Hot Stamping Experience and Tech Tour

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Holland, MI

Controlling Heating & Cooling Cycles During Hot Stamping

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American Tooling Center, Diversified Tooling Group

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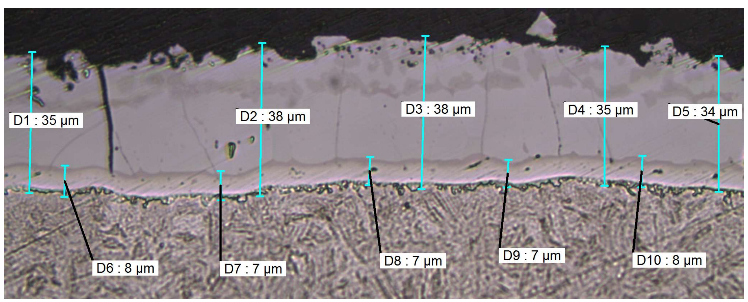
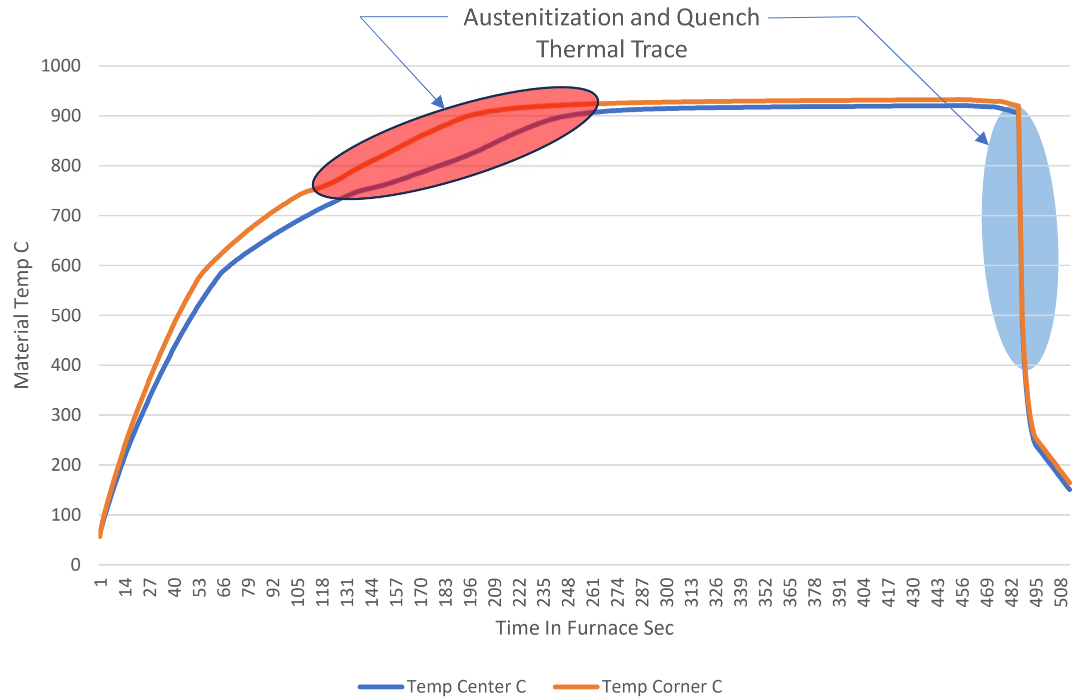
Controlling Heating & Cooling Cycles During Hot Stamping

- Managing austenitic and martensitic phase transformations for boron steel alloys
- Controlling aluminum silicate coatings during both phase transformation processes

