Dievar – Pushing performance to new limits

It is human nature to stick to what we know and be cautious; as the saying goes: "if it's not broken don't fix it?". However, if we never pushed the boundaries of what we could achieve we would never make progress. In this process of constant improvement and development which is how we are now able to manufacture tool steel which has been pushed to new levels of toughness and performance never seen before, Dievar 25 Joules. (Figure 1)

This new tool steel development gives you the perfect balance between toughness and heat checking solutions for HPDC (High-pressure die casting) and other applications.

The new Dievar gives you, the customer:

- More quality cast parts for all common size ranges
- Lower cost production
- Longer tool life
- Excellent heat checking resistance
- Best toughness in its class in NADCA (North American Die Casting Association)
- Developed for large dies and inserts

The new Dievar is now available to purchase from all ASSAB companies and has been approved and set into the new NADCA #207-2018 document. This new steel has been developed for the automotive industry with the new e-mobility and structural parts as the focus.

So why when Dievar can offer so much better performance do most die makers, foundries and OEM's in HPDC still select the tool steel grades AISI H13 or AISI H11? Amazingly, both these grades pre-date the middle of the last century. Can these steels really help solve the biggest problems faced by tool users today compared to Dievar? What about the problems faced in production with new structural and e-mobility parts with the growth of Hybrid and EV (electric vehicle)? Are the failures in structural and e-mobility parts the same as in the more traditional castings such as powertrain and transmission?

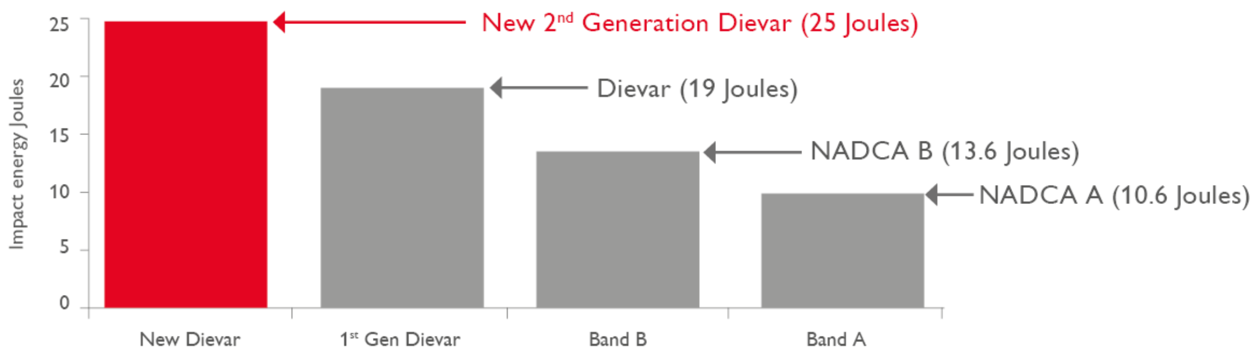

Figure 1 shows the impressive growth of toughness in the new Dievar

Structural parts pushing new limits

To answer the questions we need to ask, what are the main die failures in automotive die inserts? There are 4 main failures (Figure 2) in HPDC dies that you will see in every casting plant in the world. Erosion, soldering, heat checking and gross cracking. From our experience, we can say with confidence that the most common die failure is heat checking. This failure mechanism varies from foundry to foundry but an average of 80% is a near accurate figure with the other failures making up the rest.

