HTS

ADVANCED TECHNICAL PROCEDURE
DIE COMPONENTS MANUFACTURING

integraTool

htsgroup.com

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1. About integraTool Technical Procedure

integraTool technical procedure is an HTS established process for the production and certification of die components, based on the integration of steel supply, rough machining, heat treatment, and final inspection, into a single, rigorously controlled workflow.

By managing the entire process from material selection to post-treatment verification, we ensure that both material and mechanical properties meet the required specifications. This approach eliminates the risk of discrepancies between the steel supplier and the heat treatment contractor, providing a consistent and repetitively reliable outcome.

The integraTool procedure also includes comprehensive documentation, rom steel mill certificate to heat treatment diagrams and 3D scan report to verify compliance with quality standards and to guarantee that the final product is ready for machining.

1.1. integraTool Benefits

Continuous top-tier quality

integraTool technological procedure is based on the most stringent die component industrial standards (GM DC-9999-1) to ensure required quality and properties.
Certification document pack with complete steel, HT and machining conformity approval documents is supplied with each component.

Consistent, superior performance

We guarantee min. 14J impact toughness for SITHERM 2343 and min. 16J for SITHERM S353R.

Seamless project execution

Steel, heat treatment, machining and logistics all performed by HTS. You place the order, we deliver.

One Workflow, Zero Compromise. Always

integraTool procedure precisely defines the entire production process, ensuring repetitive consistency and reliability.

Imposing rigorous control at every production step, any discrepancies are eliminated to ensure top-tier quality and performance in every component.

1.2 integraTool Process Overview

integraTool process is based on GM DC 9999-1 standard

PREMIUM HOT WORK TOOL STEEL

- To ensure that steel conforms to integraTool standards, the steel mill must meet the pre-defined requirements regarding melt practice, chemical composition, forging, hardness, microcleanliness, grain size, annealed microstructure, banding segregation and impact capability.
- Once the steel is delivered, HTS runs a separate flow of tests in its own laboratory, to confirm steel's compliance with integraTool requirements.

Based on steel mill certificate and HTS laboratory tests, only the steel with compliant chemical composition, micro cleanliness, grain size, microbanding and impact capability passes to machining phase.

HIGH PRECISION MACHINING

- Die component is machined according to customer drawing/model with HT stock to ensure compliance with customer's final dimensional requirements.
- GOM measurement is performed to ensure dimensional compliance.

Based on GOM measurement, only the die components within the designated tolerances, pass to heat treatment phase.

ADVANCED HEAT TREATMENT

- Die component equipped with 3 thermocouples is heat treated according to required insert mechanical properties.
- HTS laboratory performs additional tests to confirm / reject the insert microstructure, hardness and toughness compliance with NADCA 207-2023.
- We guarantee min. 14J impact toughness for SITHERM 2343 and min. 16J for SITHERM S353R.

Based on testing sample analysis, only the inserts complying with NADCA 207-2023 standard requirements are supplied to customer.

COMPLETE QC DOCUMENTATION IN ONE PLACE

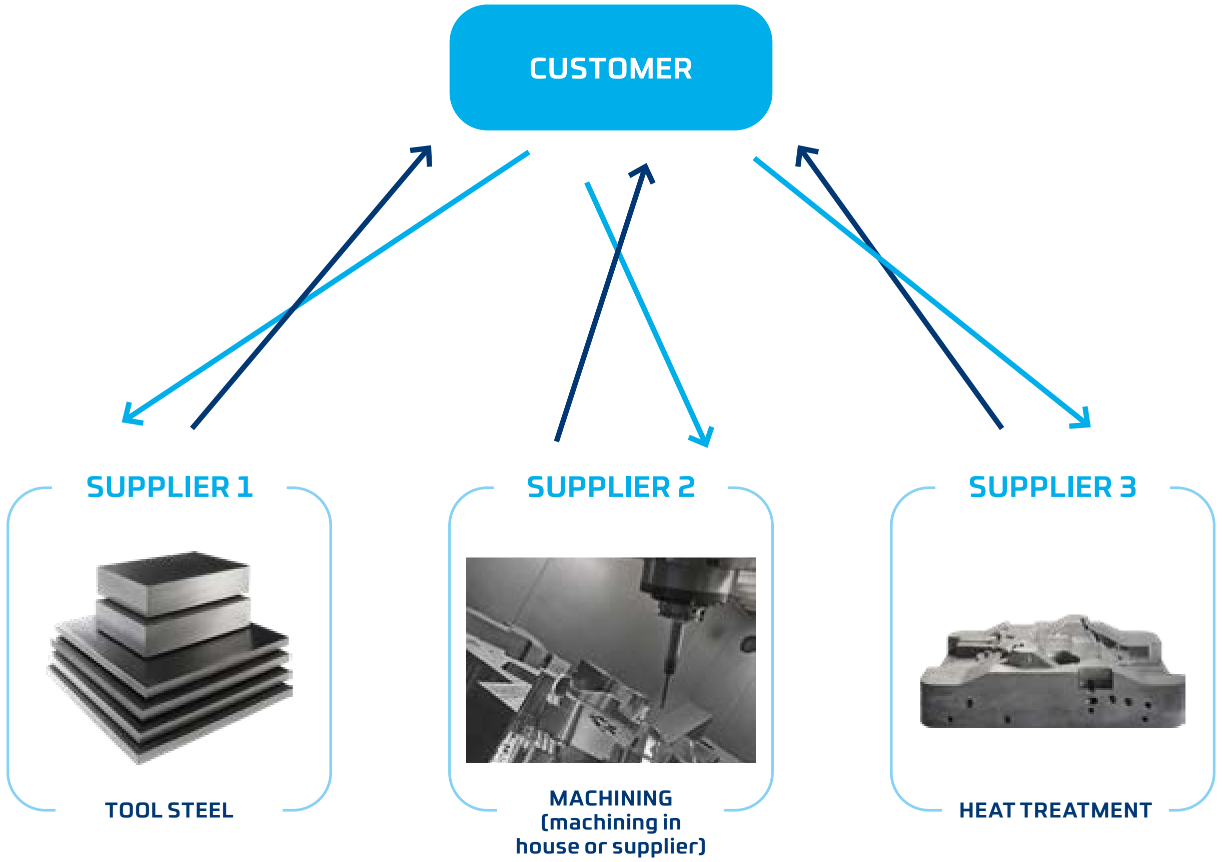
With the die components, customer receives the full QC documentation stack with steel mill certificates, heat treatment diagrams, HTS laboratory steel and heat-treated testing samples results, displaying the conformity of all production steps.