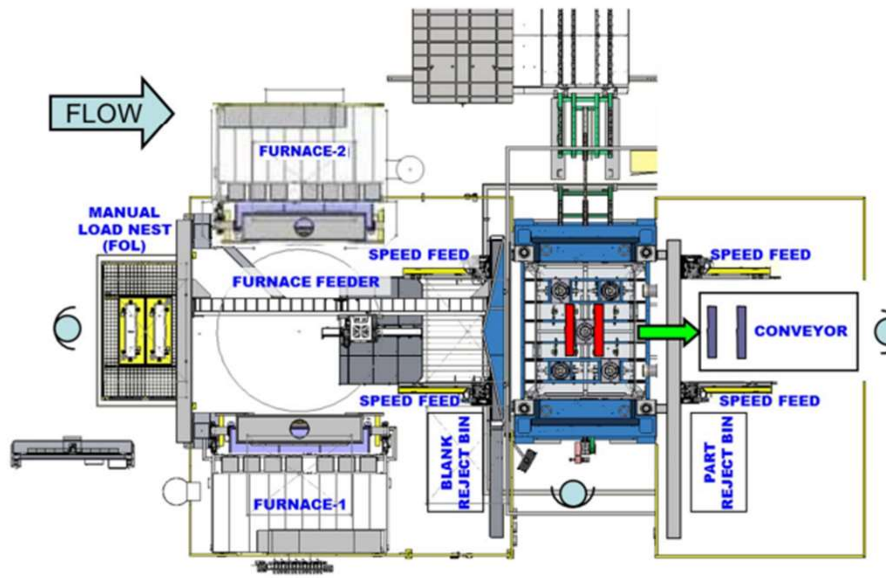




Typical thermal cycle for austenitization, form and quench
(heavy gage material, radiant furnace, average furnace thermal mass)

What is Hot Stamping (aka Press Hardened Steel)?

- Hot stamping of heat-treatable boron (or other) alloyed steel sheet metal is a mature process that creates complex structural stamped parts in the ultra-high-strength category for automotive, truck, farm-implement, construction, defense and other applications
- Two (2) processes are combined into one integrated process at the hot stamping press cell:
  - Heat treatment (Furnace + Press)
  - Hot stamping (Press)



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Typical Hot Stamping Press Cell

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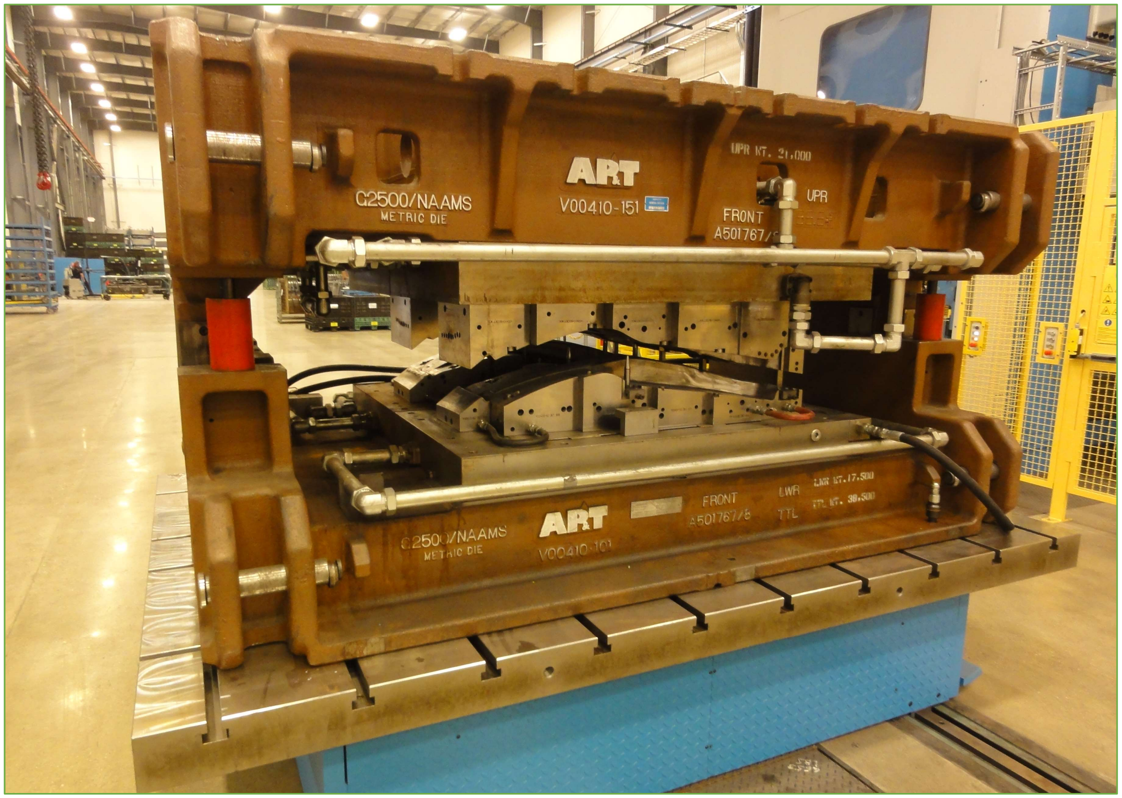
B Pillar Outer R/L Hot Stamp Die



