Heat Treatment of Hot Work steels

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Abstract

The material and its heat treatment for the die casting dies play an important role in ensuring the life of dies. An important aspect is the testing of the material for impact strength. This test makes it possible to distinguish low-quality material from high-quality material. However, the origin of the material, which clearly influences the result, is an equally important factor.

1. Introdution

The increase in the production of aluminum die casting dies is putting pressure on them to ensure their life. Due to the fact that this type of tools is highly stressed by cyclic fatigue at high temperature, thermal shocks, high mechanical stress and at the same time abrasion, it is a very complex problem that does not have a simple solution. It is known that only 15% of the cost of the mold is the cost of the steel and its heat treatment, but almost 50% of the damage to the mold is caused by these effects. Therefore, the demands on the choice of material and its heat treatment for these applications are constantly increasing and it is necessary to pay due attention to them.

2. Material requirements

Therefore, in order for the material to meet the requirements for the required service life, some prerequisites are necessary:

- the steel must have a low sulfur content <30 ppm
- the steel must be deoxidized and must have precisely limited amounts of impurities and inclusions
- the steel must be produced by ESR or VAC method
- the steel must have a defined primary grain size
- the steel must have a minimum amount of primary carbides and their even distribution
- the steel must have a defined toughness and it must be greater than the minimum allowed
- the steel must have a high resistance to thermal fatigue, preferably based on a CWRU test (Case Western Reserve University "Dunker" test)

The sum of these properties gives the limits for the purchase of material. Therefore, in order for a material to meet these properties, it must have a clear definition of its origin. Therefore, in order for a material to ensure the required durability, its structural properties are more important than its chemical composition. The chemical composition of these steels satisfies (except for material changes) almost always, but the structure only sometimes.

3. Initial structure

The initial structure is important for material acceptance. Its definition is given, for example, by the NADCA standard 207-97. This determines A) the chemical composition of the material, B) the hardness of the annealed structure max. 235 HB, C) the size and amount of impurities such as sulphides, aluminates, silicates and globular oxides, D) the absence of cracks after ultrasonic testing, and E) impact tests.

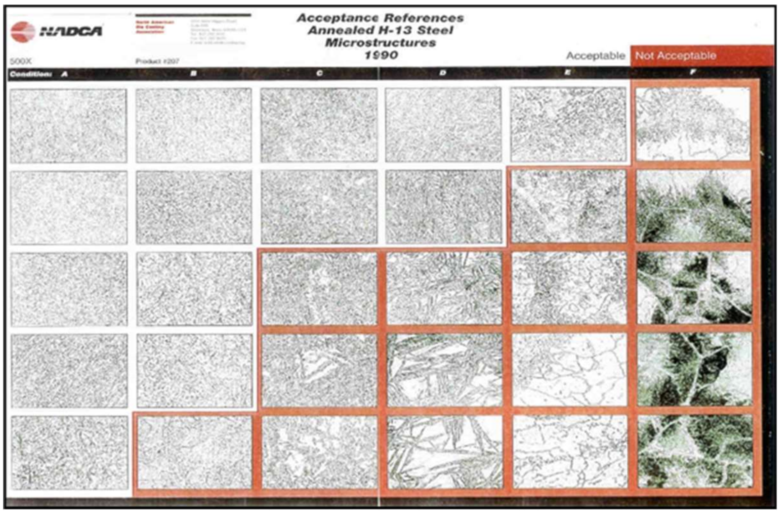


Fig. 1
Acceptable and unacceptable annealing structures according to NADCA 207-97

The parameter that gives a general idea of all the above properties is impact toughness. It is tested on 10 x10 mm samples either without a notch, and then its minimum value is 166 J, or with a "V" notch, and then its minimum allowable value is 10.5 J at an average value of 12.5 J.

There are standards, such as DC-9999-1 for General Motors, which further tighten these values, and where notched toughness testing is a prerequisite for the entry of material into the dies making process. This requirement is not an end in itself. Any deviation from the required parameters reduces the value of toughness, and thus the resistance to thermal fatigue.

Of the key influences, it is the influence of the shape and distribution of primary carbides that most reduce toughness. Their small amount and even distribution gives result up to 10 times higher than when their amount grows above 0.03 volume. %. In Fig. 2 is a graph of the relationship between the amount of primary carbides and toughness, and Fig. 3 is the relationship between the number of thermal fatigue cracks and toughness.

