

NADCA 207-2016 JAKO NÁVOD PRO SYSTÉM ŘÍZENÍ JAKOSTI TEPELNÉHO ZPRACOVÁNÍ OCELÍ PRO PRÁCI ZA TEPLA

NADCA 207-2016 AS MANUAL FOR HEAT TREATMENT OF HOT WORK STEELS

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ABSTRACT

Nadca 207-2016 is a document developed by the North American Die Casting Association and sets acceptance criteria for steel purchase, heat treatment and welding. The document itself describes in detail the procedures for the above-mentioned areas, however, in order for this document to be practically usable, it is necessary to put into practice a system for quality management of die casting tools, which will bring these processes into practical life. For steel suppliers, for heat treatment plants, for tool shops and for tools users as well. The lectures give some principles that need to be applied so that the outcome of the whole process is a tool with an expected life.

1. Introduction

Hot working tools have their own specifics in that they are required to be highly resistant to thermal fatigue cracking. Over time, it has been found that there is a correlation between this requirement and the toughness of the material. This is essentially logical, since the tool surface is subjected to cyclic tensile / compressive stress during die casting and the toughness of the material can significantly push the limit of applicability of the mold for defect-free casting. However, it must be stated that Nadca is conceived as a methodology for ensuring tool life in terms of thermal fatigue, but does not address the issue of defects in terms of improper shapes, improper procedures, unprofessional interventions, etc.

Although the toughness parameter is not mentioned anywhere in the heat treatment orders, largely because there is no awareness of this parameter among tool manufacturers, no entity (steel supplier, tool manufacturer, hardener, user) can fully escape from it, that he would not know about this parameter.

Each heat treatment must take place in accordance with the customer's order. However, the fact that no toughness values are required on the order, but only the final hardness and the number of temperings does not mean that this parameter should be ignored. Although it is not usual to state legal terminology in the technical lecture, a reference to the Civil Code, § 1914, must be made here.

Whoever performs for a fee to another is obliged to perform without defects with the properties requested or usual so that it is possible to use the subject of performance under the contract, and if known to the parties, also according to the **purpose of the contract**. In this case, the purpose of the

contract is the heat treatment of the die-casting dies, and only this fact says that the heat treatment must take place according to Nadca.

However, the same principle applies to tool manufacturers as well as material suppliers. If the die-casting operator orders a die-casting die from the tool shop, the tool shop must perform according to the purpose of the contract, even if this does not have to be dealt with in detail in the contract. If the tool manufacturer orders material from a steel supplier, the steel supplier should also perform according to the purpose of the contract.

2. What is performance according to the purpose of the contract in the sense of the Nadca

For steel suppliers, this means that they must supply material that meets the requirement,

- The steel must have a controlled chemical composition, especially for S and P content
- The steel must be soft annealed, with a hardness of max. 235 HBW
- The steel must be remelted under slag or in a vacuum with controlled micropurity
- The steel must be inspected by ultrasonic testing according to ASTM A338 and E114 for forged materials
- Assumed impact strength derived from parent block testing performed by the steel manufacturer within its quality system
- Grain size of at least 7 and more according to ASTM E112 examined on a quenched and tempered sample
- Annealed structure, examined at a magnification of 500x, after polishing and etching in 5% NITAL, should correspond to the permitted structures according to Nadca metallographic maps.
- Permitted banding of the material should correspond to Nadca's metallographic maps

According to ASTM A681, all claims for deviations from the expected quality must be made within 30 days of delivery of the material. If any of the above parameters is not met, the customer has the right to request a replacement or withdrawal from the contract and a refund. At the same time, however, it may also demand compensation for damages resulting from defective performance. In this case, the damage may be wasted costs or lost profits. Although, under Czech law, claims for defective performance can be asserted within 2 years, it is necessary to realize that once the material undergoes a heat treatment process, this input defect will be difficult to prove. The term ASTM therefore has its significant logic.

For tool manufacturers, this means that the selection of steel and its input control is absolutely crucial. The material for die casting applications must be selected from the list of approved Nadca steels and from an approved supplier.

As heat treatment is a special process based on a change in the state of the material, it is necessary to know and have a documented initial state and a final state for the evaluation of defects. Although the tool manufacturer is not obliged to perform this inspection step, there is a risk of undetectable defects after heat treatment or by the user of the tool.

