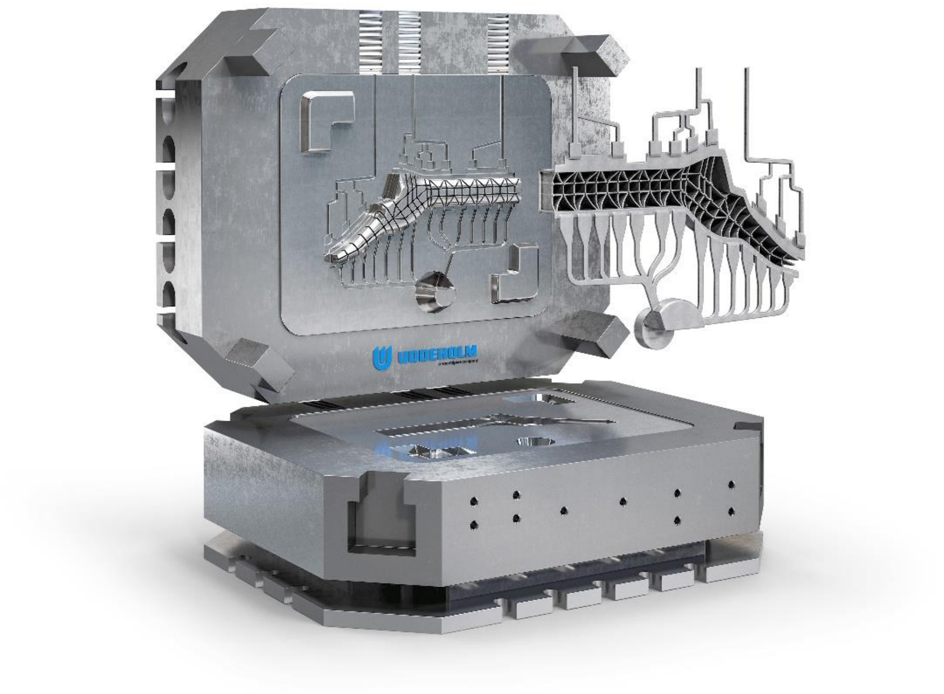

Key properties of die material needed for structural Aluminum-High Pressure Die Casting (HPDC)

In the automotive segment, demands for light weight components have increased in order to acquire low fuel consumption and less environmental impact. This has opened an opportunity for structural aluminium component manufacturing through high pressure die casting (HPDC). Lighter in weight and suitable mechanical properties has shown to be competitive in parts where structural steel normally is used. These parts are different from conventional HPDC parts as they are normally larger in size and have a complex design because several parts have been integrated. Conventional HPDC aluminium parts normally have low yield strength and for that reason the components are normally used where impact toughness and yield strength are not a critical demand. Figure. 1. Show type of car body component which is manufactured through structural Al-HPDC.

The die-life has a tendency to decrease for manufacturing of structural Al HPDC parts in comparison with the manufacturing of conventional Al HPDC parts. The reason for the decrease in die-life can vary but the biggest failure mechanism is thermal fatigue or heat checking. Requests have been received for die material solution that provides suitable die-life for dies with bigger dimensions to fulfil the demands for structural Al HPDC. Three criteria have been set to fulfil suitable die-life for structural Al HPDC. The die material needs to have a chemistry which provides the material with properties that result in a high thermal fatigue resistance. The material needs to have a high homogeneity in order to have suitable properties throughout the die. Recommendations of heat treatment parameters need to be investigated to ensure the optimum properties in the big dimensional dies are achieved.

Material

Based on chemistry comparison test of thermal fatigue resistance between two hot work grades, Uddeholm Orvar Supreme and Uddeholm Dievar that are both commonly used for HPDC have been made. The result has shown that Uddeholm Orvar Supreme exhibited deeper maximum cracks after all three cycle tests compared to Uddeholm Dievar (Figure. 2). The average crack depth was also deeper for Uddeholm Orvar Supreme than Uddeholm Dievar (Figure. 3).