By following rigorous procedure, we eliminate any quality deviations.

1.3 Simplifying Complexity

Typical toolmaking process

- Separate and multiple communication points and document flow with each supplier
- Logistical hassle between numerous facilities
- Separate QC documentation and limited guarantee by each supplier
- Complex claim solving process, involving 4 parties
- Longer lead times



integraTool process

- **One point of contact for the complete project:** streamlined communication and project management with a dedicated contact.
- **No time and effort spent on logistics:** seamless coordination within HTS Group facilities.
- **One folder with all QC documentation:** consolidated quality control documentation and comprehensive guarantee.
- **Elimination of claims:** any quality deviations are detected and resolved during the internal HTS process.
- **Short lead times:** efficient processes lead to quicker turnaround times for projects.

1. Premium Tool Steel

For integraTool we use premium hot work tool steels produced by SIJ Metal Ravne.

SITHERM 2343R

High tempering resistance and toughness in hot applications. Since the steel is an ESR-steel, it is recommended for the most demanding processes (where significant temperature shocks exist). Can be nitrated.

Applications

Tools for the die casting of aluminium and zinc, for die forging and aluminium extrusion: pressure plates, pistons, recipients, die holders. For plastics processing with the option to polish. Blades for shredding waste rubber. Usual working hardness of between 42 and 48 HRC.

SITHERM S353R

Customely developed steel grade with high toughness and good thermal fatigue resistance within the normal range of hardness for hot-work applicationslike die casting, die forging and extrusion.

Applications

Primarily designed for die casting of light metals and alloys as well as extrusion and die forging. It is often used for highly stressed hot-work structural parts where superior toughness is required. SITHERM S353R is also recommended for die forging and extrusion. Because of its good polishability, the grade can be used for plastic molding applications.

1.1 Steel quality requirements SITHERM 2343R

To ensure the quality of steel, the steel supplier, adheres to the following requirements:

1.1.1 Melt practice

All hot work tool steels are refined using the ESR method.
Under no circumstances any piece of steel is non-ESR steel.

1.1.2 Chemical composition

The chemical composition of forged steel corresponds to the composition specified in the standard SIST EN ISO 4957: 2018.

2343R	C	Si	Mn	P	S	Cr	Ni	Mo	V	Cu
MIN	0,35	0,80	0,30			4,90		1,25	0,30	
MAX	0,40	1,00	0,50	0,015	0,003	5,20	0,25	1,55	0,50	0,20

Table 1: SITHERM 2343R chemical composition

1.1.3 Forging

Processes are designed to achieve homogeneity and meet the ultrasonic testing conditions according to the SEP1921 Group 3 standard, ESR: Class E/e.

1.1.4 Hardness

The hardness of the soft annealed steel does not exceed 229 HB.

1.1.5 Microcleanliness

The micro-cleanliness of the steel complies with DIN 50602 using method K and ASTM E45 method A.

At	Bt	Ct	Ad	Bd	Cd	Dd
≤ 1.0	≤ 1.0	≤ 0.5	≤ 1.0	≤ 1.0	≤ 0.5	≤ 1.0

Table 2: ASTM E45 - method A

1.1.6 Ultrasonic inspection

An ultrasonic test according to EN 10228-3 cl 4 is performed. The steel must not have internal defects (slag residues, oxides, porosity, coarse segregation) that could lead to damage during further processing.

1.1.7 Impact capability testing

The test is performed on a calibrated ISO 148 device. The highest and lowest values are not used in calculating the average value. The obtained values and average are compared with the values of annealed steel given in Table 3, NADCA # 207-2018, and the table where the classification into size classes and the H/W ratio is added.

Hardened* 44-46	Size classes/NADCA#207-2016: KV2 (J)							
	R1 ≤ 810x365		R2 ≤1010x450		R3 >1010x450		NADCA#229	
Ratio H/W	Avg.	Min.	Avg.	Min.	Avg.	Min.	Avg.	Min.
Ratio 1-1,5	26	20	24	19	23	16		
Ratio 1,5-2	25	20	24	19	23	16		
Ratio 2-3	25	20	23	17	/	/		
Ratio 3-5	24	19	/	/	/	/		
Ratio 5-8	23	18	/	/	/	/	19	15

Table 3: Table of impact toughness values for SITHERM 2343R steel.

1.1.8 Grain size

Grain size according to ASTM E112, is 7 or finer. Grain size is developed by direct quenching and tempering at 590 °C.

STEEL	HEIGHT (T): ≤ 365 mm*	HEIGHT (T): > 365 mm*
SITHERM 2343R	Min. 7 or finer	Min. 6 or finer

Table 4: Grain size requirements for SITHERM 2343R.