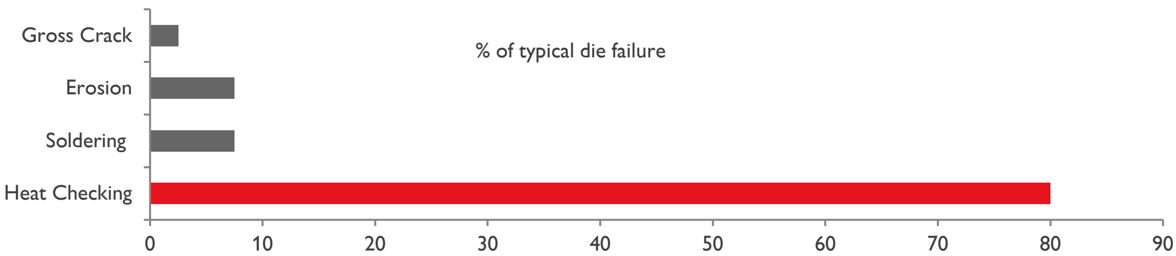

Figure 2 shows the breakdown of typical die failure (percentage) in HPDC

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 interestingly heat checking seems to come 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 80-150K shots (depending on the design and press used) but in structural parts, this can be under 75K shots. For example, some types of shock tower dies have been known to produce under 30K shots due to their operation, design and complex geometry. Some have even been known to prematurely crack if the die has poor process control combined with insufficient material properties. However, this poor performance is not just limited to shock tower dies as all structural parts are often complex in design and push the older die materials to the limit of what they can do.

Why is this? If we look at this longitudinal bridge part and die (Figure3), we can see that it has a very large surface area with many thin and thick sections. As these castings will make up the structural elements of the vehicle, it is important that the injection process is optimal 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, 14 gates in this example! This means extra heat is generated in the gates and when you combine that with the general heating and cooling of the casting cycle, along with spraying of the die, you then get high levels of thermal fatigue or heat checking.

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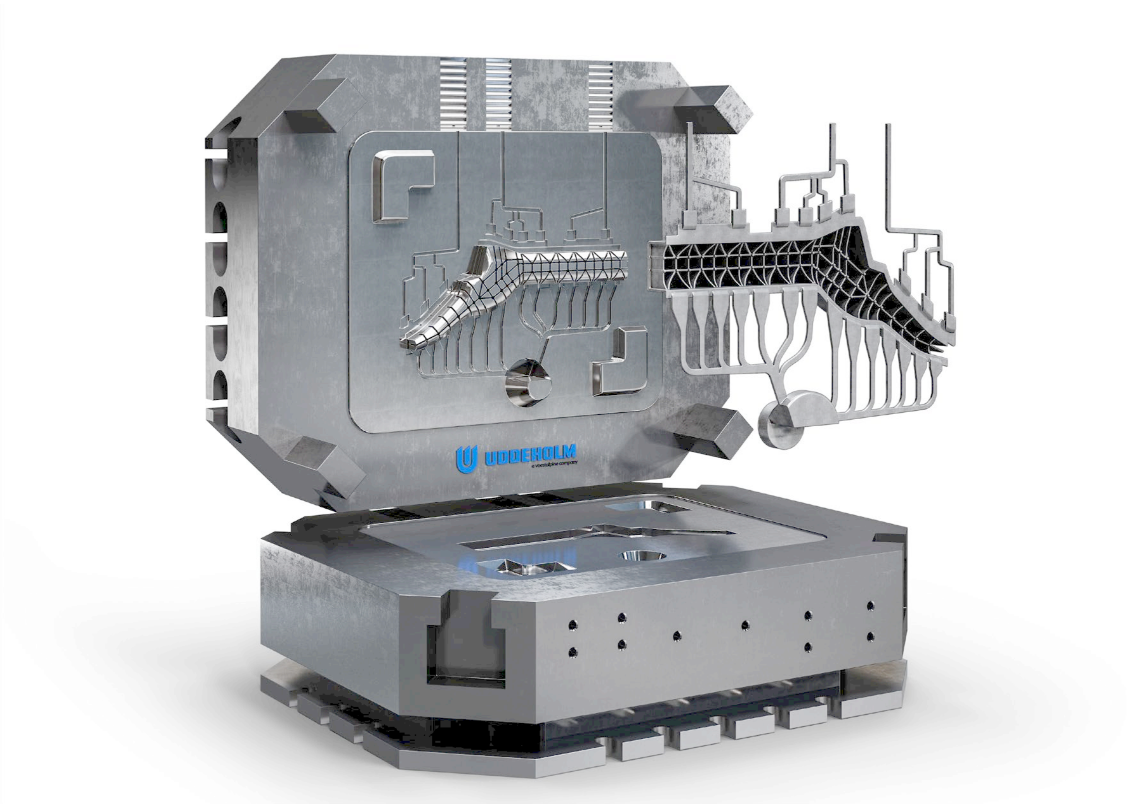