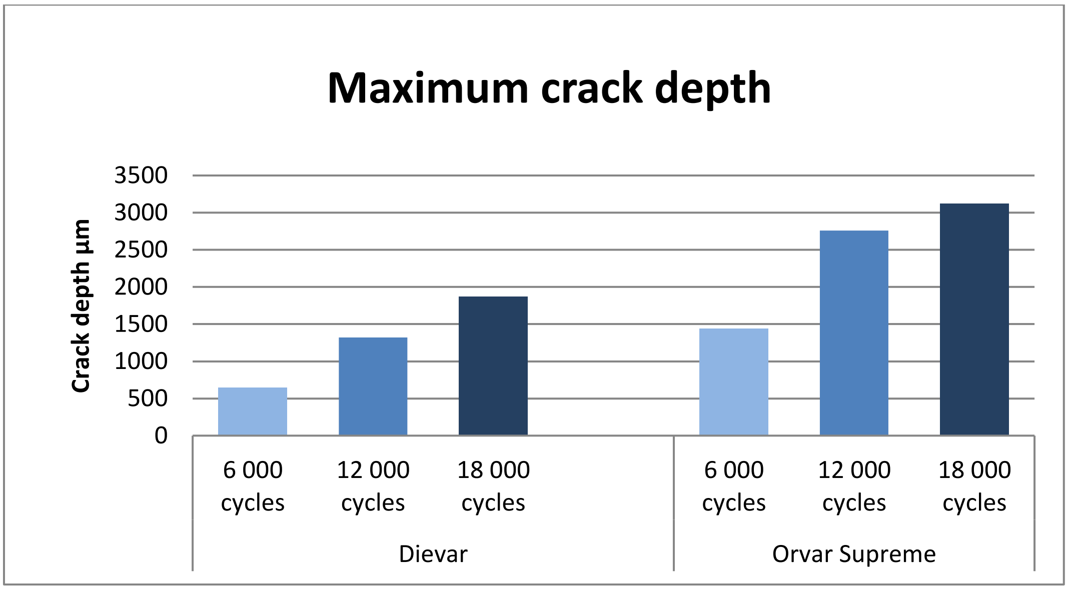

Figure. 2 **Shows the maximum crack depth**

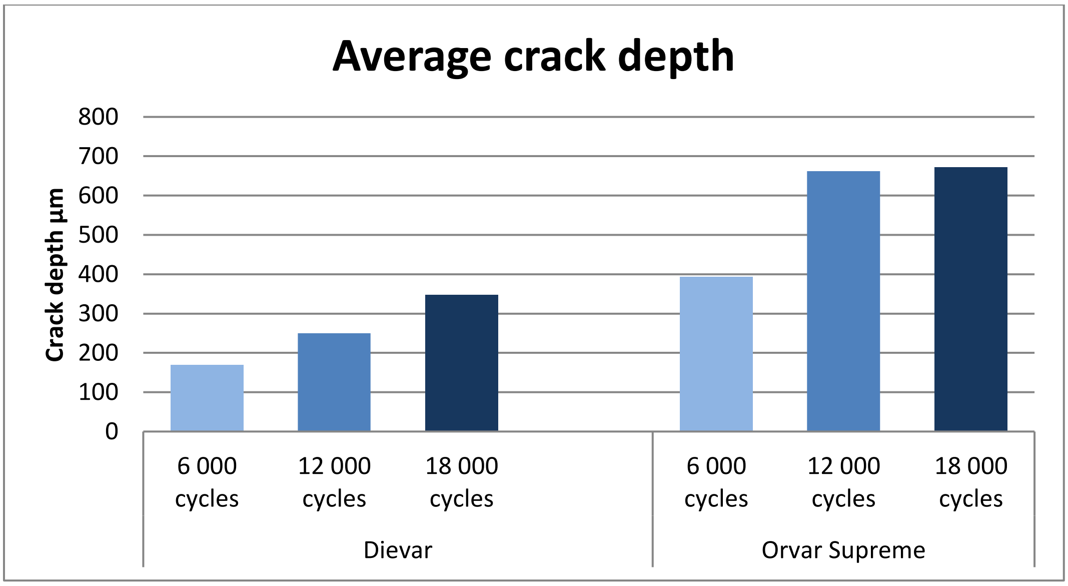

Figure. 3 **Shows the average crack depth**

Measurement of hardness from the surface into the material showed that Uddeholm Orvar Supreme had softened more and deeper into the material than Uddeholm Dievar. The hardness softening increased for both materials with an increasing number of cycle, however Uddeholm Orvar Supreme decreased more in hardness due to lower temper-back resistance.