1.1.9 Annealed microstructure

The annealed microstructure is homogenized ferrite with spherical carbides. Depending on the size class, the steel is assigned the expected microstructure according to AS NADCA # 229.

R1	R2	R3
AS1-AS6	AS1-AS9	AS1-AS9+ do 15% AS10-AS15

Table 5: Microstructure quality for size classes.

1.1.10 Banding segregation

Check according to the NADCA #229 reference list is performed to assure that there is no excessive segregation.

1.2 Steel quality requirements SITHERM S353R

To ensure the quality of steel, the steel supplier, adheres to the following requirements:

1.2.1 Melt Practice

All hot work tool steels are refined using the ESR method.
Under no circumstances any piece of steel is non-ESR steel.

1.2.2 Chemical composition

The chemical composition of forged steel corresponds to the composition specified in the standard SIST EN ISO 4957: 2018.

S353R	C	Si	Mn	P	S	Cr	Ni	Mo	V	Cu
MIN	0,36	0,20	0,40			5,00		2,30	0,45	
MAX	0,39	0,30	0,60	0,012	0,003	5,20	0,30	2,40	0,60	0,20

Table 6: SITHERM S353R chemical composition

1.2.3 Forging

Processes are designed to achieve homogeneity and meet the ultrasonic testing conditions according to the SEP1921 Group 3 standard, ESR: Class E/e.

1.2.4 Hardness

The hardness of the soft annealed steel does not exceed 229 HBW.

1.2.5 Microcleanliness

The micro-cleanliness of the steel complies with DIN 50602 using method K and ASTM E45 method A.

At	Bt	Ct	Dt	Ad	Bd	Cd	Dd
≤ 1.0	≤ 0,5	≤ 0.5	≤ 1.0	≤ 0.5	≤ 0.5	≤ 0.5	≤ 1.0

Table 7: ASTM E45 - method A

1.2.6 Ultrasonic inspection

An ultrasonic test according to SEP1921 Group 3 , ESR: Class E/e is performed. The steel must not have internal defects (slag residues, oxides, porosity, coarse segregation) that could lead to damage during further processing.

1.2.7 Impact capability testing

The test is performed on a calibrated ISO 148 device. The highest and lowest values are not used in calculating the average value. The obtained values and average are compared with the values of annealed steel given in Table 3, NADCA # 207-2018, and the table where the classification into size classes and the H/W ratio is added.

Hardened* 44-46	R1 < 810x305		R2 > 810x305		NADCA#229	
Ratio H/W	Avg.	Min.	Avg.	Min.	Avg.	Min.
Ratio 1-1,5	25	20	23	18	19	15

Table 8: Table of impact toughness values for SITHERM S353R steel.

1.2.8 Grain size

Grain size according to ASTM E112, is 7 or finer. Grain size must be developed by direct quenching and tempering at 1020 °C.

STEEL	HEIGHT (T): ≤ 325 mm*	HEIGHT (T): > 325 mm*
SITHERM S353R	Min. 7 or finer	Min. 7 or finer

Table 9: Grain size requirements for SITHERM S353R.

1.2.9 Annealed microstructure

The annealed microstructure is homogenized ferrite with spherical carbides. Depending on the size class, the steel is assigned the expected microstructure according to AS NADCA # 229.

R1	R2
AS1-AS6	AS1-AS6

Table 10: Microstructure quality for size classes.

1.2.10 Banding segregation

Check according to the NADCA #229 reference list is performed to assure that there is no excessive segregation.

1.3 HTS internal steel conformity testing

1.3.1 Inspection of the values on steel mill certificate

Upon receipt of the steel, all the required values indicated on the steel mill certificate comply with those indicated in the Steel Quality requirements paragraph (1.1).

1.3.2 Inspection of the values in HTS laboratory

For premium steel compliance, HTS Laboratory, upon receiving the steel, performs the following tests:

- Hardness
  - Hardness of steel HB,
- Mechanical properties
  - Toughness test
- Metallographic properties
  - Annealed microstructure NADCA 229
- Grain size
  - Grain size according to ASTM E112.

If the tested values do not comply with the certificate, the steel is returned to the mill.

1.3.3 Inspection Requirements

Test items are those listed in the Steel Quality requirements (point 1.1). Frequency of testing is 100%. All steel blocks are tested without exception. Testing is performed by the HTS Laboratory.

1.4 Test coupons handling before HT

1.4.1 Tool block dimensions specification

The size and shape of the tool block are clearly defined to ensure adequate extra stock is included for machining and adjustments.

1.4.2 Tool block cutting

A parent block with a minimum thickness equal to or greater than the smallest dimension of the tool block is selected. The tool block is cut from this parent block, ensuring it has sufficient material for all intended machining processes.

1.4.3 Toughness test plate cutting

After cutting the tool block to the specified dimensions, a 15 mm thick plate is cut from the end of the block. This plate is used for toughness testing.