Figure 3 we can see why the challenge, structural parts, big surface areas, thin sections, complex geometry

Many of these new structural parts are safety-critical and if the vehicle is to perform as designed in a crash situation, the panel must be clean of potential crack initiation marks. Heat checking damage would class as a potential crack initiation area and hence becomes a big problem on these structural parts. A trend is also for bigger and bigger parts and presses, this means that the inserts for the tool are also getting bigger. In some cases, split lines and inserts are not allowed in the design which presents a problem as the bigger the insert the higher the risk of gross cracking! Now the die steel you select not only needs to have the ability to solve the main production problem of heat checking but also needs to be very tough and ductile in operation.

Heat Checking and the current tool steels

In applications such as HPDC, there will be a large temperature difference on the tool's work surface as the casting goes through its cycle. The difference in maximum and minimum temperature will create stresses in the material and eventually fatigue cracks will develop.

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 will 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.

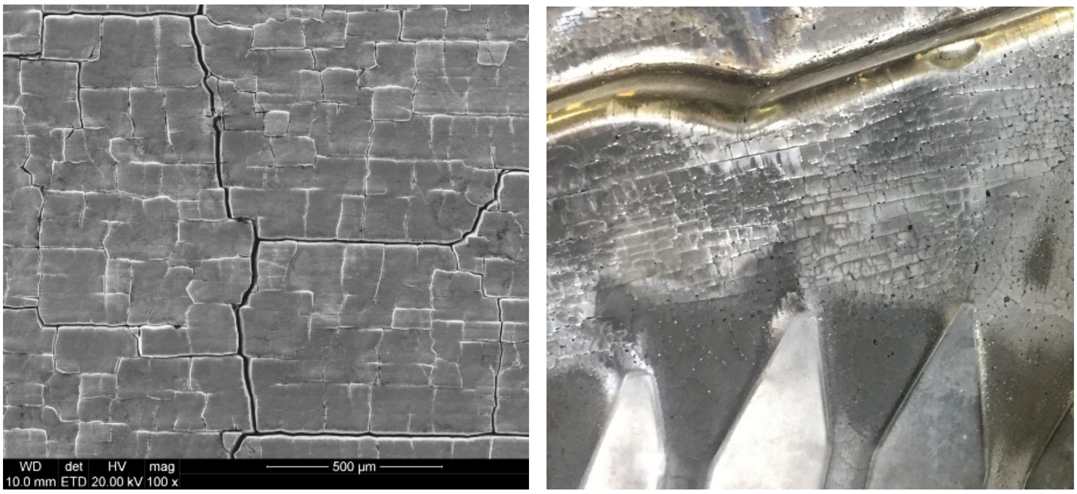

Figure 4 shows heat checking on the left under magnification and on the right as seen in a real production die

Above (Figure 4) 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 minimise the risk of this failure mechanism (heat checking) some superior material properties are an advantage. For example, better heat conductivity 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. 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 slightly better temper-resistance and hot strength due to the precipitation of fine alloy carbides. This can be seen in some production results where heat checking resistance is slightly better over H11 but is not a significant advantage. H11 has a lower content of Vanadium, which lowers the risk of primary carbide formations thus promoting higher toughness and ductility. Therefore, it is a reverse of the result for H13 with H11 slightly better with toughness over H13. But again not a significant difference in both grades, not when compared to a tool steel grade like Dievar.

Dievar, a solution optimised for heat checking

Is Dievar the solution to heat checking? 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 5) have also shown that Dievar has better heat-checking depth resistance than premium H13 grades as we see in the below chart where we see the depth of crack is much greater in the H13 material than Dievar at the same hardness levels.