Nadca divides steels into Class 1 and Class 2. For Class 2, the steel must meet all the above criteria, but for Class 1, an input impact test for the tool manufacturer, is also mandatory. Therefore, if the

order states that the material is to meet the criteria for Class 1, the steel supplier must also supply the material for test coupons for incoming inspection and for tests after heat treatment according to the specification below. However, the test material must not be delivered separately from the supplied block, but must be part of it with a cut of up to 97% of the cut. The customer must consider that it has been proven that the test material actually comes from the delivered block and not from another.

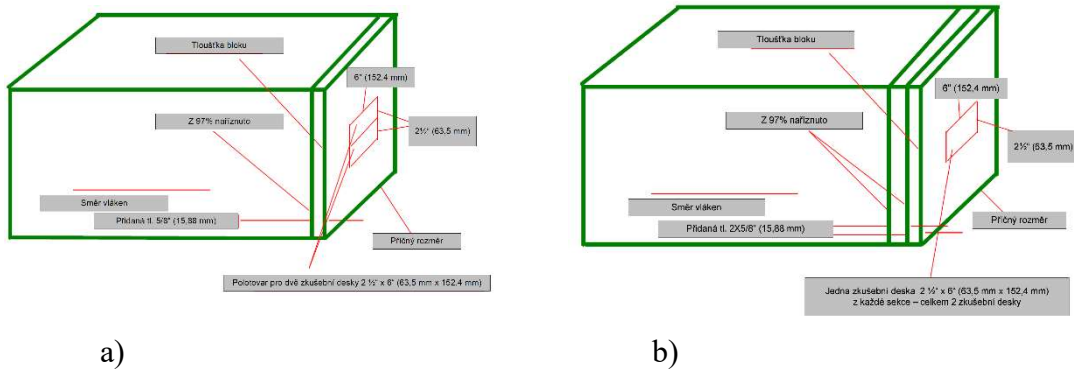


Fig. 1 - Determination of material blank for impact tests before and after TZ from large blocks (1a) and from blocks smaller than 152x165x25 mm (1b) [3]

Although this is a seemingly complex operation, in reality the tool shop is only obliged to cut part of the block for test coupons and machine two inserts measuring 63.5 x 152.4 x 15.8 mm from this part of the material.

The first test coupon will be sent to the heat treatment plant for ideal heat treatment. This is exactly specified in Nadca and is a reference oil hardening and two temperings. After the operation, the heat treater will send the coupon directly to a certified testing laboratory, which in CZ is only Element Material Technology (formerly Exova) Plzeň. He, usually within 48 hours, makes samples for impact tests and performs a Charpy test. The test report is sent to the heat treater, resp. tool shop. If the impact tests are within the prescribed limits, the block can be released for tool production.

If not, the input material does not demonstrably meet the required criteria and the entire procedure for claiming defects must be applied to it.

The second sample is attached to the actual die for heat treatment, eg by spot welding - see Fig. 2. The coupon undergoes heat treatment together with the block and at the end of the process is separated and sent for a second impact test. If the results are within the allowable range, the block returns to the tool shop for completion.

If the results are not OK, and the input tests were the norm, the tool shop will apply the defect procedure to the heat treater. The heat treater has one repair attempt. Before applying it, the part must be soft annealed again at the expense of the heat treater. If the result is not within the permitted limit even on the second attempt, the heat treatment source must supply a new block of material and cover all previous purposefully incurred costs.

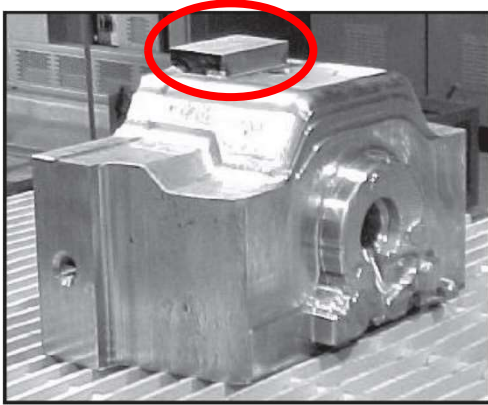


Fig. 2 – Example of coupon attachment for impact testing after hardening

For a heat treatment source, this means that it must both have equipment that meets Nadca's conditions and must apply documented procedures with parameters based on Nadca.