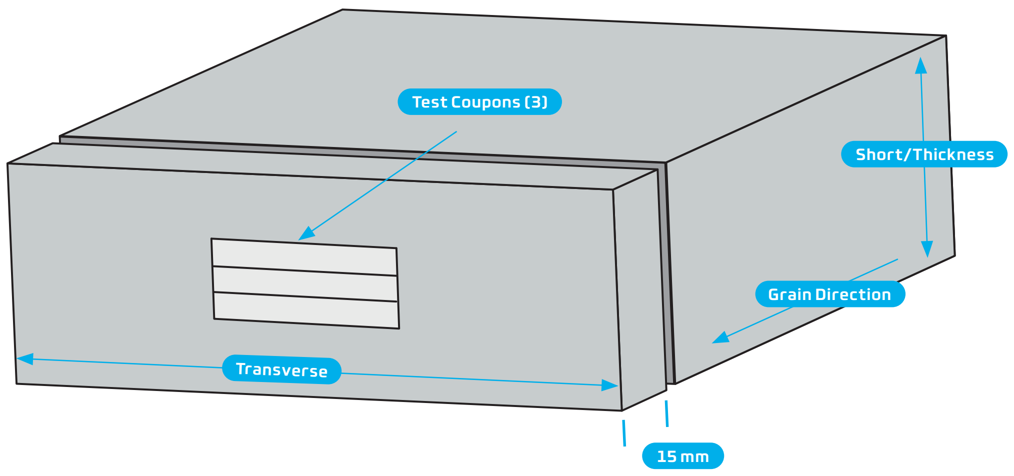


Figure 1: The position of the plate cut and the extraction of toughness coupons.

1.4.4 Toughness coupons extraction

From the center of the 15 mm thick plate, 3 toughness coupons are extracted. Each coupon measures 90 mm × 60 mm × 15 mm. These toughness coupons are used to assess the steel's properties and ensure that it meets the required standards.

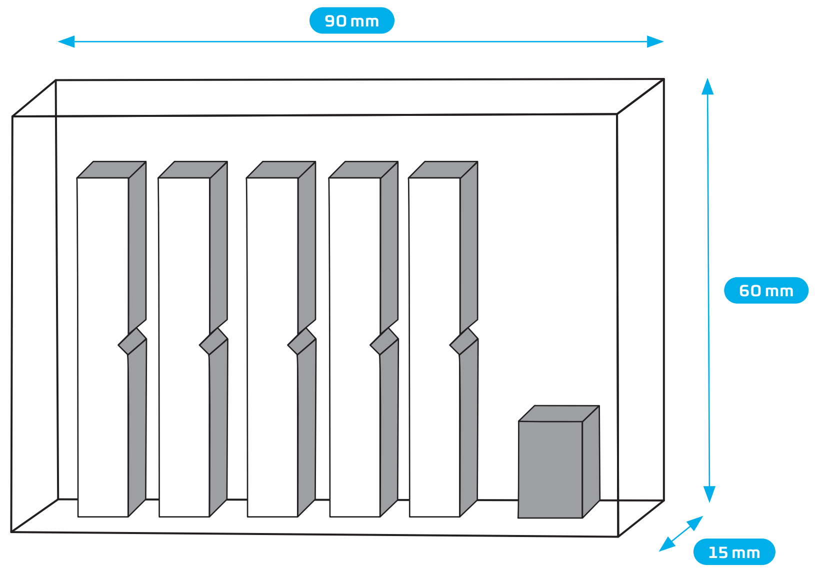


Figure 2: Testing coupon and specimens.

1.4.5 Coupon handling

Coupon 1 Testing
The purpose is to ensure the steel meets premium steel compliance standards.

Testing Location: HTS Laboratory.

Tests Performed:
- Hardness: Evaluation of the hardness of the steel (HB).
- Mechanical Properties: Assessment of the mechanical properties through a toughness test.
- Metallographic Properties: Analysis of the microstructure of the steel according to NADCA 229 standards.
- Grain Size: Grain size determination using ASTM E112 methodology.

Coupon 2 Processing
The purpose is to ensure that the Heat treatment procedure meets the requirements.
After testing, this coupon proceeds to the HT process along with the tool. Detailed testing procedure is described in point 3.4 of this document.

Coupon 3 Handling
The purpose is to be kept as a spare for potential future testing or analysis.

2. High Precision Machining

Compliance with integraTool requirements is ensured throughout the order process, machining requirements, and machining process

2.1 Machining service order process

1. Model Transmission: Once HTS accepts the order, the 3D model of the tool is sent to OROMET d.o.o.
2. Tool Selection: The appropriate machining tool and its corresponding machining radius are selected.
3. Machining Simulation: A machining simulation is performed using the selected tool.
4. Model Review: The obtained model is sent to Steel d.o.o. (HT) for review.
5. Extra Stock Assessment: Steel d.o.o. assesses whether the offset is sufficient for the execution of the HT process. If the offset is greater than defined in Table 10, it requires agreement from the customer or the final machining party.
6. Order Finalization: A three-sided agreement between HTS, Steel d.o.o., and the customer is reached. Once consensus is achieved, the order confirmation is submitted by HTS to the customer, and the process begins.

2.2 Machining requirements

2.2.1 3D surface machining complies with the following general offsets:

Dimension	Offset per Wall
< 400 × 400 mm	1.0 mm
< 600 × 600 mm	1.5 mm
> 600 × 600 mm	2.0 mm

Table 11: General integraTool offset

2.2.2 Offset

If the offset is greater than defined in Table 11, it requires written agreement from the customer or the final machining party.

2.2.3 Additional requirements

The smallest milling tool defined for rough machining is diameter 10 R5.

2.2.4 Milling tool specification

Any additional machining requirements are defined, documented and confirmed separately before proceeding with the order or the machining process.

2.3 Machining process

- **ABC Milling**
- **Cooling Channels and Thread:** Ensuring that the ends of the channels are rounded.
- **Machine Holes:** Machine holes for cores and ejectors with the defined offset.
- **Non-Tolerance Holes:** Finish machining is conducted on non-tolerance holes.
  3D Surface Machining with Offset
- **GOM measurement** is performed to verify the accuracy of the machining.