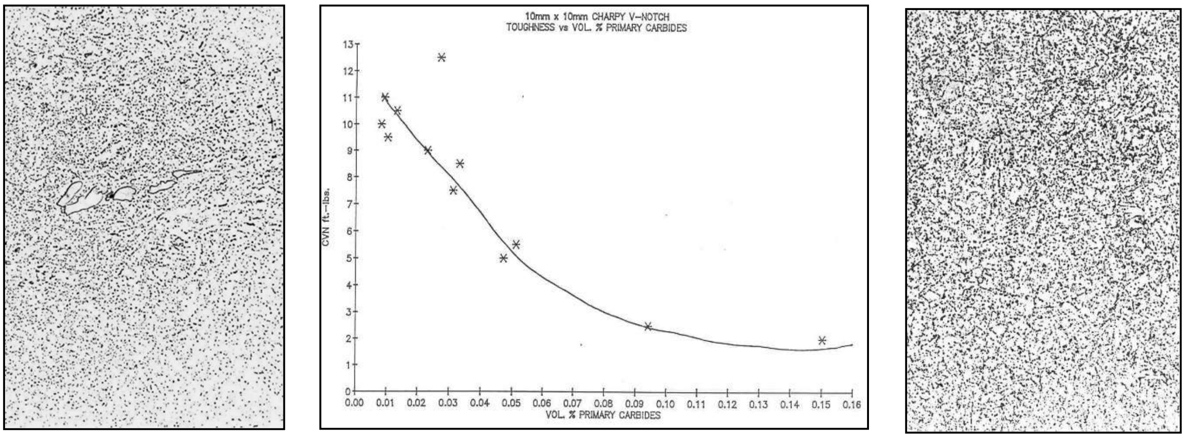
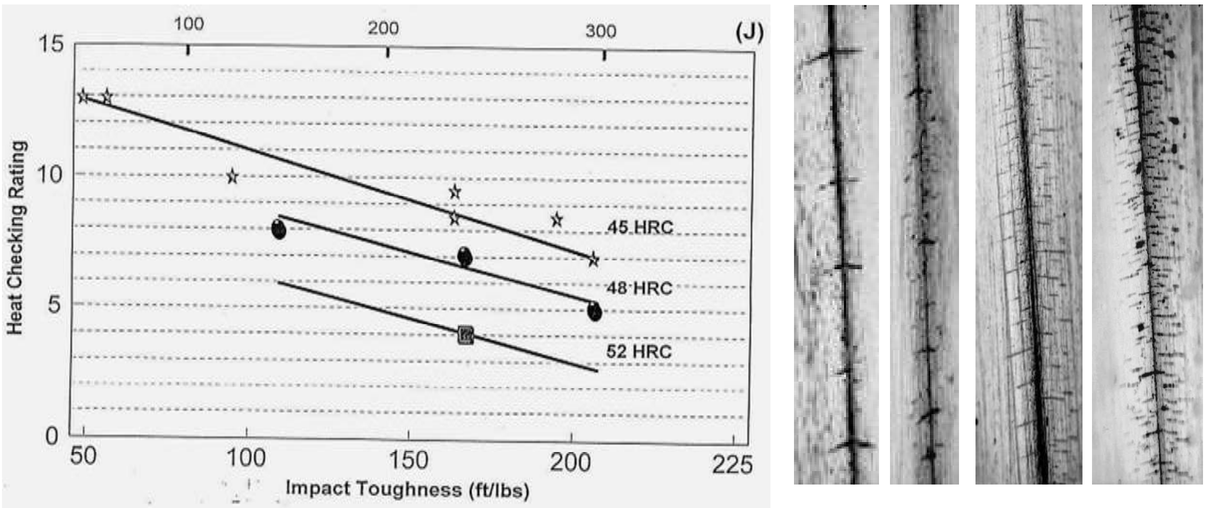


