HPDC
New challenges require new ideas

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HPDC – New challenges require new ideas

It is human nature to stick to what we know; the saying is, ”if it is not broken why fix it” and this phrase is known all around the world. But is it true to say that most of us stick to this rule in reality? Many of us loved our first mobile phone back in the 90s. Was yours a Nokia 6110? Do you remember this popular innovation? It was amazing that you could not only make phone calls, but it also had a calculator, currency converter, 4 colour settings and you could even use it as a pager! Would I buy that phone today? No, you and I would buy the latest phone on the market because we want to benefit from all the new technologies and abilities of these new phones.

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How to select the correct die steel in the era of innovation within HPDC

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So why is the first tool steel selection for most die makers, foundries and OEM's in HPDC (High Pressure Die Casting) the tool steel grades AISI H13 or AISI H11 which both pre-date 1945? Can these steels really help solve the biggest problems faced by tool users today? What about the problems faced in production with new structural and e-mobility parts? Are the failures the same in structural and e-mobility parts as in the more traditional parts, such as powertrain and transmission?

To answer these questions we need to ask, what is the main die failure in powertrain & transmission die inserts? There are 4 main failures (Figure 1) in HPDC dies that you will see in every casting plant in the world, namely erosion, soldering, heat checking and gross cracking. At Euroguss 2018 many industry experts spoke about this subject and the universal winner of the most common die failure was heat checking. The lowest estimate was 60% and the highest almost 80% (average 70%), so not by a small margin, with the other failures making up the rest. What about the new growth areas in HPDC of structural and e-mobility cast parts? Do they have the same main failure? Yes they do and what is interesting is that Heat Checking comes quicker and harder on structural cast parts than with more traditional cast parts. Often a die made in H13 within powertrain has to last around 125,000 shots but in structural parts this can be as low as 75,000 shots.

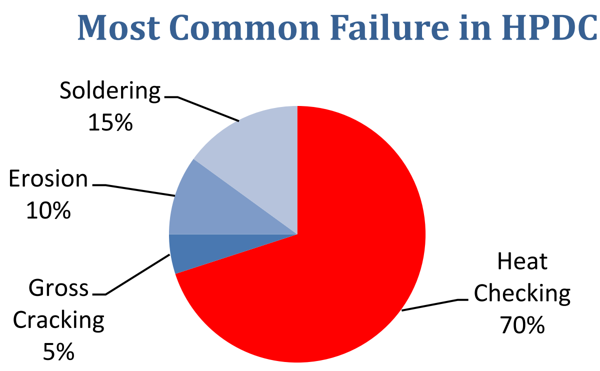

Figure 1 shows the main problem faced by casting companies is heat checking and this failure is even more rapid in structural parts

Why is this? If we look at this typical part below (Figure 2) we can see that it has a very large surface area and this can have many thin sections. As these castings will make up the structural element of the vehicle, it is important that the part fills well to avoid porosity and other internal defects. Hence gate speeds are often very high, to fill the die as fast as possible, and a typical structural part die has many more gates than the traditional powertrain die. This means that you get lots of heat generated in the gates and when you combine that with the cooling part of the casting cycle, along with spraying of the die, you then get high levels of thermal fatigue, or heat checking!

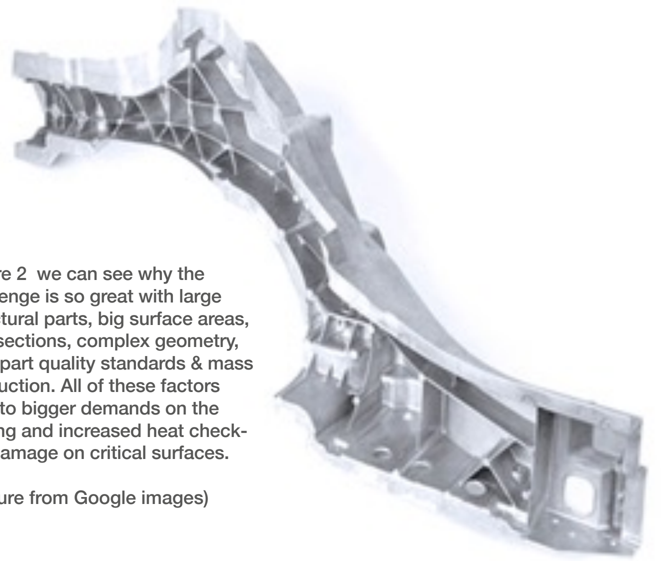

Figure 2 we can see why the challenge is so great with large structural parts, big surface areas, thin sections, complex geometry, high part quality standards & mass production. All of these factors lead to bigger demands on the tooling and increased heat checking damage on critical surfaces.