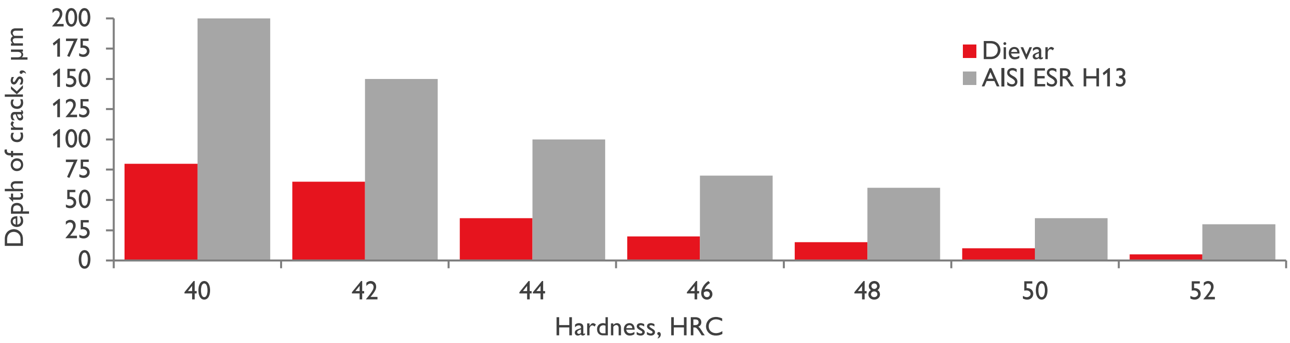

Figure 5 clearly illustrates that Dievar has far superior resistance to heat checking cracks over premium H13

Important material properties for heat-checking resistance are hot-yield strength, temper resistance, creep strength, ductility and toughness. Dievar outperforms premium H13 grades in all these properties. Ductility and toughness are especially of interest because the biggest difference lies in these areas. High toughness is needed to protect the die from a catastrophic failure and now Dievar has the answer giving the die user peace of mind in production. High ductility is also important because it delays the initiation of cracks and recent testing of Dievar at 44-46HRC in unnotched testing showed over 400 Joules impact value. High ductility and toughness also facilitate the possible use of a higher hardness level in the die as it is a known fact that higher hardness contributes to improved heat-checking resistance (Figure 5).

Customers recently asked ASSAB to test the new Dievar above 44/46HRC to see just how tough Dievar is compared to high-quality ESR H13. These customers recognised that if you can go up in hardness you will extend heat checking resistance, but the concern is a drop in toughness. Testing showed that Dievar even at 51HRC (Figure 6) had superior toughness to an ESR H13 grade in comparable sizes. If you are intending to raise your hardness in a die we strongly recommend that you ask your local ASSAB technician to view your die and processes first so the optimal performance level can be reached.

Toughness comparison – 51 HRC

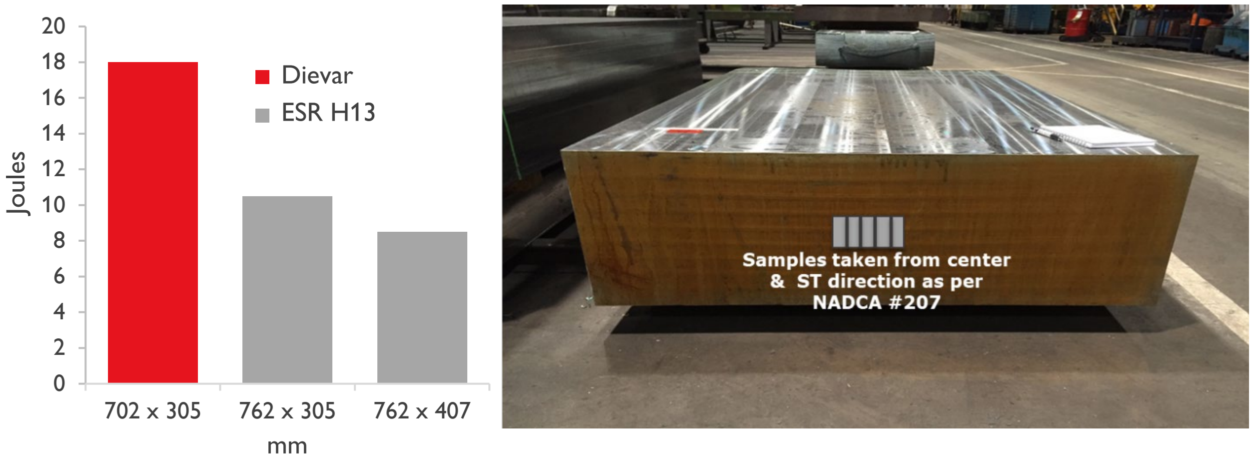

Figure 6 clearly shows Dievar is tougher at higher hardness to premium H13

The hot-yield strength, temper resistance (Figure 7), creep strength, thermal conductivity and the thermal expansion are properties, which depend upon the chemical composition of the material. Dievar shows superior results in all these areas, mainly linked to the higher amount of molybdenum in combination with the vanadium content.