What Is The Hot Stamp Heat Treatment Process?

- To ensure the desired material mechanical and metallurgical properties are achieved using the two-step process, a highly controlled heat treat process is required:
  - **Austenitic Transformation** - Phase transformation of the ferrito-pearlitic matrix (as received from the steel mill) into an austenitic structure is accomplished using an austenitizing furnace which heats the material to over 900C for a programmed minimum-maximum period of time. The change to austenite allows additional carbon to be absorbed. This improves material strength following quench.
  - **Martensitic Transformation** – High speed forming during martensitic phase transformation allows deep drawn parts to be made without splits or excessive wrinkles. Rapidly forming completely to die bottom irons out wrinkles, and the material is quenched quickly enough to prevent bainite/soft spots and long enough to minimize springback and geometric variance after die quenching.

Austenitization
Furnace Heat Treatment Changes
Ferrito-Pearlite to Austenite

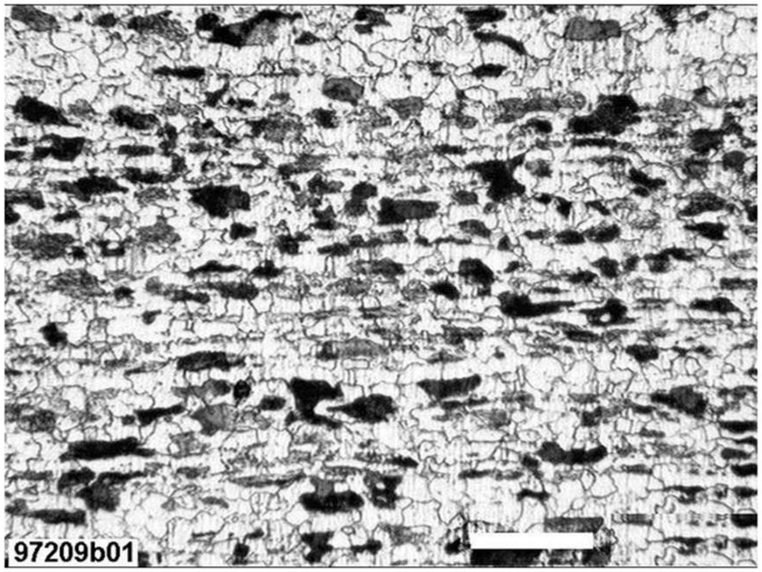
- Austenite, also known as gamma-phase iron (γ-Fe), is a metallic, non-magnetic allotrope of iron or a solid solution of iron with an alloying element.[1]
- In plain-carbon steel, austenite exists above the critical eutectoid temperature of 1000 K (727 °C); other alloys of steel have different eutectoid temperatures. [2]
- Hot stamp 22MnB5 boron steel alloy is delivered from the steel mill in ferrito-pearlitic crystal matrix formations and "undergoes a phase transition from body-centered cubic (BCC) to the face-centered cubic (FCC) configuration" known as austenite during the austenitization process. Austenitic phase crystals then absorb the carbon released from dissolved carbides during the process. [2]

[1] Wikipedia - Reed-Hill R, Abbaschian R (1991). Physical Metallurgy Principles (3rd ed.). Boston: PWS-Kent Publishing. ISBN 978-0-534-92173-6.

