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Gross crack mechanism analysis for die-casting die

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1. Preface

On the die-casting die for making automotive parts, gross cracks that propagate from heat checking cause low productive efficiency and more maintenance time. To prevent the heat checking, increasing hardness and decreasing thermal stress amplitude are effective. On the other hand, to prevent the gross cracking, improving toughness is recommended. Therefore, it is not easy to prevent both heat checking and gross cracking.

In this paper, the case study to improve die service life by applying high hardenability and toughness hot work die steel, "DHA™-WORLD" has been introduced. The effect of die steel properties such as hardness, thermal conductivity and fracture toughness to die failure was also explained.

2. Case study of die service life improvement

The trial dies were upper, right and left slide cores of cylinder block mold in NISSAN MOTOR. The steel grade of conventional die was JIS SKD61 (AISI H13 and DIN 1.2344 eq.) with 43 HRC hardness. In this trial, DHA-WORLD with 45 HRC hardness was applied to prevent heat checking. DHA-WORLD has higher thermal conductivity and hardenability than SKD61 by alloy design[2)], then it has high fracture toughness even under the high hardness condition. Also, DHA-WORLD is contributed to save the cost because it is single melted general use grade, not double melted special grade. The same nitriding was applied to both the trial dies, and the trial run was made with the same conventional die-casting conditions. The die failure state was evaluated by the die appearance observation and the number of welding repair positions compared with SKD61 dies.

The number of welding repair positions at the first maintenance on the both SKD61 and DHA-WORLD dies are shown in Figure 1. The total number of shots was almost the same at the first maintenance. The number of welding repair positions on all the DHA-WORLD dies were less than half of those of the SKD61 dies. All welds were for repairing the liner heat checking along the root part. These results indicate that the number of heat checking positions were decreased by applying DHA-WORLD compared to SKD61.

After that, in increasing the number of shots, the gross cracking occurred on the SKD61 dies. Figure 2 shows comparison of die appearance photographs at the gross crack positions. On the SKD61 die, the gross cracking initiated from the heat checking at the root part. On the other hand, the DHA-WORLD dies have some heat checking cracks, but there are no gross cracking. Therefore, applying DHA-WORLD had an effect of gross crack prevention.

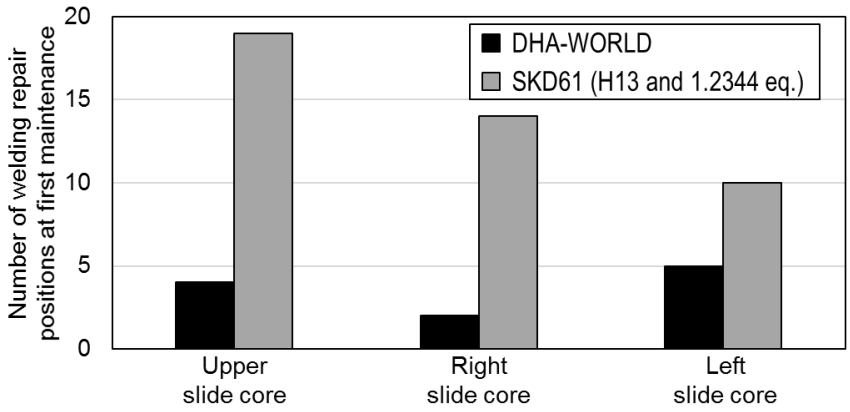

Figure 1 Number of welding repair positions at the first maintenance.