(Picture from Google images)

The problems faced by the foundries are many. As some parts are safety critical in a crash, no crack initiation points are allowed, either from heat checking damage or split lines. As these new parts are getting much larger, this means that the inserts for the tool are also getting bigger and in some cases there is less space for the holder block to do its job.

Some companies are even replacing the entire holder block and insert with a solid tool steel block. This means that the die steel you select not only needs to have the ability to solve the main production problem, but also needs to be available to be made in some very large sizes. If you have a very large die insert, then you also need good quality throughout the insert's cross section.

So if heat checking is the main challenge facing all cast parts within HPDC, what are the amazing properties of H13 & H11 which fight this problem? Is one of these steels better than the other in solving the issue and if not is there a tool steel solution that can help? We will now discuss this and answer these questions.

Heat Checking and the current tool steels

In applications such as aluminum high pressure die casting, there will be a temperature difference on the tool's work surface. This is due to the temperature of the molten metal and the cooling channels of the die that makes the process rapid and efficient. The difference in temperature will create stresses in the material and eventually fatigue cracks.

A bigger temperature difference, coupled with full production, will increase the thermal fatigue resulting in a shorter die life. The heat checking pattern that forms on the die's surface will also make marks on the castings that will lower the aesthetic and tolerance of the product.

Cracks can also appear very rapidly if the cooling channels in the die are inefficient and cooling is applied directly on the die's work surface. This will result in a big temperature difference and stresses will result in cracks instantly occurring.

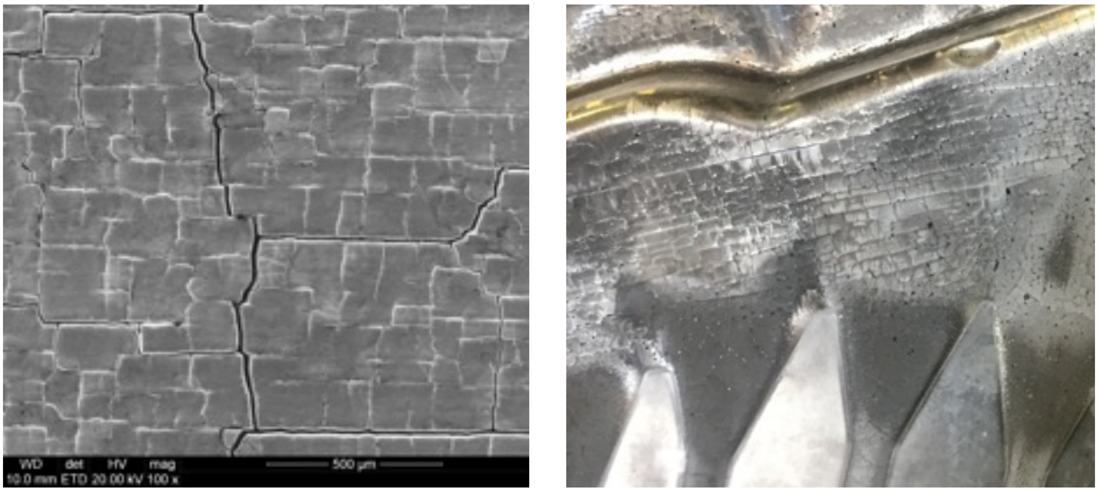

Figure 3 shows heat checking on the left at 100x magnification and on the right as seen by the eye in a real production die. This level of damage can be very similar when using H11 or H13 as these materials do not have the chemistry to make a significate improvement, unlike Uddeholm Dievar. Parts either need to be reworked or dies welded at this level of damage which will greatly increase production and maintenance costs.

Above (Figure 3) on the left we see the typical heat checking damage on a die surface under a microscope (100x) and from normal appearance to the eye on the right. To minimize the risk of this failure mechanism, heat checking, then some material properties are demanded. For example, heat conductivity is demanded as it will result in less temperature difference and therefore less stress builds up in the material. Additionally, a good temper-back resistance is desirable, to prevent the surface of the material from losing hardness due to heat exposure. A high ductility is also important in order to lower the risk of crack initiation. The material also needs a good toughness, both in room temperature and higher temperature, in order to reduce the rate of crack growth.