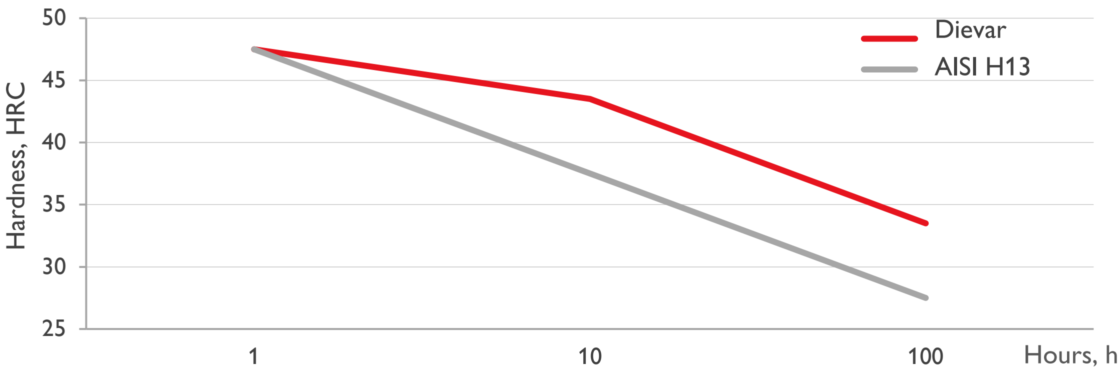

Figure 7 shows just one of the multiple advantages of Dievar chemistry over H13 to fight heat checking, superior temper back resistance

Dievar's ductility and toughness reflect the quality of the steel and 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 increased cleanliness, homogeneity and 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 ASSAB are equipped with protective gas atmosphere and pressurized gas atmosphere that improves the cleanliness of the process and increases the steel properties again. After remelting the new ingot is heavily forged, this efficiently breaks down the solidified structure into a finer-grained and more ductile structure. Specialised heat-treatment processes give further improvements to 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 Dievar was developed the aim was mainly improvement of the ductility, toughness, hardenability and heat-checking resistance of dies.

Today we see an increasing demand for Dievar and in sizes, which no one could have imagined when Dievar was originally developed with some dies as big as 18 tons in weight as the below picture (Figure 8) shows. On blocks this big, it has quality as high as 28 Joules and fine grain sizes of ASTM 7 and above.

Figure 8 shows just how big some special sizes of Dievar can be manufactured

However, using the best material available is not a guarantee against early heat-checking problems. The focus must also be taken to look at other critical parameters such as design, die making, heat-treatment, surface treatment and casting parameters etc. However, if you have heat-checking problems with your tooling when using H11 or H13 then using Dievar is a great start to a successful die life improvement, as the customer case study (Figure 9) shows.

Heat Checking – case study

- 4 cavity die trial
- Dievar in 2 cavities
- ESR H13 in the opposite side
- Examined at 95,000 shots

Performance increase using Dievar is clear, why is this?

	AISI H13	Dievar
Hardness	44 – 46 HRC	44 – 46 HRC
Result	Heavy Heat Checking	No Heat Checking

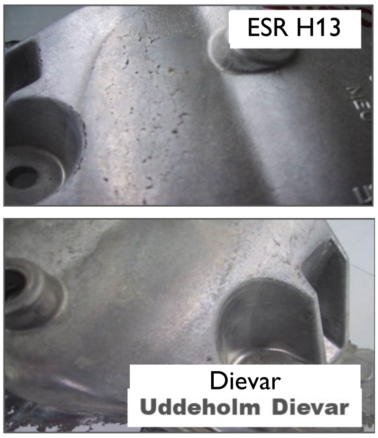

Figure 9 shows a customer case of Dievar and ESR H13 in production with heat checking as the concern

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