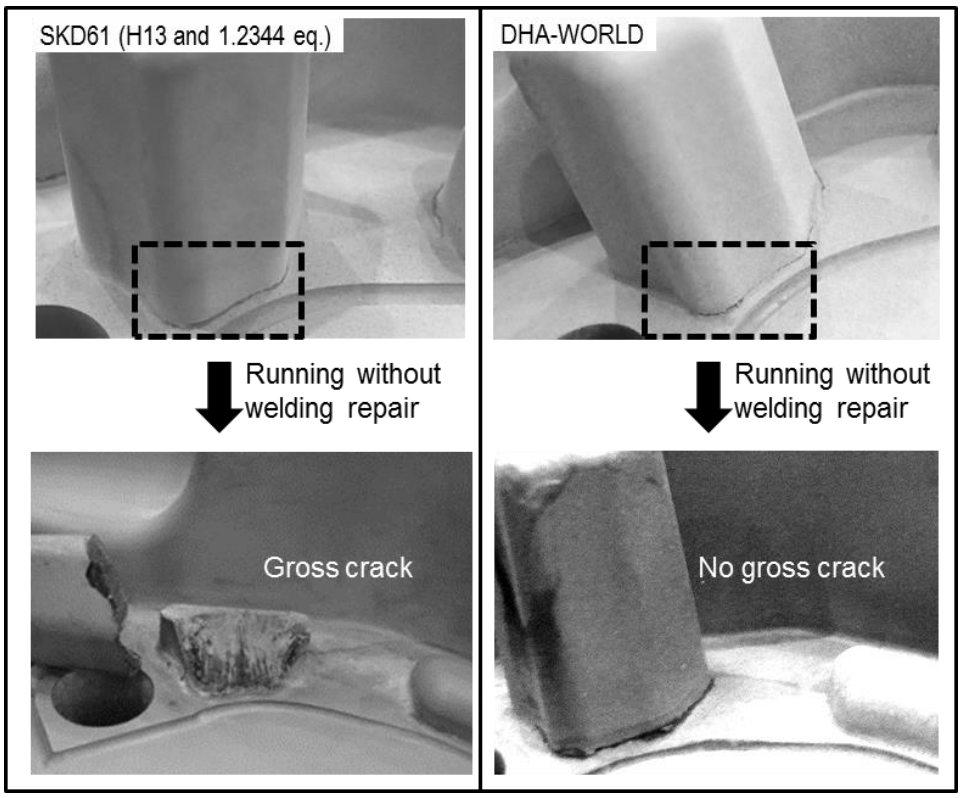

Figure 2 Comparison of the die appearance photographs at the gross crack positions.

3. Discussion on the die failure mechanism

First discussion is about the prevention of heat checking. Figure 3 shows comparison of temperature profiles on the upper slide cores at 2 minutes after die opening between DHA-WORLD and SKD61 die. DHA-WORLD die temperature was about 20 ℃ lower than that of SKD61 at the indicated circle area on the Figure 3. This indicates that applying high conductivity DHA-WORLD affected to prevent the die temperature from rising, then the thermal stress amplitude generated by die heating and cooling was decreased. From this mechanism, the number of heat checking cracks on the DHA-WORLD dies were decreased.

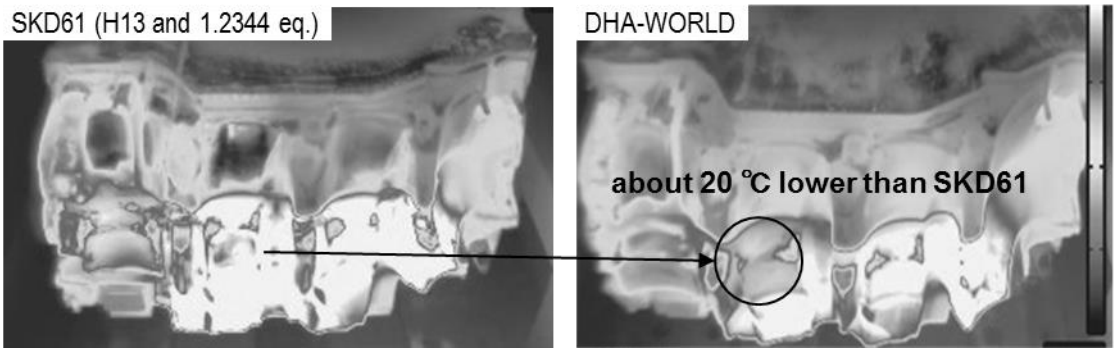

Figure 3 Comparison of the temperature profiles on the upper slide cores at 2 minutes after die opening.