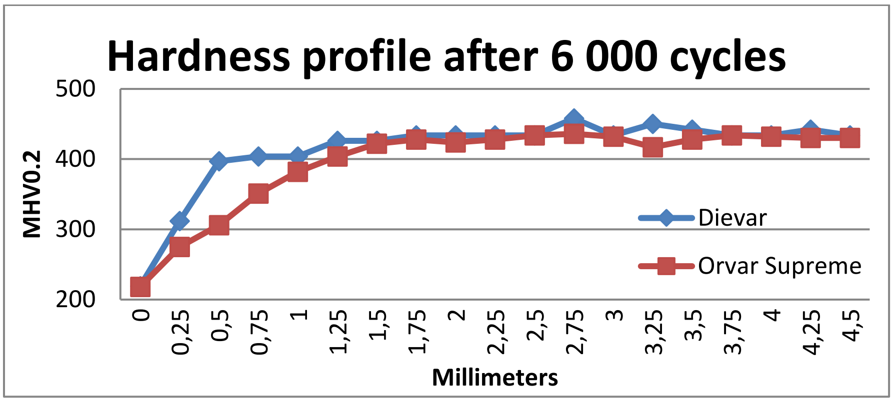

Figure. 4 Shows the decrease in hardness after 6 000 cycles

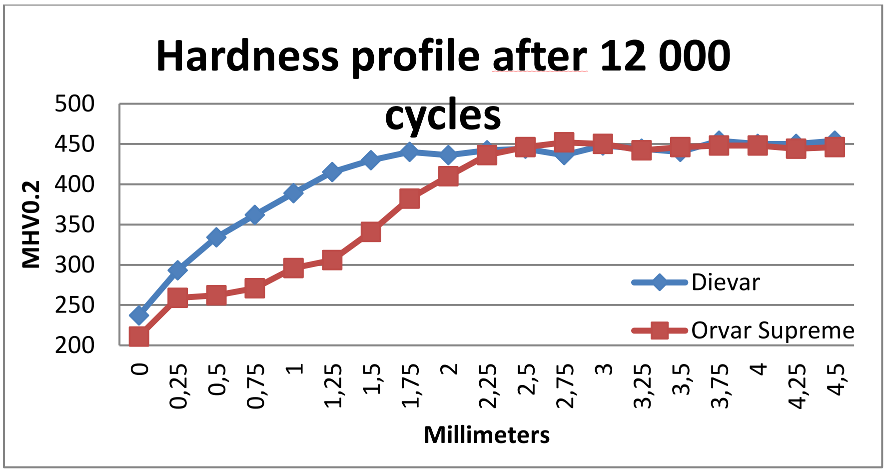

Figure. 5 Shows the decrease in hardness after 12 000 cycles

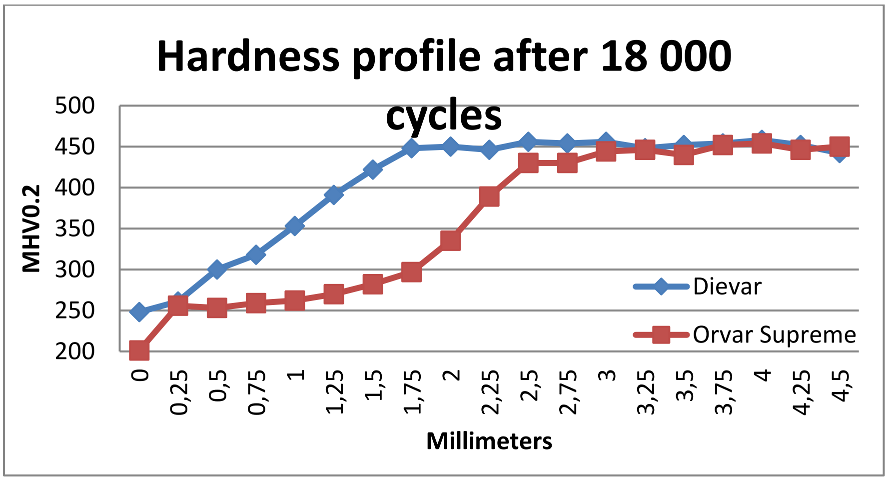

Figure. 6 Shows the decrease in hardness after 18 000 cycles

Method phase 1

Based on the thermal fatigue result Uddeholm Dievar has the best properties for thermal fatigue resistance. In order to receive the similar properties for these bigger dimension that result in suitable die-life for big casting products such as structural Al-HPDC, trials where performed on bigger dimensional blocks.

