

Detail view of a pressure die cast structural component (Photos + Graphics: Kind & Co Edelstahlwerk)

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Pressure die cast structural components for lightweight automotive construction

The European Union's commitment to carbon reduction requires the automotive industry to bring down CO₂ emissions from new passenger cars down to 95 g/km by the year 2020. The consistent implementation of lightweight design in automotive engineering has a direct positive impact on CO₂ emissions. This was motivation during the last few years to strongly promote the use of pressure die cast structural components made of light metal

Pressure die casting competes with alternative techniques, such as tailored blanks – i.e. parts made by joining steel sheets of special properties to meet specific requirements of use – or press-hardened high-strength steel sheets. Pressure die cast structural components can only succeed in this competitive environment if high-capacity, reliable dies are available. The key advantage of pressure die cast structural components over alternative solutions is that they are made to high precision and are vir-

tually ready for installation. Compared to tailored blanks, many manufacturing steps can be dispensed with.

Pressure die cast structural components

Today, a wide range of automotive structural components are pressure die cast, for example, pillars, various beams, strut mounts and even complete frames for side and rear doors. While this type of pressure die cast components initially used to be in-

stalled primarily in premium-class vehicles, today they are also employed in many middle-class cars.

The high complexity of these parts is an extremely challenging task for die casters, die makers and steel producers. Ribbings in the castings are prone to cause localized stress peaks. Side and rear doors are frame-type constructions. During casting only relatively small volumes of the die are in contact with the casting alloy, making it very difficult to achieve a homogeneous

Mat. no.	Steel grade		Alloying contents in % by mass								
	Brand	Short name	C	Si	Mn	P	S	Cr	Mo	V	Nb
1.2343	USN	X37CrMoV5-1	0.38	1.00	0.40	< 0.020	<0.005	5.20	1.20	0.40	---
1.2344	USD	X40CrMoV5-1	0.40	1.00	0.40	< 0.020	<0.005	5.20	1.30	1.00	---
1.2367	RPU	X38CrMoV5-3	0.38	0.40	0.40	< 0.020	<0.005	5.00	3.00	0.60	---
---	TQ 1	---	0.36	0.25	0.40	< 0.012	<0.003	5.20	1.90	0.55	---
---	HP 1	---	0.35	0.20	0.30	< 0.012	<0.003	5.20	1.40	0.55	+

Table 1: Chemical composition of hot working steels for pressure die casting dies

temperature distribution in the die inserts, with the consequence of thermally induced stresses in the dies.

Thin-walled components are often cast with very high pressure and/or at high flow rates in order to prevent the alloy from solidifying prematurely during die filling. For this reason, such components are frequently cast at a higher than usual casting temperature, leading to additional mechanical and thermal stresses in the die inserts.

The steel alloys must be able to comply with extremely exacting requirements in terms of thermal shock resistance if the structural components will later on be used in exposed applications and painted. Otherwise, costly reworking of the castings will be unavoidable.

Hot working steels suitable for making dies used to cast structural components

The above said has made clear that the demands on steels used to make dies for structural components are often significantly higher than for other die castings.

In order to compensate thermal and mechanical stresses, steels of very high toughness are needed. Good tempering properties protect the inserts against a rapid decrease in hardness, and the high surface quality required for exposed parts can only be achieved with steels featuring extremely high thermal shock resistance. High thermal conductivity reduces local temperature peaks in the die inserts.

Many die casting dies are made of the three standard hot working steels 1.2343, 1.2344 or 1.2367 [1]. A basic prerequisite for the use of these steels in this application is that they have been remelted. However, these steels do not always come up to the special requirements to be met by cast structural components. For such cases, Kind & Co., Wiehl, Germany, has developed two special hot working steels: TQ 1 and HP 1. Both these steels boast extreme cleanliness. Not only the contents of phosphorus and sulphur, but also harmful trap elements have been dramatically reduced. Steel HP 1 is a variant of steel TQ 1. It is additionally microalloyed with niobium. The chemical analyses of the steels are given in **Table 1**.