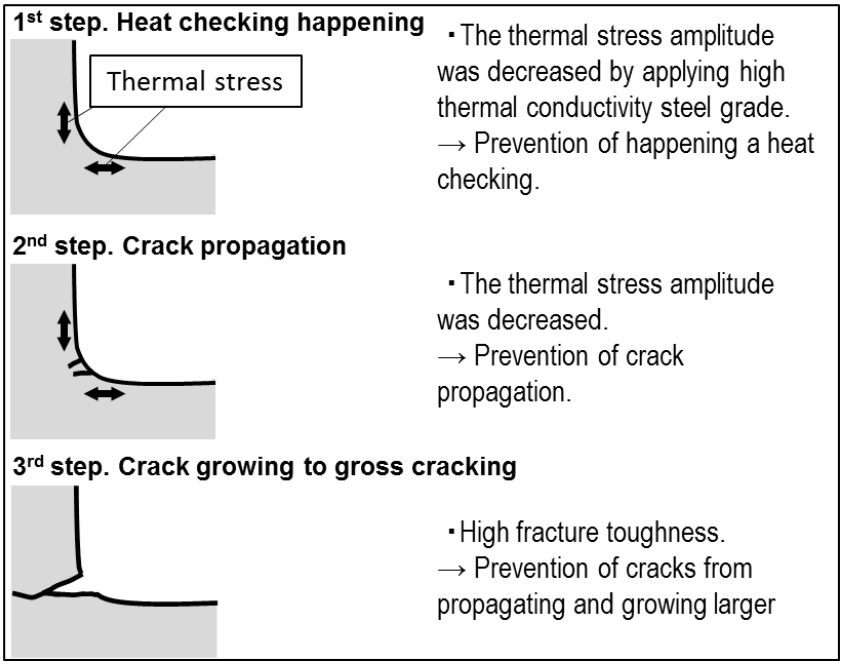

Figure 4 Schematic diagram of the gross crack mechanism.
(Comments: The advantages of DHA-WORLD compared with SKD61)

Next discussion is about the prevention of gross cracking. Based on the study by Hasuno[3)], the gross crack mechanism is divided into three steps as shown in Figure 4. At first, on the heat checking happening step, heat checking was prevented by applying DHA-WORLD as mentioned above (See 1st step on Figure 4). Then, on the 2nd step of heat checking crack propagation, it was prevented by decreasing of the thermal stress amplitude (See 2nd step on Figure 4). On the final 3rd step of crack growing to gross cracking, applying DHA-WORLD was contributed to prevent cracks from propagating and growing larger because the fracture toughness of DHA-WORLD with 45 HRC is higher than that of SKD61 with 43 HRC as shown in figure 5. From these discussion, DHA-WORLD worked better on all the 3 steps of the gross crack mechanism compared with SKD61. Therefore, DHA-WORLD could prevent the gross crack.

In this study, the effect of high hardness for heat checking prevention could not be discussed enough because it needs to isolate the nitriding effect. It needs to continue further considering in the future.

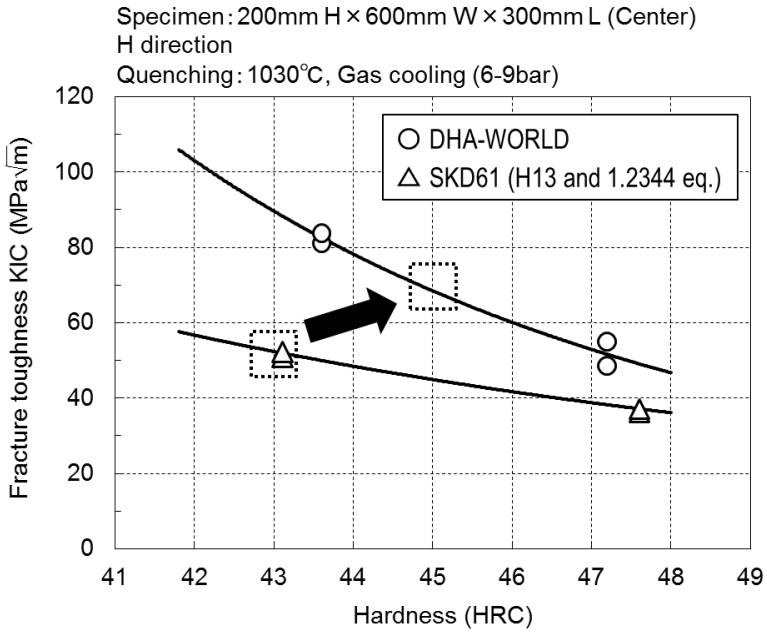

Figure 5 Fracture toughness

4. Conclusion

These results of evaluation on this actual die-casting die trial confirmed that applying DHA-WORLD has an effect to prevent the die failure such as heat checking and gross cracking, which are always hoped to improve at production lines. Moreover, a part of gross cracking mechanism was revealed from this trial. We will continue to clarify all of the mechanism through comparative studies.

*DHA is a trademark or registered trademark of Daido Steel Co., Ltd.

(Reference)

1) Kawano, M: SOKEIZAI, Vol.59, No.3 (2018), p11
2) Morikawa, H: DENKI-SEIKO (Electric Furnace Steel), vol. 81 (2010), No.1, p47
3) Hasuno, A: DENKI-SEIKO (Electric Furnace Steel), vol. 78 (2007), No.4, p323