A block with dimension 61” X 21.65” (1550 mm X 550 mm) were manufactured through electro slag remelting to achieve through homogenous properties and forged after suitable reduction ratio. Samples were taken in the center and the surface of the block to investigate the received properties, (Figure. 7). An evaluation was performed based on mechanical properties where toughness and ductility were evaluated in the hardened condition.

Figure. 7 Shows where samples were taken

Method phase 2 Heat treatment

Experiments for the second experiment was to investigate the potential to use step quenching to investigate the hardenability through the block. Hardenability trials were performed with quench rate to get close to what happens to a real die at the surface and center during vacuum heat treatment.

Step-quenching

Quenching is performed to transform the material from austenite to martensite. Austenite is a phase the material receives when it is heated up to a certain temperature that allows carbon to be dissolved. The quench rate needs to be performed fast to receive a wanted martensitic structure and minimize un-wanted bainite formation which lowers the mechanical properties.

To reduce the amount of bainite in the core due to slower quenching than the surface, step quenching trials were performed. Quenching was performed with a rate of 28 °C/82.4 °F per minutes and stopped before martensite starts and the step-quenching temperature trial begins. Step quenching was performed with three different step temperatures: 350 °C/663 °F, 425 °C/797 °F and 500 °C/932 °F with a holding time of 30 minutes (Figure. 8). After the holding time, a quench rate of 30 °C/86 °F per minute was applied down to a temperature of 50 °C/122 °F. To investigate the influence of step quench, the microstructure was examined and toughness measurements were made.

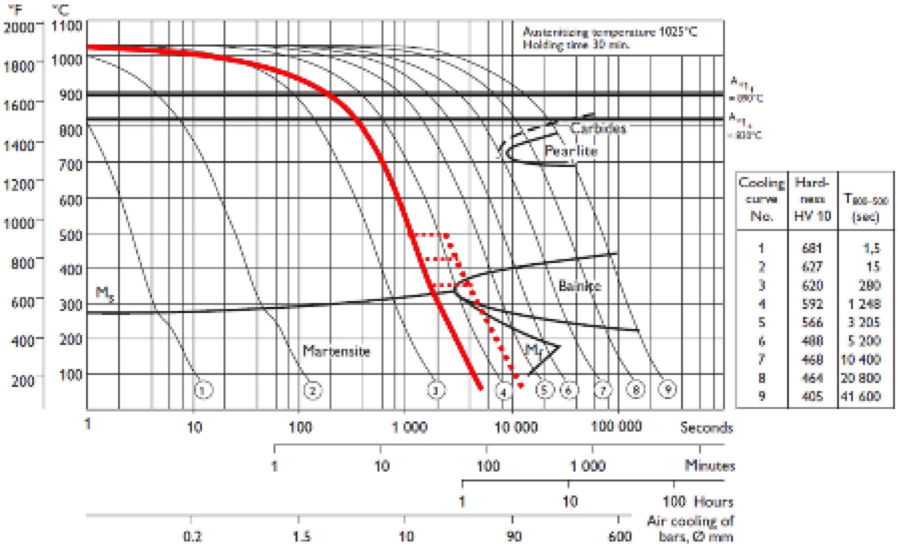

Figure. 8 CCT diagram for Uddeholm Dievar austenitized at 1010 °C for 30 minutes. The red curve corresponds to a quenching with constant cooling of T8-5 = 650s (28°C/min). The dashed lines are only indicative of the interrupted quenching temperatures tested in this investigation.

Result phase 1 material dimension

Values for experiment phase 1 are shown in Table. 1 based on samples taken from the surface and center of the material. The result shows that the toughness and ductility where suitable properties have been achieved, both in surface and center of the material.

Table. 1 Show values for experiment phase 1

Position	**Toughness ST** **Average J/ft-lbs**	**Ductility ST Average J/ft-lbs**
Surface	27/20	414/305
center	26/19	362/267

Result phase 2 Heat treatment

Step-quenching

The toughness values of the Charpy-V impact tests are reported together with the microstructure results in Table 2.