The most important properties of the steels include good tempering properties, good strength properties at high temperatures and high impact strength. For reasons of clarity, steel 1.2344 has been excluded from the comparison. The superior tempering properties of the two special hot working steels (**Figure 1a**) becomes obvious at tempering temperatures above 550 °C. Plotting the yield strength versus temperature (Figure 1b) illustrates that TQ 1 and HP

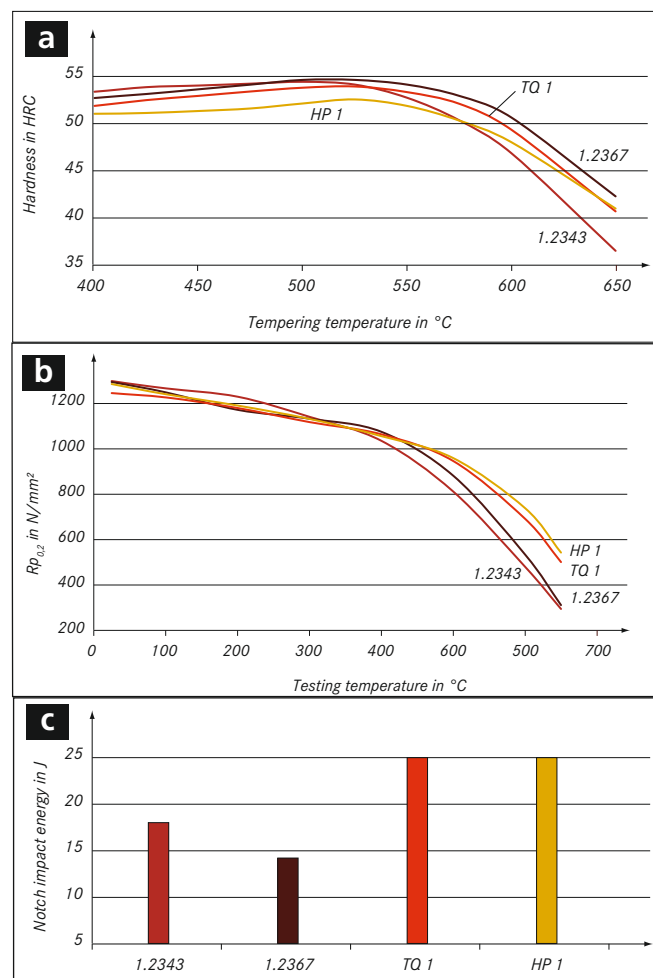


Figure 1: Comparison of mechanical-technological properties of selected hot working steels for pressure die casting dies: a) Tempering properties; b) Yield strength $R_{p0.2}$ as a function of the testing temperature; c) Typical notch impact energy values (ISO V-specimens, core, transverse direction, 45 HRC)

1 develop their outstandingly high hot working strength at temperatures above 400 °C. This temperature range plays a decisive role especially in the contact zone between the alloy and the die insert. A third important mechanical-technological property of the steels is their impact strength (Figure 1c) because the die inserts are subjected to high sudden mechanical loads at each shot. Steel 1.2343 features the highest impact strength of the three standard alloys. Based

Mat. no	Brand	Thermal conductivity in W/m x K		
		20 °C	200 °C	400 °C
1.2343	USN	26.8	27.8	27.3
1.2367	USD	29.9	32.1	32.4
---	TQ 1	29.5	30.5	30.5
---	HP 1	29.8	31.0	31.4

Table 2: Thermal conductivity of hot working steels for pressure die casting dies. All steels hardened and tempered to 45 HRC