Fig. 2 Influence of the amount of primary carbides on the toughness of steel



H13 TQ1 QRO90 DIEVAR

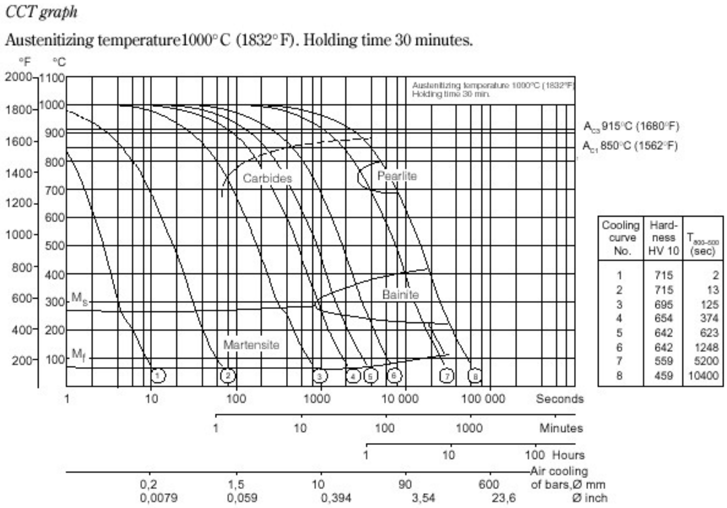
Fig. 3 Influence of toughness on thermal fatigue resistance

4. Heat Treatment

Heat treatment can affect the resulting properties of the material. The basic problem is that the material must be cooled so fast that carbide precipitation cannot occur during austenite conversion. In Fig. 4 is a typical CCT diagram for material type 1.2343, where in addition to the area of martensite formation, the area of carbide, perlite, or bainite. Therefore, in order for the steel to be well processed, a cooling rate must be chosen that allows the carbide precipitation area to be missed. This speed should be greater than 30 C/min and this is an essential parameter for the technical equipment of the hardening equipment.

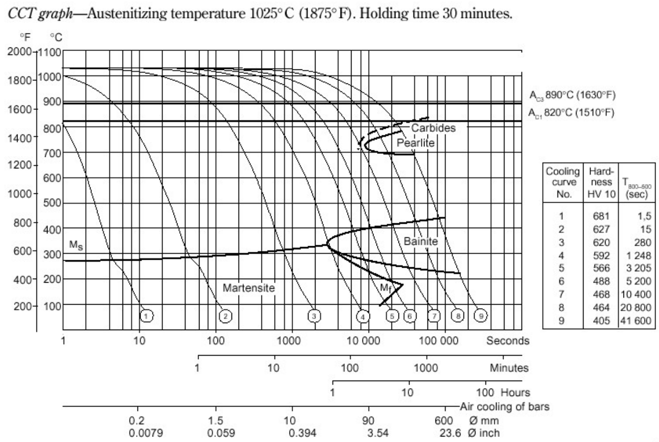
Fig. 4

CCT diagram
for 1.2343



Obr. č. 5

CCT diagram
for DIEVAR



Failure to comply with this parameter can result in either the matrix containing more carbides than is acceptable or, worse, a proportion of perlite or bainite. All variants reduce toughness and are unacceptable (see Table 1). Another way is to use materials that have a significantly shifted area of perlite and carbides so that even with slow cooling, this cannot happen. A typical example is DIEVAR (Fig. 5)

STRUCTURE AFTER HARDENING	J/cm2
Martensite without precipitated carbides	24-27
Martensite with finely precipitated carbides	20
Martensite with a small proportion of bainite	20
Martensite with heavy carbides	16
Martnesite with significant carbides and bainite content	9
Martensite with portion of perlite	5

