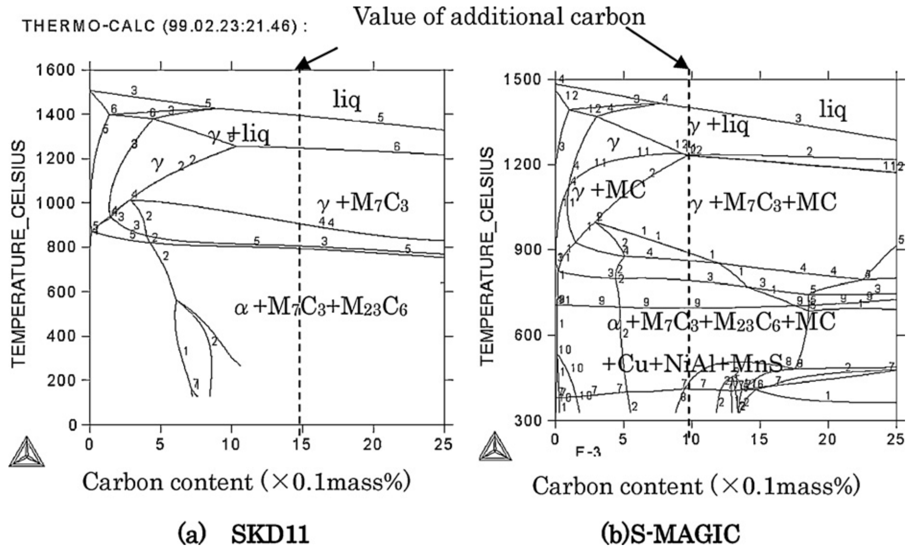

Fig. 1. Calculated phase diagram of cold die steels.

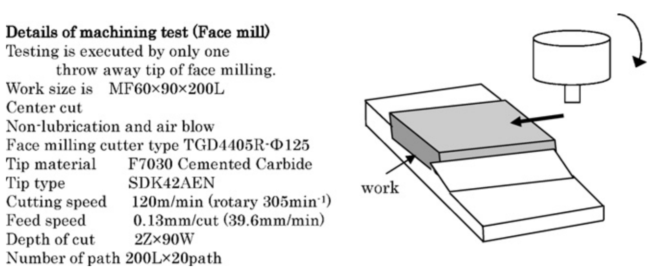

Fig. 2. Detail conditions of face milling test and schematic drawing of machining test.

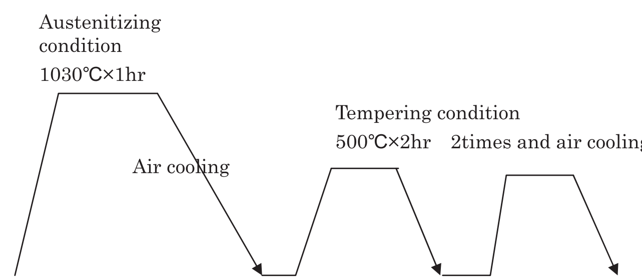

Fig. 4. Heat treatment diagram of die steels for galling test.

Table 1
Chemical composition of typical cold work tool steels in Japan.

S-MAGIC	Fe–1.0%C–8.3%Cr–Ni–Mo–W–Al–Cu–S
SKD11	Fe–1.5%C–12.0%Cr–Mo–V
8%Cr Steel	Fe–1.0%C–8.3%Cr–Mo–V
10%Cr Steel	Fe–1.2%C–10%Cr–Mo–V–S

of conditions are selected because machining methods of dies and molds are mainly intermittent cutting as compared to continuous cutting of ASTM E618. Details of face milling condition for evaluation of worn width of tip were summarized in Fig. 2. This condition is set up on sever side because cutting volume must be suppressed while same damage mode is kept. Fig. 3 shows the details of end milling condition for measurement of cutting temperature. This condition is set up as for easy side of temperature measurement. Temperature of the end mill was measured at opposite side of cutting edge by radiation thermometer. The friction tests, which were used for evaluating the anti-galling property, were performed with Crank Press (Komatsu 80 ton) after the heat treatment shown in Fig. 4. Fig. 5 shows the detail condition of so-called hat-shaped bending method [14] as the galling test. Stroke speed is 40spm, wrinkle depression force is 2.2 ton, stroke length is 60 mm without lubricant. In addition, works are adopted as 590 and 980 grade HTSS of thickness 1.6 mm whose surface state are $R_a = 0.04\ \mu m$ polished by 1000th grid sandpaper and without Zn plating. Surface texture is measured by surface roughness measurement equipment (Tokyo seimitsu, Surfcom). Determination of galling length after galling test is sum of length which sequential amplitude over 2.5 μm exists. Measurement, which is executed 1 path by a work, is near end point on which galling is tend to occur strongly, as mentioned below. The galling rate is defined as the ratio of galling length to length measured. Schematic drawing of ball-on-disk type test, which was also performed with friction testing machine (Orientic Corporation, EFM-III-1020), shown in Fig. 6. Details conditions of this experi-

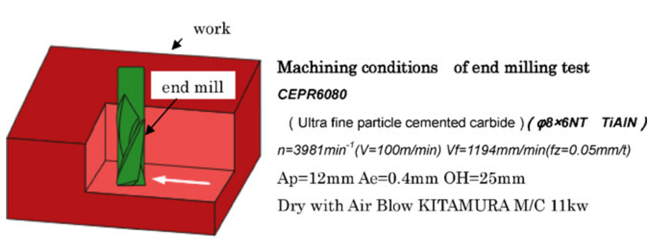

Fig. 3. Detail conditions of end milling test and schematic drawing of machining test.

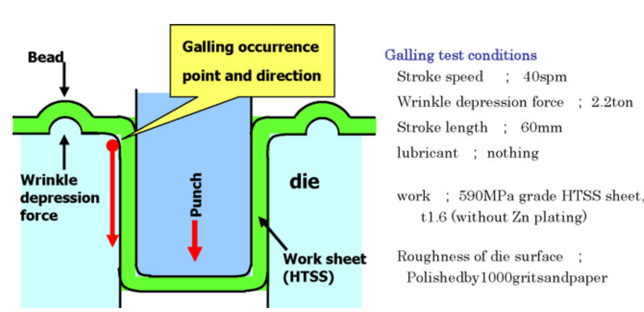

Fig. 5. Schematic drawing of hat bending test which evaluates anti-galling properties of die steel by HTSS forming.