H13 has a higher alloy content then H11 and therefore H13 will have a better temper-resistance and hot strength due to the precipitation of fine alloy carbides. H11 has a lower content of Vanadium, which lowers the risk of primary carbide formations, thus promoting higher toughness and ductility. There are some small differences in properties between H11 and H13, but nothing that says that H13 should have a significantly better resistance against heat checking.

Uddeholm Dievar, a solution optimized for heat checking

Is Uddeholm Dievar the solution to heat-checking? Uddeholm customer feedback and case studies have reported that Dievar provides excellent results compared to H13 & H11 tool steels when heat checking is the main failure. Laboratory tests (Figure 4) have also shown that Uddeholm Dievar has a better heat-checking resistance than premium H13 grades, as we see in the chart below, where we see the depth of crack is much greater in the H13 material than Dievar at the same hardness levels.

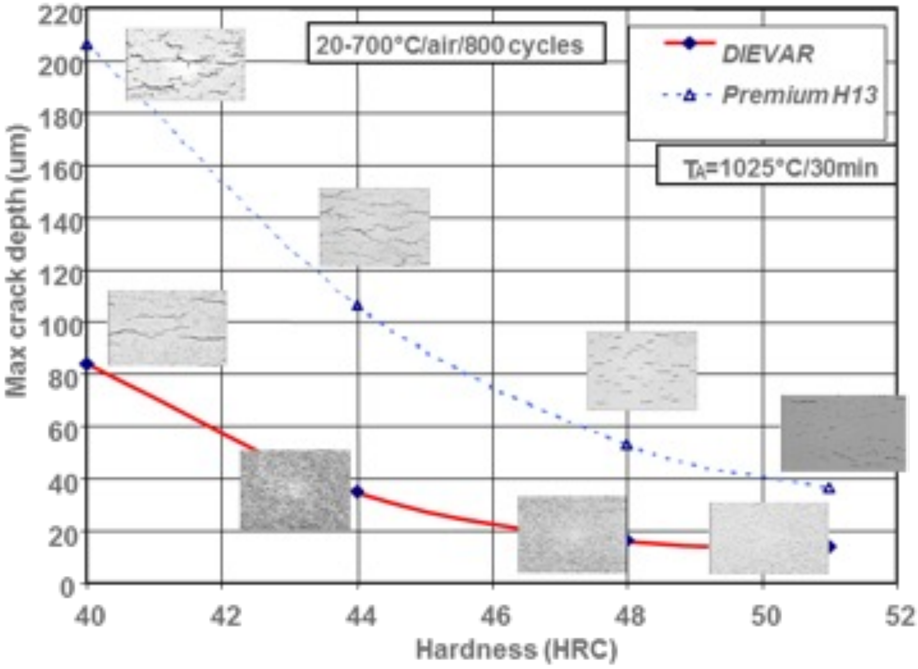

Figure 4 clearly illustrates that Uddeholm Dievar is far superior to premium H13 in solving the industry's biggest problem of heat checking also known as thermal fatigue. If we take the industry standard hardness of 46HRC then Uddeholm Dievar in this test has around 2.5x better resistance to heat checking over premium H13.

Important material properties for heat-checking resistance are hot-yield strength, temper resistance, creep strength, ductility and toughness. Uddeholm Dievar outperforms premium H13 grades in all these properties. Ductility and toughness are especially of interest because the biggest difference lies in these areas. A high degree of toughness is needed in order to protect the die from a catastrophic failure. Of even greater importance is high ductility, because it delays the initiation of cracks. High ductility and toughness also facilitate the possible use of a higher hardness level in the die. It is a known fact that higher hardness contributes to an improved heat-checking resistance.

The hot-yield strength, temper resistance, creep strength, thermal conductivity and the thermal expansion are properties which depend upon the chemical composition of the material, which can be seen in the composition table (Figure 5) below. The good results which Uddeholm Dievar shows in this area are mainly linked to the higher amount of molybdenum in combination with the vanadium content.

Material	C	Si	Mn	Cr	Mo	V
Uddeholm Dievar	0.35	0.20	0.50	5.00	2.30	0.60
H11	0.38	1.00	0.40	5.00	1.30	0.40
H13	0.39	1.00	0.40	5.20	1.40	0.90

Figure 5 shows the very different chemistry Dievar has to H11 & H13 to successfully fight heat checking.