- The furnace must allow a cooling rate of min. 28 C / min and prove this
- The furnace must work with two batch thermocouples Ts (surface) and Tc (core)
- The heating of the parts must be checked and the surface / core temperature difference at the measured point must not exceed more than 110 C at temperatures up to 650 C
- The austenitization temperature must be in exact accordance with Nadca regulations
- The austenitization time should be max. 30 min after reaching $T_s - T_c < 14$ C, or max. 90 min after reaching $T_s = T_p$
- The cooling of the part should be at least with a cooling rate of 28 C / min in the range between the austenitization temperature and the moment when the surface of the part T_s reaches 425 C +/- 28 C.
- The isothermal hold should be activated automatically whenever the temperature difference $T_s - T_c$ is greater than 90 C at this point. However, this is a recommendation and this condition can be ruled out depending on the shape of the mold.
- The isothermal hold must end after 30 minutes at the latest, or if $T_s < 400$ C, or if $T_c - T_s < 110$ C. It depends on which condition is met first
- Furthermore, the part is cooled at the same rate as before the delay up to a temperature of 150 C and then at a reduced cooling rate or in air up to 50 C on T_s
- If re-hardening is to be performed, it must be preceded by soft annealing.

3. Quality management system in heat treatment plant

Although vacuum heat treatment, with the exception of LPC, is not yet included in CQI-9, reference may be made to this standard at some points. The quality system must take into account Nadca's requirements in the following chapters:

Section 1 – Management responsibility and Quality planning

- The heat treater must have a qualified person trained at Nadca, with at least 5 years of experience in working with this type of processing (CQI-9, point 1.1)

- The heat treater must have a sufficiently sophisticated the goods reception to distinguish the purpose of use of the tool for different applications so that it is able to assign Nadca procedures to parts according to die casting requirements (CQI-9, point 1.2)
- The heat treater must have sufficiently qualified procedures for inquiring towards the customer so that the purpose of the part, its history, Nadca test requirements, part history in terms of previous operations such as welding, annealing processes, etc. are recognized so that the work can be performed with due care according to §2590 OZ (CQI-9, point 1.2)
- The heat treater must have precisely specified procedures where the part can be accepted, when parts can be accepted with reservations, and when parts must be rejected for processing (CQI-9, point 1.2)
- Although the heat treater may not have FMEA (Failure mode and Effects analysis) for each Nadco part, its procedures from receipt to delivery must include a risk analysis (CQI-9, Section 1.3)
- Each part must have production documentation, including both customer requirements and Nadca parameters, and specifications of heat treatment procedures. These procedures must be registered in writing or electronically and documented both in terms of the steps required and in terms of how the steps were actually taken and what the deviations from the requirement were (CQI-9, point 1.4).
- The heat treater must have standards assigned to the individual procedures and must keep these standards up to date (CQI-9, point 1.5)
- For each operation, there must be a written record of the planned values and a written record of the actual values, including the registration of deviations (CQI-9, point 1.6)
- Each production order should have a feasibility test and this test should be recorded in the ERP system (CQI-9, point 1.7)
- Each heat treatment cycle should have a record of the process values, and data from these records should be recorded, archived and analyzed (CQI-9, point 1.8)
- The heat treater should have detailed records of nonconformities, deviations and analyze these defects every 24 hours with subsequent corrective action (CQI-9, point 1.9)
- The heat treater should have a system of internal audits and self-assessment (CQI-9, point 1.10)
- The heat treater should register, inspect and analyze all rework related to customer parts (CQI-9, clause 1.11)
- The heat treater quality system should be able to register, analyze and take corrective action on all customer comments (CQI-9, paragraph 1.12)
- The heat treater should have a system of continuous improvement based on previous points (CQI-9, paragraph 1.13)
- The heat treater should have a system of registration, marking and storage of nonconformities with complete traceability (CQI-9, point 1.14). The system must prove that only authorized persons have the opportunity to handle such parts
- All heat treatment procedures must be documented in writing, including the registration of all change procedures. It is necessary to ensure the evidence of the implementation of heat treatment procedure in terms of history and subsequent validity of all documents related to it (CQI-9, paragraph 1.15)
- All employees should be periodically trained and their training should be properly recorded (CQI-9, paragraph 1.16)
- The heat treater must have an authorization matrix specifying that each process and each operation is performed only by authorized persons (CQI-9, paragraph 1.17)
- The heat treater must ensure a system of preventive maintenance, and the validation of furnaces and equipment must meet the requirements for the reliability of equipment and quantities (CQI-9, point 1.18)

- If more than one type of material is processed in the process, documentation of this condition must be provided and it is demonstrated that if this condition is applied, it is ensured that austenitization, quenching, tempering and other parameters are appropriate for each material individually (CQI -9, paragraph 1.20)

If we simplify all of the above, the heat treatment must be performed according to the purpose of the contract. The heat treatment must take place according to the usual conditions, ie in this case according to the conditions usual for Nadca. What does this mean in the quality management system?