The scanned model is reviewed to ensure the tool has been processed according to the agreed dimensions. If the values are within the required, the process can proceed to HTS heat treatment (point 3). If values do not comply with the 3D model, the machining process needs to be redone.

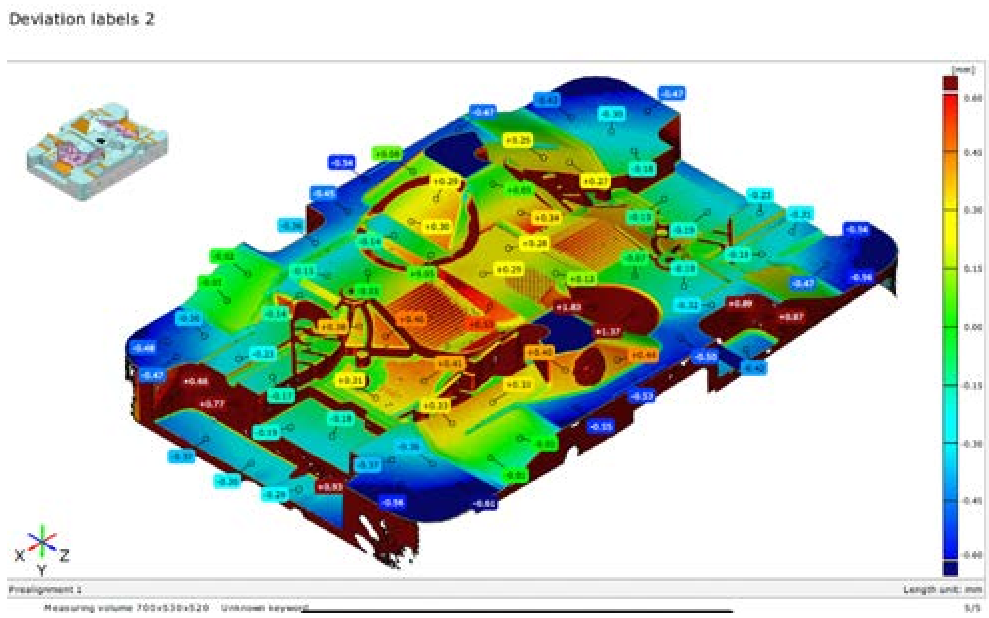


Figure 3: Example of a tool GOM measurement scan.

3. Advanced Heat Treatment

The quality of the Heat Treatment is ensured by the heat treatment partner STEEL d.o.o., who must guarantee the following requirements

3.1 Heat treatment quality requirements

3.1.1 Equipment

- A vacuum furnace with a capacity of 10 bar nitrogen back pressure is required. The furnace must be able to quench at a speed of 28 °C/min, depending on the surface thermocouple.
- A programmable controller that can be connected to a minimum of 6 thermocouples simultaneously is used to control interrupted quenching for a high difference between surface and core temperature.
- Thermocouple type K.

3.1.2 Furnace loading

- The HT parts are arranged in the furnace in such a way as to allow even heating and cooling.
- The complex geometry of the part is taken into account to ensure even heating and to prevent cracking.
- The furnace is not overloaded because doing so prevents it from achieving the necessary cooling rate. This could lead to inadequate temperature control and compromise the quality or safety of the process (see furnace instructions). Pictures of the inside of the furnace are taken before proceeding to the HT process.

3.1.3 Thermocouple placement

- Two thermocouples are placed in the tool to control the heat treatment cycle.
- The surface thermocouple (Ts) is installed in a screw that is screwed into the threaded holes. The hole in the screw is 15 ± 3 mm deep and has a diameter of 2 mm.
- The screw for the surface thermocouple is installed in the threaded hole as far away from the edges and overhangs as possible.
- The core thermocouple is placed as close as possible to the center of the tool mass. Existing cooling ducts are used for installation. If installation through ducts is not possible, a test cube of the same thickness is used to monitor the condition.
- All thermocouple holes are filled with glass wool to avoid direct contact with the quenching medium.
- The wires of the thermocouples are secured to prevent them from moving during hardening.
- If several tools are hardened at the same time, the thermocouples are placed in the tool with the largest cross section.

3.2 Heat treatment process instructions

3.2.1 Stress relieving after rough machining

Tools with complex geometry require stress relief after rough machining. This is decided by the Steel d.o.o. Technology department upon receiving the tool for HT. Stress relieving process:

- We heat to 650 °C. The maximum heating rate is 220 °C/h.
- We keep the core thermocouple (Tc) at the temperature for 240 minutes.
- We cool to 425 °C at a rate not exceeding 110 °C/h.
- Then air cool to 65 C.
- All listed values refer to the core thermocouple.

3.2.2 Preheating

- The tool is placed in a cold furnace and heating is started with maximal heating rate of 220 °C/h, measured with Tc.
- The furnace is heated to 1st preheating level (680 °C) and then hold to Ts-Tc <110 °C.
- The furnace is heated to 2^{nd} preheating level (850 °C) and keep to Ts-Tc <10 °C, heating rate max. 170 °C/h.
- Additional preheating steps can be performed.

3.2.3 Austenitizing

- Rapid heating is applied to reach the austenitization temperature.
- When using two thermocouples: once Ts-Tc <10 °C, the temperature is held for at least 30 minutes.
- When using only a surface thermocouple: once Ta-Ts <10 °C, the temperature is held for up to 90 minutes.

3.2.4 Quenching

Harden at maximum quenching rate without risk of damage, as this achieves the best metallurgical properties.

- Te tool is tempered as quickly as possible to a Tc temperature below 150 °C and Ts above 50 °C.
- The cooling rate is kept, between austenitization temperature and 540 °C, at 28 °C/min. (measured with Ts).