The ductility and toughness are very much linked to the quality of the steel, that is, how the steel is produced. This in turn means that the whole production path is of great importance for the quality, from the melting shop to the electro slag refining, and further on to the forging/rolling and heat-treatment. Especially important is the ESR (Electro slag refining) process which results in an increased cleanliness, homogeneity and more or less equal properties in all directions of the block. The ESR process is when you take the conventional cast ingot and remelt this through a slag bath which then forms a new purified ingot with these superior properties.

ESR furnaces at Uddeholms AB are equipped with a protective gas atmosphere and a pressurized gas atmosphere which improves the cleanliness of the process and also further increases the steel properties. After remelting, the new ingot is heavily forged which efficiently breaks down the solidified structure into a finer grained and more ductile structure. Specialised heat-treatment processes give further improvements to the quality.

The cleanliness of the steel highly influences the ductility. Non-metallic inclusions, primary carbides and a network of coarse secondary carbides have a significantly negative impact on the ductility of the material. Poor toughness, on the other hand, is more decided by a microstructure containing coarse grain size, grain-boundary precipitations and the presence of bainite and pearlite.

When Uddeholm Dievar was developed, the aim was mainly an improvement of the ductility, toughness, hardenability and heat-checking resistance of dies. Today we see an increasing demand for Uddeholm Dievar, and in sizes which no one could have imagined when Dievar was originally developed. Uddeholms AB has manufactured and tested Dievar in these big dimension ranges, which is shown in the box below (Figure 6) with excellent Charpy-V and grain size results. The blocks have been tested according to the NADCA specification.

Uddeholm Dievar tested in big sizes as indicated and block shown is 18 tons in weight	Cross section mm	Charpy-V [J]	Grain Size (ASTM)
	1235 X 514	27	9
	1235 x 458	25	9
	1500 X 510	26	7
	1550 X 550	26	7
	1300 x 600	28	7
Figure 6, finished 18 ton block of Dievar with excellent results. Testing results across many sizes to the right.	1300 x 400	25	8

In these large dimension ranges, the ductility, toughness and hardenability become even more important, as the figures show in the results box above, for Dievar produced in large cross sections. The desired excellent performance at high temperature, which contributes to the heat-checking resistance, is an additional advantage promoting the use of Uddeholm Dievar.

Case Study - AL - HPDC - Uddeholm Dievar

	Uddeholm	Uddeholm	Uddeholm
Steel grade	H11 ESR	H13 ESR	Dievar
HRC	44	44	50
Main failure	Heat checking	Heat checking	Still running
Tool life	78,000	100,000	*125,000

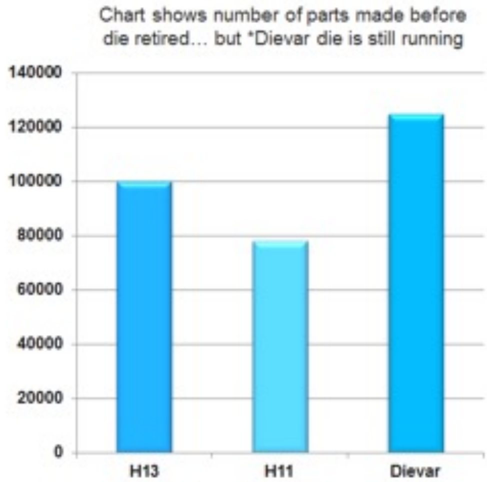

Figure 7 confirms the laboratory testing that H11 and H13 do not give a vastly different resistance to heat checking and Uddeholm Dievar is still running long after both H11 and H13 have both failed.

However, using the best material available is not a guarantee against early heat-checking problems. Careful concern must also be taken to other parameters such as design, die making, heat-treatment, surface treatment and casting parameters etc. However, if you face heat-checking problems with your tooling when using H11 or H13, then using Uddeholm Dievar is a great start to a successful die life improvement, as the customer case study (Figure 7) shows from 2017.

Manufacturing solutions for generations to come

SHAPING THE WORLD®

We are shaping the world together with the global manufacturing industry. Uddeholm manufactures steel that shapes products used in our every day life. We do it sustainably, fair to people and the environment. Enabling us to continue shaping the world – today and for generations to come.

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