Materials which underwent interrupted quenching at 425°C showed the highest impact energy, about 26J/19 ft-lbs. The impact energy was lower, about 22J/16 ft-lbs, for the interrupted quenching at 500°C. The impact energy of samples with interrupted quenching at a temperature of 350 °C was very low, 12J, less than half of the optimal condition. The lowered impact toughness of the samples which underwent the lowest interrupted quenching temperature can be explained by a step quenching temperature and holding time that interfered with bainitic microstructure. In the CCT-diagram (Figure. 13) it can be seen that the temperature of 350 °C/663 °F has the highest potential to interfere with the bainitic region.

Table. 2 Shows toughness values of the microstructure in hardened condition and Charpy-V impact toughness

Step quenching **°C/°F**	**Microstructure**	**Toughness ST** **Average J/ft-lbs**
350/663	Presence of bainite	12/9
425/797	Martensitic	26/19
500/932	Presence of more pronounced cementite precipitation	22/16

The microstructure of samples which underwent interrupted quenching at 500 °C/932 °F, 425 °C/797 °F and 350 °C/663 °F are reported in Figure 9 and Figure 10 respectively.

The martensitic structure is observed in all materials, independently of the step-quenching temperature. The martensitic laths, however; are significantly coarser in the case of TS = 350 °C/663 °F compared to the other two-step temperatures. The samples which underwent interrupted quenching at 350 °C/663 °F, showed a substantially different microstructure. Bainitic formations are clearly visible along with martensite laths. This type of microstructure well correlates with the effects of lower impact energy observed. Therefore, the cause of the lower toughness is related to the bainite in the microstructure.

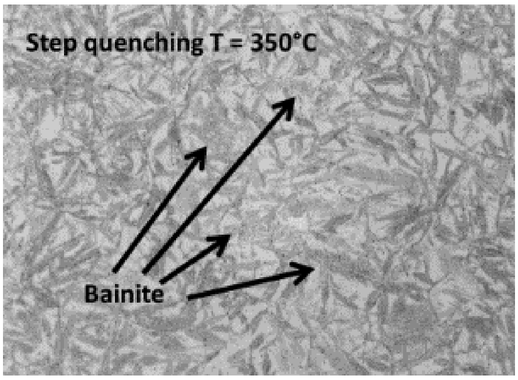

Figure. 9 Show interrupted quenching at 350 °C/663 °F, Left after quenching and right after tempering

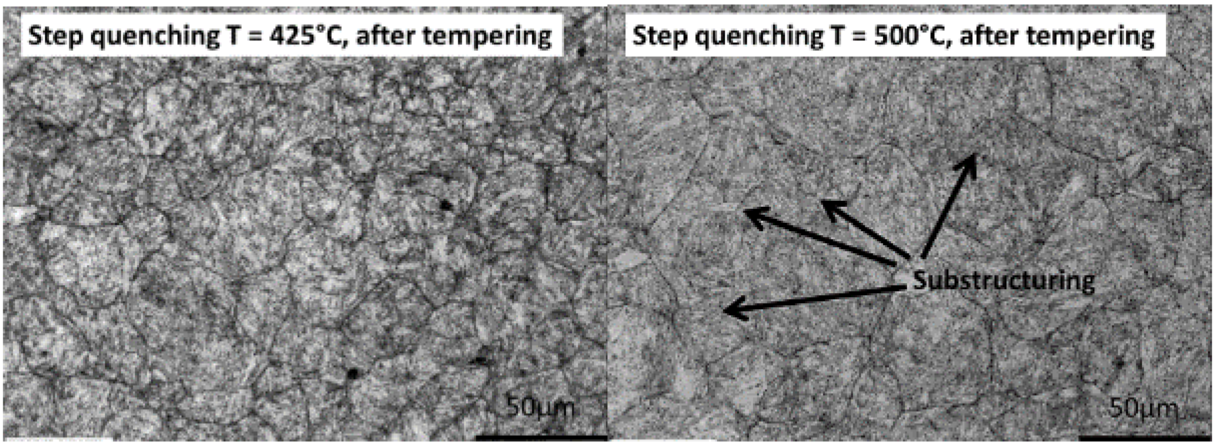

Figure. 10 Show interrupted quenching Left at 425 °C/797 °F after tempering, Right at 500 °C/932 °F after tempering

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