3.2.4.a An interrupted quench

Method 1

1. Hardening is stopped if Ts reaches 475 - 425 °C, or when the difference between Ts and Tc is greater than 110 °C.
2. If stopped, rapid quenching is resumed when (using the fastest method):
   - Ts-Tc difference is less than 100 °C;
   - Ts reaches 425 °C;
   - Interruption of quenching takes max. 10 min
3. Rapid quenching is continued to Tc <150 °C.

3.2.5 Tempering

When Ts reaches 100 - 50 °C and Tc reaches bellow 150 °C the tempering process is initiated.

First Tempering Cycle
Initially, the tool is tempered at temperatures ranging from 540 °C to 565 °C. During this phase, the furnace is maintained at this temperature for one hour for every 25 mm of tool thickness. Meanwhile, the core of the tool is held at this temperature for a minimum of two hours. After this period, the tool is allowed to cool to room temperature.

Second Tempering Cycle
Following the first tempering cycle, the tool undergoes a second tempering at temperatures between 550 °C and 615 °C. Again, the furnace is kept at this temperature for one hour per 25 mm of thickness, with the core remaining at this temperature for at least two hours to achieve the desired hardness. Once this cycle is complete, the tool is cooled to room temperature. The hardness of the tool is then measured. If the hardness is deemed appropriate, the first tempering cycle may be repeated, although this time the minimum core time is reduced to one hour. If the hardness is found to be inadequate, the tool is tempered again to reach the desired hardness temperature, marking the second cycle.

Additional Tempering Cycles
Typically, a minimum of three tempering cycles is required to achieve the desired properties of the tool.

3.2.6 Recommendation

A tool with a complex geometry is tempered again after the final machining. This process is not included in the standard integraTool process and needs to be agreed upon in advance before the purchase order. It can also be performed at a third location.

- First, the tool is heated to 540 °C or 30 °C below the maximum tempering temperature.
- Second, the furnace is kept at this temperature for 1 hour per 25 mm of thickness, while the core is maintained for a minimum of 2 hours.
- Third, the tool is cooled to room temperature.

3.3 Test coupons handling during HT

A minimum of one set of five test pieces shall be tested for each batch. The test pieces must be made to an oversize of 15 × 15 × 60 mm.
The test coupons are heat-treated according to the following procedure:

- During the heat treatment, the coupon is placed on the tool away from corners and edges, so that the surface of 60 × 90 mm is in full contact with the engraving. A graphite cover is placed over the coupon
- The coupon is present during preheating, austenitization, hardening, and first tempering.
- If the final hardness of the tool is 44-46 HRC, the coupon can be also present at the second tempering. Otherwise, it is withdrawn and the second tempering is made separately.
- From the coupon, we get 5 test specimens for the Charpy test, and a sample for the metallographic test.

3.4 HTS heat treatment conformity testing

To ensure steel quality, HTS Laboratory tests the following requirements:

3.4.1 Hardness

Usually, the hardness is in the range of 42 to 52 HRC. The customer must specify the 3-point strength range he wants (e.g., 44-46). Hardness tests are performed according to ISO 6508-1. At least 5 hardness measurements (four angles and center) are performed. If the hardness is not within the specifications the tool cannot proceed to the customer.

3.4.2 Furnace chart data

- Data on heat treatment cycles should be kept for a minimum of 7 years.
- Required data are:
  - Preheating steps.
  - Temperature and time of austenitization (Ta).
  - Quenching rate for Ts from Ta-540 °C.
  - Tc and Ts from Ta to 150 °C.

3.4.3 Hardened microstructure

- The metallographic sample is prepared according to ISO 4499-1 and etched with 5% Nital solution.
- The hardened microstructure is made of martensite, with some bainite.
- Perlite, residual austenite, decarburization, and excessive dislocations are not present in the microstructure.
- The microstructure is assessed according to HS NADCA # 207: 2018.

3.4.4 3D scan of tool after HT

- After HT, the tool is sent back to OROMET for 3D scanning.
- A comparison of the 3D model before and after HT is prepared.
- From the deformations visible on the 3D scan, a report is issued to the customer, which will give an optimized plan of fine machining.