Tab. 1 Impact toughness values for different structures

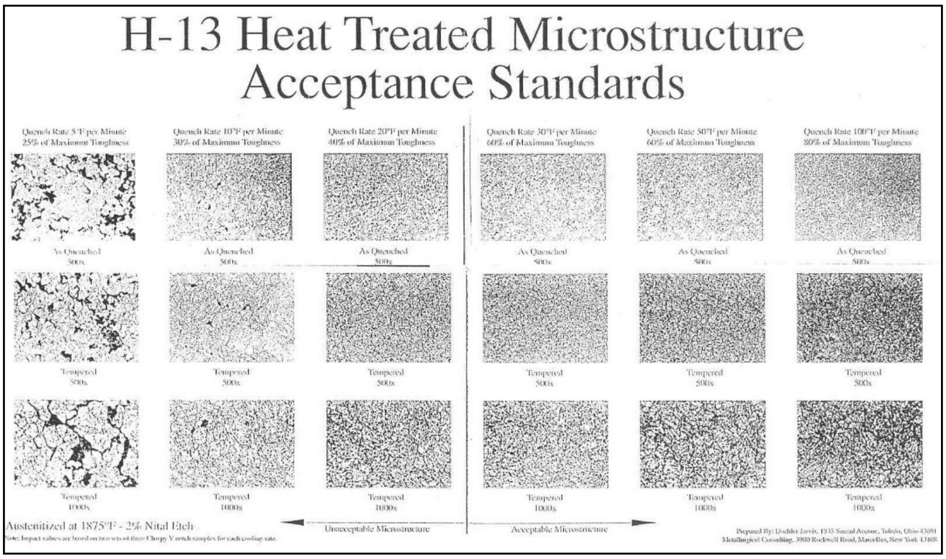


Fig. 6 Structures of material H13 (1.2344) after hardening - in the left part when cooling <15 C/min, in the right part when cooling> 30 C/min.

The structures after hardening of H13 steel (1.2344), which are acceptable, are shown in Fig. 6. The required structures can only be achieved if the cooling rates are increased. In vacuum furnaces, this is due to the nitrogen overpressure at which cooling takes place, as well as the furnace design, fan power, heat exchanger etc. It is therefore largely an individual matter of the furnace itself and the results from one furnace cannot be clearly transferred to another. The DC-9999-1 standard states that the supplier of heat treatment for die casting dies can only be one who has furnaces operating with an overpressure of 10 bar. However, even if in the heat treatmen plant is available, long-term impact results are tested, which only then are the basis for the heat treatment plant's ability to be certified for the DC-9999-1 system. The effect of the cooling rate on the formation of a crack from thermal fatigue is shown in Fig. 7. The speed of 180 C/min corresponds to the ideal hardening of the samples into oil, the speed of 25 C/min then the overpressure of approx. 4 bar.

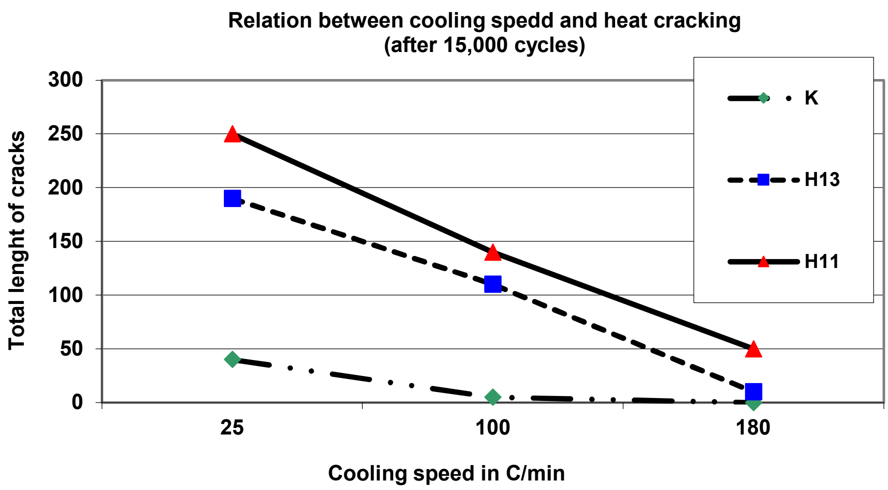


Fig. 7 Dependence of thermal fatigue cracking on cooling rate during hardening

Therefore, in order to achieve the optimal structure, it is necessary that the parts be tempered 3 times. This requirement is based on the fact that each material has a certain amount of residual austenite after hardening, which is transformed into martensite after the first tempering. However, even this martensite must be tempered twice, so it is therefore necessary to always include a third additional tempering.

