HOT-WORK TOOL STEELS WITH IMPROVED PROPERTIES FOR DIE CASTING APPLICATIONS

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Abstract
To get a better die life in die casting it is necessary to look at the main reasons for damage. More than 80% of the dies fail by crack initiation caused by heat checking. To increase the heat checking resistance the tool steel must possess good high-temperature strength, high-temperature toughness and thermal conductivity. Thyrotherm 2367, a steel with 3% molybdenum, combines the good properties of the well-known grades mat.-No. 1.2343 (H11) and 1.2344 (H13) while offering better high-temperature strength and temperature resistance. It is thus increasingly replacing these grades in the production of die castings made of light metal.

Another reason for damage of moulds are tension cracks. Causal for these tension cracks is mainly the constructional design of the tool with corners and sharp edges. If it is not possible to change the design it is helpful for the die life to use a tool steel with high toughness. The new developed steel Thyrotherm E 38 K has the highest toughness potential compared to the other hot-work tool steels. This advantage has a particularly positive effect in the production of large dies.

Due to the combination of high tensile strength and toughness the maraging hot-work tool steel Thyrotherm 2799 has the best potential for getting the highest life time of all.

Keywords: Hot-work tool steel, die casting, thermal fatigue resistance, thermal conductivity, maraging steel, heat checking resistance
INTRODUCTION

Die casting is a very economic way to produce a large amount of castings with good dimensional accuracy. In comparison with other casting methods a much higher expense for the necessary production devices has to be taken into account.

An important part of the production costs are the costs for the mould. Therefore the economic success of the die casting process depends on the die life. There are a lot of different influencing factors on the performance of die casting dies as shown in Fig. 1. The material properties as one of the factors are mainly influenced by the choice of the steel grade. Errors made here are not correctable.

During the last years a lot of new developed steels have been offered for die casting applications. Most of the users nevertheless still apply only one well known grade for their tools because of their poor knowledge of differences in steel properties and little experience in using these differences
for their purpose. Therefore it is necessary to give some advice on steel selection and to present experiences made by choosing different grades.

**HOT-WORK TOOL STEELS FOR PRESSURE CASTING DIES**

The main demands on the properties of hot-work tool steels for die casting dies are

- Heat checking resistance
- Toughness at high temperature
- Wear resistance at high temperature.

Figure 2 shows a selection of tool steels realizing these demands.

![Figure 2. Steel selection for pressure die casting dies](image)

<table>
<thead>
<tr>
<th>Grade</th>
<th>ISO Steel Name</th>
<th>C</th>
<th>Si</th>
<th>Cr</th>
<th>Co</th>
<th>Ti</th>
</tr>
</thead>
<tbody>
<tr>
<td>THERM 2343</td>
<td>X37CrMoV5-1</td>
<td>0.38</td>
<td>1.00</td>
<td>1.30</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>THERM 38K</td>
<td>-</td>
<td>0.30</td>
<td>0.30</td>
<td>0.30</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>THERM 2344</td>
<td>X40CrMoV5-1</td>
<td>0.40</td>
<td>1.00</td>
<td>1.40</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>THERM 2367</td>
<td>X38CrMoV5-1</td>
<td>0.37</td>
<td>0.30</td>
<td>0.30</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>THERM 2365</td>
<td>32CrMoV12-28</td>
<td>0.32</td>
<td>3.00</td>
<td>2.80</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>THERM 2885</td>
<td>-</td>
<td>0.32</td>
<td>0.30</td>
<td>1.00</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>THERM 2900</td>
<td>-</td>
<td>0.45</td>
<td>1.00</td>
<td>1.00</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

X37CrMOV5-1 (H11) and X40CrMoV5-1 (H13) in the first group of this selection are general-purpose hot-work tool steels, well known and always the basis for a comparison of die steels. Some producers developed, on the basis of H11 and H13, in the last years steels with increased toughness, for instance like Thyrotherm E38K is one of these. Main characteristics of
these materials are, except small deviations in standard analysis, low silicon contents, decreased carbon content and improved metallurgy i.e. low content of tramp elements.

Therefore Thyrotherm E38K has a high toughness potential. This advantage is helpful for moulds with sudden appearing tension cracks caused by the constructional design of the tool with corners and sharp edges.