Acceptance of the order - the heat treater must have properly prepared instructions for accepting the order and for the method of inquiring about the purpose of use. Procedures for Contract review must be established and a record made of this procedure. By registering the order, the heat treater acknowledges that it accepts all the conditions of the customer. In the event that these conditions are in conflict with the purpose of performance, there must be a record of permission of deviations, refusal of processing, confirmation of tool manufacturers with consent of risks, etc. Part of the acceptance procedure must also be the determination of the price so that the provisions of the Contract for work can be fulfilled

Production order - a technological procedure with individual operations must be attached to each order. These operations must have defined parameters according to Nadca, or references to them (eg Program No. 1, Furnace No. X). In such a case, however, the Furnace Programs must be controlled by documents, including records of changes and validity. All production requirements or standards according to which the operation must be performed must also be stated on the production order. There must also be records of the validity of these standards so that it can be demonstrated when and according to which standard the operation or activity was performed.

Production process - records of all operations and processes must be ensured so that it is possible to compare the values required by Nadca and the actual values. There must be a record of the individual processes and this record must be unambiguously assignable to the processing part, the equipment or the person who performed the operation. In the manufacturing process, information must be provided on the part location in the batch or on the location of the batch thermocouples. According to Nadca, the heat treater is not obliged to provide records of the cycles, but these must be available for possible defect proceedings. The heat treater is obliged to provide a protocol on processing according to Nadca, which contains a list of parameters necessary for the correct documentation of the process.

Quality control order - the heat treater must have elaborate guidelines on the method of measuring and certifying parts for Nadca, both inter-operationally and for output control. If the acceptance procedure also includes impact toughness, full traceability of coupons for impact tests must be ensured, including an order for external testing and records of the resulting values. These must be fully assignable to the treated die. In the event of a complaint and possible reworking, there must be full traceability of the reworking process, including the identification of new results

Delivery of the subject of the order - return delivery of parts processed according to Nadca is possible only under the conditions of meeting the parameters of Nadca. It is necessary to distinguish between deliveries for materials and processing Class 1 and Class 2. The accompanying documentation for the delivery must contain data ensuring the traceability of the part and at the same time a statement by the heat treater that all conditions have been met. Sending a record of process data in the form of diagrams is not required and is not a condition for delivery. It is only up to the heat treatment operation, how it archives the records and how they can be traced back in case of complaints. However, Nadca requires a protocol that is a summary of the required and actual quantities. The certificate of conformity must contain the following 20 parameters:

- A. Heat Treat Source
- B. Item Identification
- C. Heat Treatment Quality Class (1 or 2)
- D. NADCA Steel Grade & Category
- E. Material Heat Number
- F. Shipping Weight
- G. Shipping Hardness
- H. Pre-Heat: Step 1 Temperature & Time
- I. Pre-Heat: Step 2 Temperature & Time
- J. Pre-Heat: Step 3 Temperature & Time
- K. Hardening: Temperature & Soak Time
- L. Quench Rate
- M. Quench Pressure
- N. Interrupt: Temperature & Hold Time
- O. 1ST Temper: Temperature, Soak Time, Hardness
- P. 2ND Temper: Temperature, Soak Time, Hardness
- Q. 3RD Temper: Temperature, Soak Time, Hardness
- R. Final Hardness
- S. Hardened Microstructure*
- T. Hardened Impact Toughness*

Required for Heat Treatment Quality Class 1 and shall include three individual results and average results.

* Test results can be provided by a heat treater or testing facility.

4. Conclusion

Nadca is a general, non-mandatory regulation, resp. instructions for maximizing the resulting mechanical properties of the material for application to die casting dies, in order to minimize errors at the steel supplier, tool manufacturer or heat treatment source. However, if this manual is to be functional, it must be fully implemented in the quality management system. How the individual chapters of the quality management system in the heat treatment operation are affected is mentioned above. However, the same principle must be applied to the steel supplier or tool manufacturer. In this, it is also possible to refer to the internal company standards that follow Nadca. E.g. Ford AMTD-DC2010, revision I, or GM Powertrain Group, DC-9999-1, rev. 18. In addition, they contain procedures for the approval of steel suppliers, heat treatment suppliers, and at the same time address liability for defects and damage resulting therefrom. This may seem trivial, but it is no exception that the damage caused in this process leads to significant financial amounts, so it is good to be prepared.

- [1] NADCA 2017-2016
- [2] CQI-9, 3rd edition, Heat Tret System Assesment
- [3] AMTD DC2010, rev. L