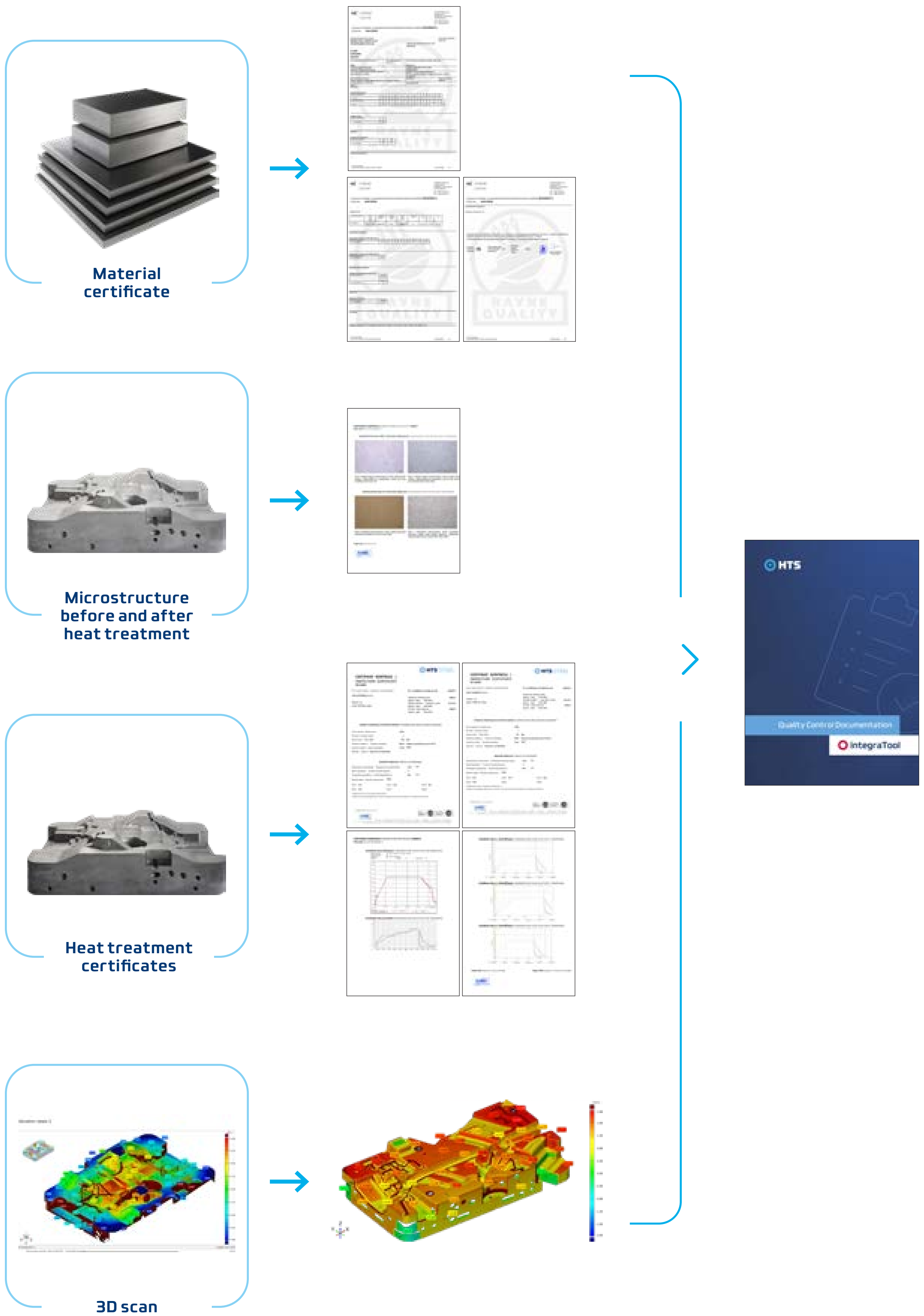
4. QC Documentation

With the Die components, we supply the full QC documentation stack with steel mill certificates, heat treatment diagrams, HTS laboratory steel and heat-treated testing samples results, displaying the conformity of all production steps.

Quality claims?

Eliminated.
Quality deviations are detected and resolved during the internal HTS process.

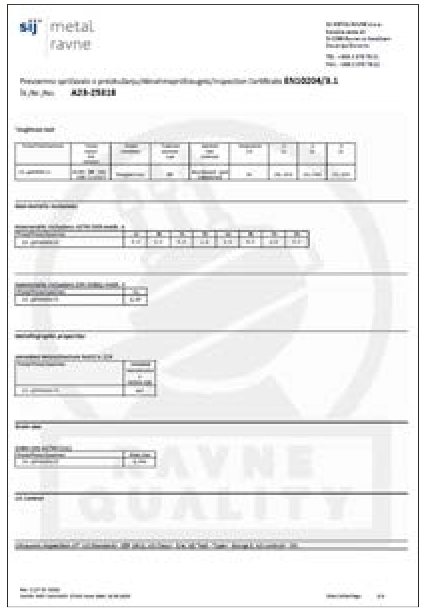
QC Documentation stack



4.1 Steel certificate

This certificate is prepared by the steel producer for each individual steel block. It ensures that every block meets the highest standards of quality and performance by providing detailed information on the following key aspects:

- **Chemical Composition:**
  Provides a detailed breakdown of the steel's key elements, ensuring it meets required specifications.
- **Oxygen Content:**
  Includes precise measurements of oxygen levels to assess the steel's purity and quality.
- **Hardness (HB):**
  Contains the Brinell Hardness value, indicating the steel's resistance to deformation and wear.
- **Toughness Test:**
  Presents the results of toughness tests, showing the steel's ability to absorb energy and resist fracture under impact.
- **Non-metallic Inclusions:**
  Analyses and quantifies non-metallic inclusions to evaluate steel quality and its mechanical properties.
- **Grain Size:**
  Offers a detailed analysis of the steel's grain size, which influences its strength, toughness, and overall performance.