Another advantage is the possibility of using higher hardness levels. More than 80% of the dies fail by crack initiation caused by heat checking. A reason for the appearance of cracks is that the tensile strength is exceeded by the mechanical stress. Therefore it is obvious that there is a correlation between tensile strength and thermal fatigue as shown in Fig. 3 [1]. Dies for aluminium die casting are frequently used in a hardness range of 45 ± 1 HRC. An increase of the hardness increases also the heat checking resistance, but this is limited by the loss of toughness and the danger of getting breakage. By using Thyrotherm E38K with its high toughness potential it is possible to increase the thermal fatigue resistance by using a higher hardness. Figure 4 shows a related case study result. The next group of steels mentioned in Fig. 2 are steels with an amount of 3% molybdenum. This level of molybdenum effects an increase in strength at high temperature and a good thermal conductivity. Thyrotherm 2367 (X38CrMoV5-3) has very good thermal fatigue resistance (Fig. 5) [2] which indicates that this tool steel is a good choice for producing aluminium parts with thick walls. These parts need more time for solidification because of their higher thermal energy and therefore the surface of the moulds reach higher temperatures.

Thyrotherm 2365 (32CrMoV12-28) and its brother Thyrotherm 2885 with the additional cobalt content are the typical tool steels for processing copper alloys. As explained in Fig. 6 the thermal conductivity at low temperatures is excellent and puts these steels in a position to tolerate even excessive cooling with water.

Figure 6 shows also that the thermal conductivity on a wide range of temperatures is a property of Thyrotherm 2999, a steel with 5% molybdenum. This steel was developed specifically for the requirements of the forging industry. Its high strength and wear resistance at elevated temperatures in combination with the high thermal conductivity makes it also interesting for die casting applications. First trials applying Thyrotherm 2999 as a mould steel for producing parts made of copper and as a material for shot sleeves show good results.
**Figure 3.** Influence of tensile strength after quenching and tempering on the resistance against heat checking

**Die Casting**

Example of a die casting mould made from THYROTHERM E38K

**Figure 4.** Example of a die casting mould made from Thyrotherm E38K
Maraging steels, developed as high-strength constructional steels for the aviation and space technology, are a young group within the tool steels. The most important advantages are their comparatively high toughness levels at maximum tensile strength. The traditional maraging steels with 18% nickel, 8% cobalt and 5% molybdenum have a major disadvantage which is their poor high-temperature resistance, because austenite retransformation, and consequently, a drop in hardness may occur already at temperatures of 500 °C. An optimisation of the chemical composition of the traditional maraging steels was carried out and the maraging steel Thyrotherm 2799 (see Fig. 2) was developed as a hot work tool steel with a reaustenitizing temperature of 650 °C [3].

Due to the high tensile strength at high temperatures the thermal fatigue resistance of Thyrotherm 2799 is the best of all tool steels compared in Fig. 5 [4].

The toughness of Thyrotherm 2799 determined in impact bending tests shows a transition temperature at about 100 °C (transition temperature of Thyrotherm 2344, X40CrMoV5-1: about 0 °C). As can be seen from the values compared for Thyrotherm 2344 and Thyrotherm 2799 in Fig. 7 good
toughness can be reached at elevated temperatures. Only a thorough pre-
heating will allow to make use of the enormous advantages of this maraging 
quality. Of course, a good preheating of pressure die casting dies is also 
obligatory for conventional hot-work tool steels.

The combination of high tensile strength and toughness leads to different 
crack behaviour of the maraging grade. The scanning electron micrograph 
in Fig. 8 gives a good impression of thermal fatigue cracks on the surface 
of a thermal shock sample. Whilst definite cracks parallel and transverse 
to the grinding marks are visible for the conventional Cr-Mo-V-steel Thy-
rotherm 2344, the maraging hot-work tool steel Thyrotherm 2799 exhibits 
a few light cracks only, parallel to the grinding marks.

Similar to the results of the laboratory tests the same crack behaviour 
can be found in real die inserts. Figure 9 shows microstructures of two die 
inserts coming from the same die. For test purposes three inserts were made 
of Thyrotherm 2367 and one insert of Thyrotherm 2799 in the same die. The
inspected samples were cut from the same location in every insert. The die insert made from Thyrotherm 2367 shows numerous cracks in all directions.
and parts of the surface are broken out. This fault was clearly seen on the cast parts. The other insert made from the maraging steel has only one crack which runs vertical into the material. The crack was not visible on the parts and was first detected by cutting the sample.

**SUMMARY**

In order to increase the service life of pressure die casting dies it is recommendable to consider that there are a lot of different hot-work tool steels with their specific properties. The present paper provides a survey about steels for this application and describes their properties.

**REFERENCES**