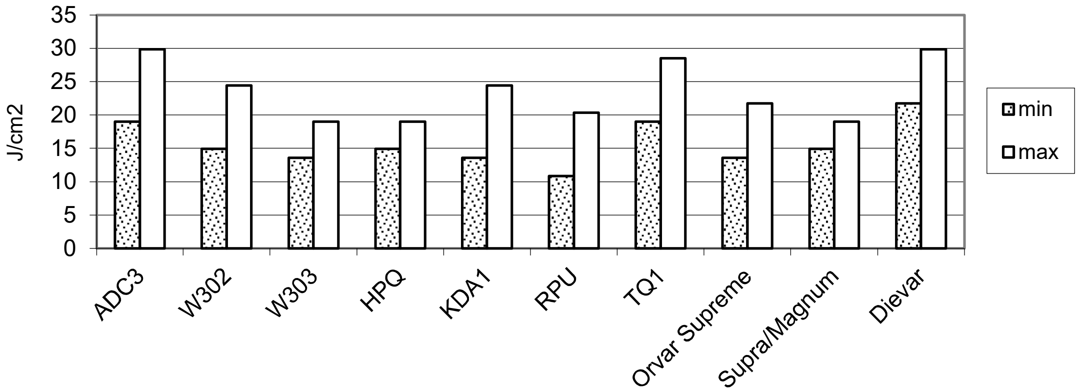


Fig. 8 Notched toughness value for different steels

5. Hot work steels

Depending on the strict conditions for the input steel grade, it can be stated that not all H11 or H13 steels meet these requirements. The quality of steel is already created in primary production and is therefore decided primarily by production technology. If the steel supplier does not have this technique available, or sells steel from a manufacturer without this technique, he risks supplying the customer with materials that will not have an adequate service life.

ZNAČKA	DIN/AISI	VÝROBCE	TVRDOST PO ŽÍHÁNÍ	C	Si	Mn	S	Cr	Mo	V	pozn.
			HB								
DIEVAR	-	UDDEHOLM	~160	0,35	0,20	-	-	5,00	2,30	0,60	ESR/VAC
ORVAR SUPREME	1.2344/H13	UDDEHOLM	~180	0,39	1,00	0,40	max. 0,003	5,20	1,40	0,90	ESR/VAC
VIDAR SUPREME	1.2343/H11	UDDEHOLM	~180	0,39	1,00	0,40	max. 0,003	5,00	1,30	0,40	ESR/VAC
QRO 90 SUPREME	-	UDDEHOLM	~180	0,38	0,30	0,80	max. 0,003	2,60	2,30	0,90	ESR/VAC
THYROTHERM 1.2343 EFS/SUPRA	1.2343/H11	THYSSEN	~230	0,38	1,00	-	-	5,30	1,30	0,40	ESR
THYROTHERM 1.2344 EFS/SUPRA	1.2344/H13	THYSSEN	~230	0,40	1,00	-	-	5,30	1,40	1,00	ESR
THYROTHERM E38.K	-	THYSSEN	~170	0,35	0,30	0,30	max. 0,003	5,00	1,35	0,45	ESR
S.M.V.3	1.2343/H11	AUBERT & DUVAL	~235	0,40	-	-	-	5,00	1,30	0,40	-
ADC3	-	AUBERT & DUVAL	-	-	-	-	-	-	-	-	-
TQ1	-	KIND	-	0,36	0,30	0,40	-	5,20	1,90	0,55	-
USN	1.2343/H11	KIND	~220	0,38	1,00	0,40	-	5,20	1,30	0,40	-
USD	1.2344/H13	KIND	~220	0,40	1,00	0,40	-	5,20	1,30	1,00	-
53SR	1.2344/H13	CARRS/KIND	-	0,40	1,00	-	-	5,00	1,40	1,00	ESR
W302 VMR	1.2344/H13	BOHLER	-	0,39	0,20	-	-	5,20	1,40	0,95	VAR
W302 ISOBLOC	1.2344/H13	BOHLER	-	0,39	1,10	-	-	5,20	1,40	0,95	ESR

Tab.. 2 Hot work steels for die casting dies

Table 2 lists the most commonly used and recommended materials. All have in common that they are produced in the required purity. In Fig. 8 are impact toughness data measured on "V" notched specimens for some of them. Practically all of them meet the basic criterion, ie. value of impact work for sample breaking> 10.5 J. However, those of them which have higher values will also have higher resistance to thermal fatigue.

Literature:

Corwyn Berger	Bodycote Material Testing, lexture in Brno, 1999
NADCA 207-97	North Amerian Die Casting Association
DC-9999-1	GM POWERTRAIN GROUP specification