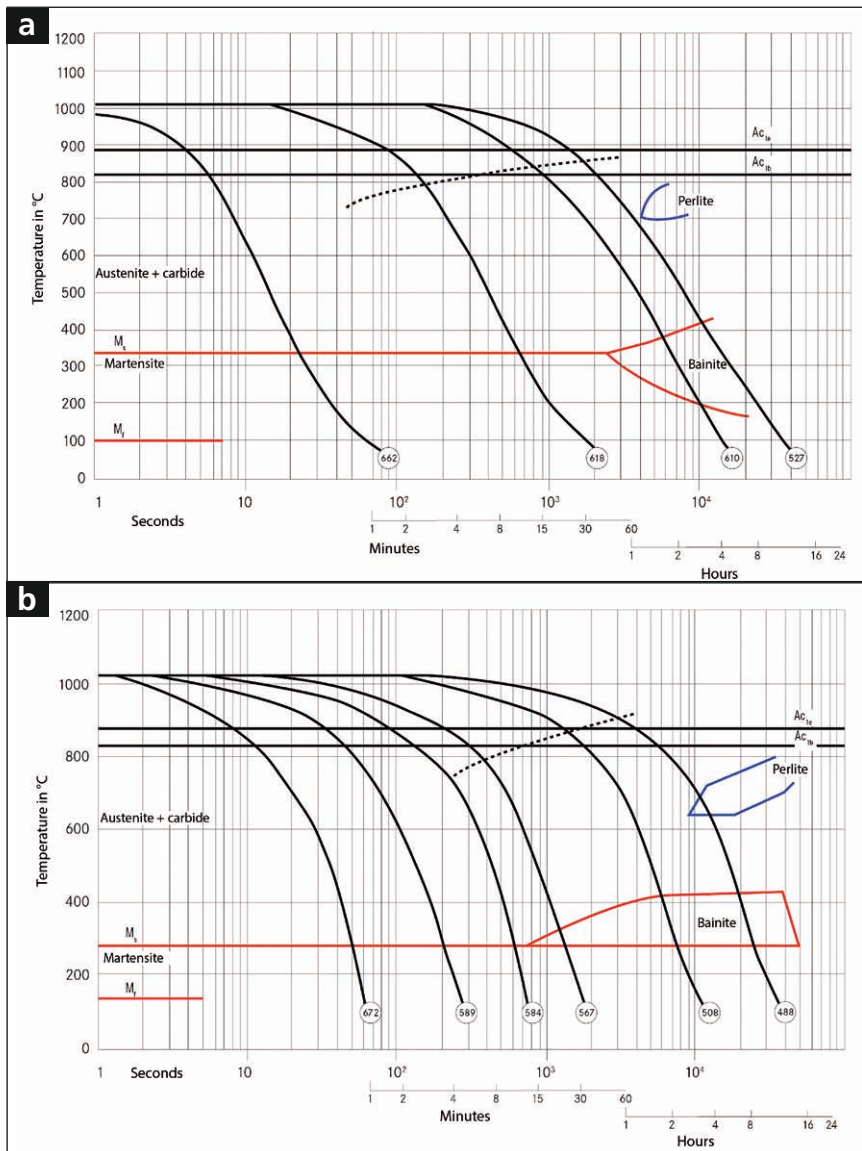


Figure 3: CCT diagrams for steels TQ 1 (top) and HP 1 (bottom)

on specimens of identical hardness, the impact strength of the three alloys decreases in the sequence: 1.2343 => 1.2344 => 1.2367. The impact strength values of two special hot working steels TQ 1 and HP 1 are both at the same level, about 25 % higher than the corresponding value for alloy 1.2343. This

comparison of the key mechanical properties illustrates the exceptional blend of properties found in the steels TQ 1 and HP 1.

Especially for the casting of exposed parts, thermal shock resistance is a crucial property of the hot working steels used to make the casting dies. The im-

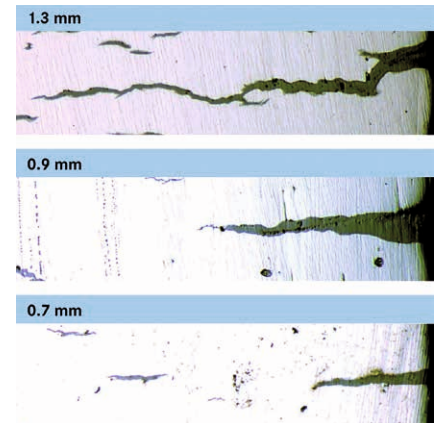


Figure 2: Thermal shock resistance of steels 1.2343 (top), TQ 1/ HP 1 (middle) and HTR (bottom). Crack formation due to thermal shock and mean crack length in mm. Testing conditions: all steels hardened and tempered to 45 HRC; testing temperature: 600 °C/water, 4,000 cycles

ages in **Figure 2** show thermal shock-induced cracks in specimens of the described steel grades. The mean length of each crack is indicated in the blue bar. Hot working steel 1.2343 is used as a reference. The significantly better thermal shock resistance of TQ 1 and HP 1 is obvious. Steel HTR, which is also shown in this comparison, has been developed for applications with extremely exacting requirements on hot working strength and thermal conductivity. However, for inserts in dies for casting structural components this steel is of less importance.

