Problem of the selection the die material for HPDC technology

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Abstract

The paper deals with problem of building new methodology for taking over die materials and new methodology for checking of heat treated die parts for HPDC technology. Today state and used methodology doesn’t correspond to modern die materials made by vacuum remelting technology or by ESR.

Keywords: High pressure die casting (HPDC), die material, methodology, die lifecycle, acceptance terms, NADCA 207

1. Introduction

The necessity of definition new taking conditions for die materials was evocated by ultimate limit state of inserts, cores or dies for HPDC technology which cracked during testing phases (or during first manufacturing cycles – maximal value is between several tens to hundreds of cycles).

The possible principals of this ultimate state are:

- Poor quality of supplied die material
- Badly made heat treatment of die material.

The main goal of this paper is description of NADCA (North American Die Casting Association) methodology, assessing its advantages and disadvantages with respecting actual technologies for material treatment – to made suggestion of new methodology for accepting supplied die materials.

2. Methodology of NADCA Nr. 207

This standard is used in major tool shops and in suppliers of die materials. There is possible to see the standard under sign - AMTD-DC2010 or DC-9999-1 (e.g. car factories Ford, Chrysler etc.).

The basis of the standard is defining of a die material quality, where is for every different material and different supplier exactly described chemical composition. There is also determination of nonmetallic inclusions content (by ISO 4967) and micrographic determination of apparent grain size (by ISO 643). The annealed microstructure
should be free of significant banding or chemical. The annealed microstructure shall exhibit a uniform distribution of fine globular carbide throughout a ferrite matrix at 500x magnification after being polished and etched with 5% Nital. Photomicrographs are evaluated as acceptable and non-acceptable limits. The next important test is impact capacity of die material (by EN 10045-1). A large number of various sized insert steels must be tested in an actual tool production to confirm capability. The confirmation process and requirements are as follows:

- The supplier should ensure material quality.
- The sampling plane must be cut perpendicular to the grain direction of the steel. Grain direction and short transverse (thickness) direction shall be indicated on the steel block by way of etching, hand ground arrows or engraving.
- The approved testing lab will remove several samples and forward the test results to the potential material supplier. The material source will pay for this testing.
- The provisional testing period shall last a maximum of 30 months from the first production insert test submitted. The provisional source must meet all requirements of this specification.
- The first time acceptance rate must be 88% or better for the total population of inserts.
- When a piece is rejected, a new block of steel must be substituted by the Supplier at his cost.
- This substitute piece must meet the requirements of the specification. If it fails, then the provisional testing period is over and the Supplier must start the whole process again.
- If 30 months is not sufficient time to complete the confirmation process, the Supplier may elect to begin the process again.

The impact test is realized as supplied and after heat treatment. Two testing temperatures are used. Temperature ca 20°C and average operational temperature of die 232 °C. Three impact tests are made from every temperature and then the average value is calculated. The same principle of testing is after heat treatment - quenching (the impact test of 3+3 specimens). The specimen must be treated together with die (to guaranteed same conditions).

High number of test specimens is limited factor for this method and mainly for small parts (e.g. core, inserts etc.) and small dies. The main reason is economical (high cost for material – average cost are 10 – 20 EUR per kg and recommended test area weight approximately from 1 to 2 kg + costs for exams). For smaller parts 2 transverse (see fig. 1) are required.

2.1. Analysis of methodology NADCA

The basic method in this methodology is Charpy impact test – this test is used around the world from 1905 and is still relevant. The main problem of this method is a large dispersion of results (mainly in room temperature) and the fact that the exam is possible to affect by human factor. Preparation of the specimen and realization of the test is also complicated. Strength test or pressure test is better indicator – smaller range of results and more accurate prediction of material properties is expected.

Next aspect for die materials is hardness test – usually is used HRC, but the disadvantage of this method is very wide scale (e.g. 48±1HRC). Vickers method (HV) is much better – is more accurate and recalculation is easy – HV is approximately 10 times HRC.

Fig. 1 The principle of made test coupons

Next important step is monitoring of a low contain of gas (oxygen, nitrogen, hydrogen) in metal matrix. These elements cause undesirable brittleness of material. Among others undesirable elements are the metal with low melting temperature (e.g. zinc, tin, copper) – source of these metals is primary metallurgy. Special metallurgical processes could eliminate these elements (vacuum remelting and ESR process).

Next suitable change of this methodology is introduction of material anisotropy. Three specimens from different angle (0°, 45° and 90°) to rolling direction are tested. The anisotropy of material and right choose of the position considering of die filling is the way how to extend die life. Many die materials from different suppliers are now available. Choice of material is the most important step to obtain maximal properties. Underestimation of the specification could lead to some material problems and also could reduce the die life.