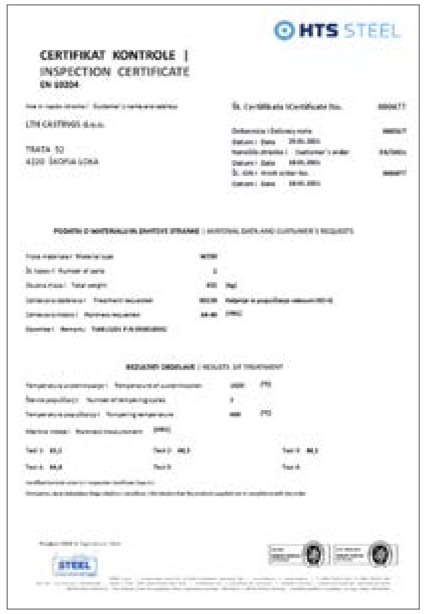




4.2 HTS laboratory tests overview

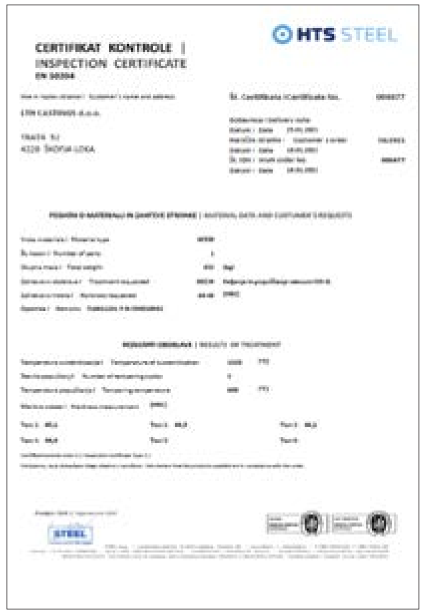
Detailed microstructure analyses, showcasing the steel's structural characteristics before and after heat treatment. This information is crucial for understanding the steel's transformation and ensuring it meets specified requirements.

Heat treatment certificates to validate performance of the tooling components:

- HT QC Certificate Hardness: Each batch of heat-treated components is accompanied by a detailed Hardness Testing Quality Control (HT QC) certificate. This certificate ensures that the hardness values meet the specified requirements with a tolerance of +/- 1 HRc.
- HT QC Certificate Toughness: Each batch of heat-treated components is accompanied by a Heat Treatment Quality Control (HT QC) certificate focusing on toughness.



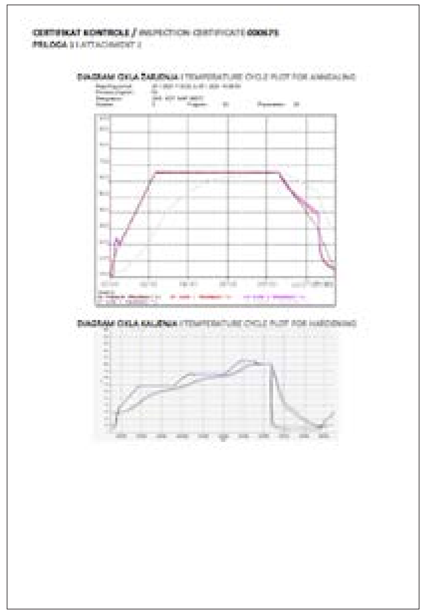
HT QC certificate hardness



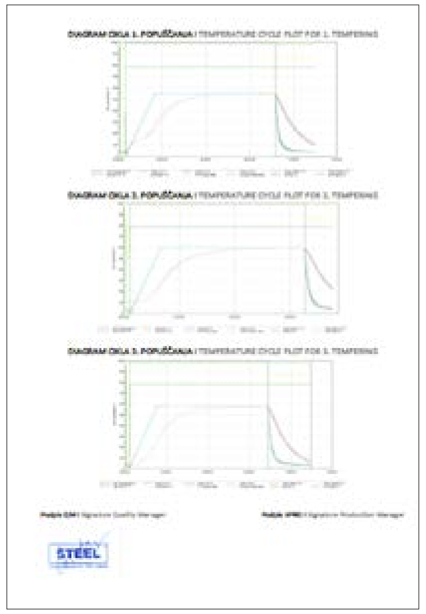
HT QC certificate toughness

4.4 Heat treatment diagrams

Hardening and tempering diagrams that depict the temperature profiles and time durations used during the vacuum hardening process. These diagrams offer a clear understanding of how the components are treated to achieve the desired metallurgical properties.



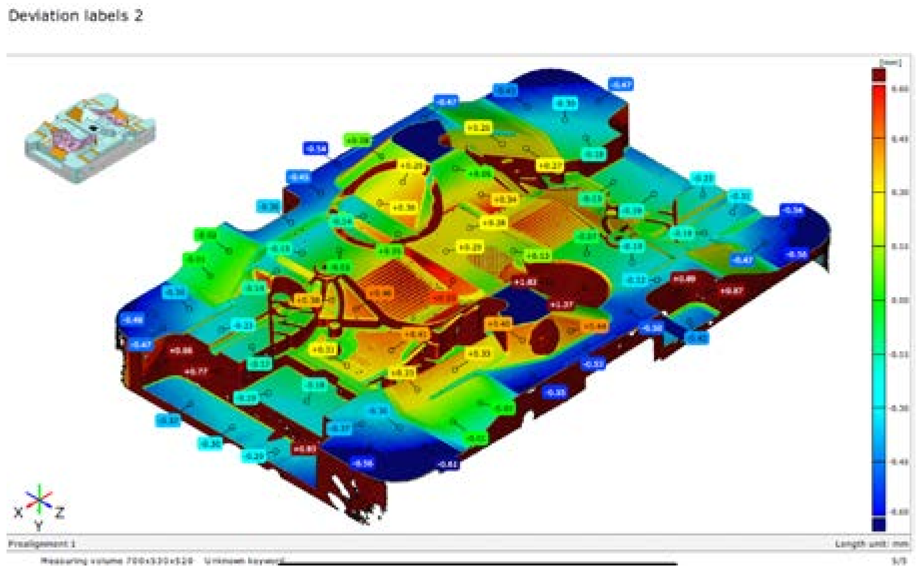
Hardening diagrams



Tempering diagrams

4.5 GOM measurement

After heat treatment, we provide a detailed 3D scan of each product, along with the corresponding STL file. This 3D scan report, combined with the STL file, offers valuable information crucial for optimizing the finish machining process. By analyzing this data, your engineers can accurately adjust machining parameters. This approach enhances overall product quality, minimizes rework, and maximizes manufacturing efficiency.



integraTool

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