In pressure die casting dies, thermal conductivity plays a key role for various reasons. Firstly, it is responsible for the heat transfer from the alloy into the cooling channels and, secondly, it contributes to the alleviation of local temperature peaks and a decrease in temperature-induced stresses in the dies. The thermal conductivity values of the here discussed steels are compiled in **Table 2**.

The comparison reveals that TQ 1 and HP 1 feature property blends far superior to those of the three standard hot working steels 1.2343, 1.2344 and 1.2367. Between TQ 1 and HP 1, the differences in the described properties are only minor. This raises the question of selection criteria between the two steels.

Due to their special blend of properties, both steels are extremely well

suited for making pressure die casting dies for structural components. A distinction between the two steels can be made based on the thickness of the die inserts. To clarify this distinction, in **Figure 3** we have plotted the continuous cooling diagrams (CCT curves) of the two steel grades.

In both cases, the CCT curves are typical curves of martensitic hot working steels. However, the difference between the two is that the bainitic transformation starts at different points in time. While in the case of TQ 1, the bainitic phase is likely to form after about 2,500 s, in the case of HP 1, this is likely to occur as early as after 800 s. This time difference of 28 min is crucial especially to the solidification of thick-walled inserts because, in order to achieve high toughness of the material, everything possible should be done to ensure that during solidification the steel microstructure transforms completely to the martensitic phase. Bainite transformation starting at a later stage, facilitates the desired transformation to the martensitic phase especially in the core area of thick-walled die parts. From this, the following recommendations can be derived: Use HP 1 preferably for die inserts up to approx. 200 mm thick; beyond that thickness use TQ 1.

TQ 1 should also be used for smaller die inserts with extremely filigree engraved structures that require a maximum of toughness.

To summarize the recommendations: HP 1 is suitable for die inserts of up to 200 mm thickness for structural components which have to comply with exacting requirements in terms of toughness and surface quality. TQ1 is recommended to be used for dies which have to comply with extremely exacting requirements in terms of toughness and surface quality, and particularly for die inserts of greater thickness. TQ 1 has also proved to be more appropriate for die inserts with pronounced height offsets or a jagged surface structure.

These steels feature a useful hardness typically ranging between 44 and 46 HRC. In order to cater to specific properties, the values can be lower or higher. The choice should always be based on a



Figure 4: Modern vacuum hardening furnace at Kind & Co. for pressure die casting dies weighing up to 6,000 kg (Photo: Georg Fischer AG)

Mat. no	Short name	Brand	Hardening temperature in °C	Holding time in min
1.2343	X37CrMoV5-1	USN	1000	45
1.2344	X40CrMoV5-1	USD	1020	45
1.2367	X38CrMoV5-3	RPU	1030	45
---	---	TQ 1	1010	60
---	---	HP 1	1020	60
---	---	HTR	1060	60

Table 3: Recommended parameters for vacuum hardening pressure die casting dies

joint decision by the steel producer, die maker, hardening shop and foundry.

The die inserts can exhibit the desired properties only after an appropriate heat treatment. For the vacuum hardening treatment of pressure die casting dies, special steelmaker Kind & Co. recommends the temperatures and holding times compiled in **Table 3**. The company's modern, high-capacity vacuum hardening shop can heat treat pressure die casting dies weighing up to 6,000 kg (**Figure 4**).

Summary

Extremely exacting demands are placed on dies used for the production of pressure die cast structural components due to their size and their often highly sophisticated design. Common standard hot working steels cannot guarantee

compliance with these demands. In contrast, the special hot working steels TQ 1 and HP 1 offer a significantly improved combination of properties, such as increased toughness, higher hot working strength, better thermal shock resistance and improved thermal conductivity. The choice between these two steel grades basically depends on the thickness of the die inserts to be produced.

Provided that they have been properly heat treated, die inserts made of these steels make a major contribution to the cost-efficient production of pressure die cast structural components made of light metals.

www.kind-co.de/en

References:

www.cpt-international.com