In general term is possible to say that there is large competition between suppliers and much effort is expected to realize the requirements of tool shop.
3. The suggestion of methodology for taking-over die material from suppliers

- Checking of chemical composition – for all elements (not only for guaranteed) – mainly with accent to appearance of gases and metals with low melting temperature – because trace amount have large influence to die life.
- Made the cylindrical specimens for pressure exam - 3x cylinders Ø6mm – length 12mm
- Analyze metallography – the size and orientation of grain, evaluation of banding segregation and evaluate the content of nonmetallic inclusions.

<table>
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<th>2. measure</th>
<th>3. measure</th>
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<th>Recalculation on HRC</th>
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</table>

4. The suggestion of methodology taking-over after heat treatment

- Specimens for the pressure testing will be heat treated together with part of die - evaluation of pressure test
- Evaluation of hardness with Vickers method – tolerance ± units of HV.
- Metallographic evaluation after heat treatment – size of martensite grain

There is the most important question: when is the right time to make heat treatment? After machining or before machining? From this point of view is the most complicated spark erosion machining – after this operation thin white layer will appear on the surface. Very similar situation is in HSC machining – a large stress in surface layer causes small cracks.

5. Experiment

Several parts were evaluated during experimental phases. Inserts for HPDC dies, which cracked after testing phases (a few cycles) or during first tens of cycles in manufacturing, were main target of the tests. The damage was the same as after several hundreds of thousands cycles fatigue.

The problematic die inserts from material W403 (Böhler) and TQ1 (Kind&CO Edelstahlwerk) were tested. The material W403 cracked during testing phases – sampling. The cracked insert was repaired by welding. After several next cycles same situation was repeated. This part of the die was suitable for our destructive experiments.

The specimens were prepared by wire cutting method and their sign are shown on fig. 2.

Some metallographic test (banding segregation etched by Vilella, non metallic inclusion by standard ČSN ISO 4967
– for types of inclusion, at 50x, the size of grain at 500x, etched by 5% NITAL) were evaluated.

Fig. 2 The system of specimens from cracked die insert

Hardness on functional surfaces was measured during testing phases, as shown on tab. 1. From this table is possible to see large difference between hardness (difference is 5 units HRC on length 10 cm). The large difference is possible reason of die damage – stress and deformation after heat treatment.

From experiments were deduced next steps:

- The weld deposit was made with the goal to repair the crack as fast as possible (manufacturing reasons) – from fig. 3 is possible to see detail of the weld – the reason of fatigue. Annealing wasn’t realized between welding operations.
- Limit value of banding segregation and limit grain size of martensite was found. It was tested by NADCA 207 comparable tables. All structure could be evaluated as acceptable and simultaneously non acceptable (e.g. banding segregation and material cracks is possible to see on fig. 4.
- The evaluation of material W403 and TQ1 (in standard NADCA 207 it is the same class of material) is reflecting large differences – mainly in martensite distribution, the size of martensite grain and matrix composition (see fig. 5. and 6.)

Fig. 3 Detail of cracks in place 3.2. after weld deposit at 25x

6. Conclusion

Because of the high financial and time demands of NADCA is necessary to create a new (or modify existing) testing methodology. Method for measuring impact toughness, which is used by NADCA, but not fully sufficient to determine the material properties - particularly because of the size of the forms used
(according to NADCA would not be advisable to carry out initial tests on about 90 - 95% ordered preparations for the rest of it would be very expensive - especially when the average price of the tool material is between 10 - 20 EUR/kg).

What is also needed is a detailed specification of the technological process for the processing of dies for conducting the tests and in particular the initial specifications of the material properties from the supplier. We are now in the process of testing a new methodology, every step is verified and we are creating the first database of knowledge that everything could be generalized to more tool materials. First results showing diametric difference in access to material in the regulations NADCA 2005 and 2008. The rules in the year 2005 clearly defined criteria for the approximately 20 most frequently used tool materials from different manufacturers, while in the new version is everything already generalized. The biggest difference is in the generalization of the types of alloys (by only grade A - E and production - vacuum remelting or electroslag remelting), content of allowed inclusions in the new standard increases by around 1 to 2 grade (eg inclusions of type B - aluminate was size 0 - 0.5 - now is 1 - 1.5). Similarly, eg globular oxides (inclusions of type D) was in some materials 0 (no inclusions may be present) - it is now permissible range of 0.5 – 1.

Given that significant cracking inserts and dies starts practically this year (in the CR, we have recorded about 20 cracked inserts at the beginning of casting. In recent years, it was rather rare cases), we think that the fault lies with a new regulation which allowed more inclusions that can cause the cracking and low melted eutectics, which deteriorates heat resistance and will form the acceleration of fatigue phenomena in the form. Therefore, we recommend: go back to delivery terms according to the regulations of 2005.

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