[2] Wikipedia - Austenite

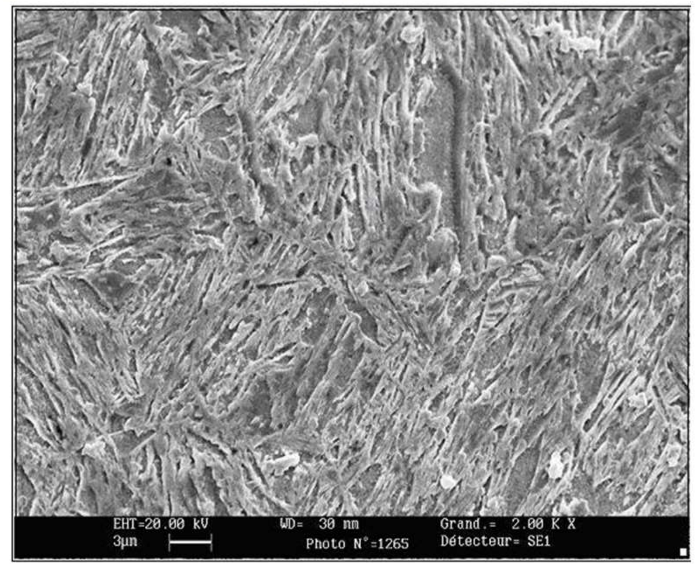
Austenitization
Furnace Heat Treatment Changes
Ferrito-Pearlite to Austenite

The microstructure of Usibor® 1500 before heat treatment exhibits a ferrito-pearlitic matrix.



Usibor® 1500 microstructure before hot-stamping heat treatment (delivery condition)

Following heat treatment and quenching, the microstructure is 100% martensitic.

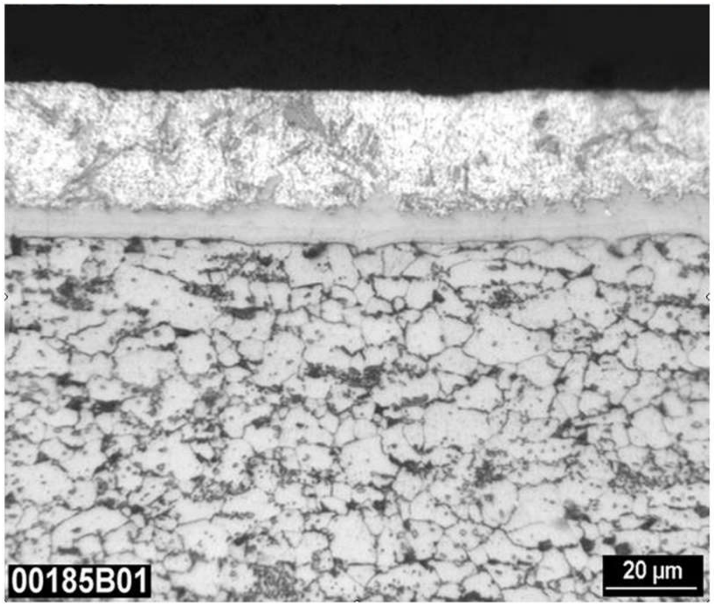


Usibor® 1500 martensitic microstructure following hot-stamping heat treatment (example: 5-minute austenitisation at 900°C, followed by water quenching or die quenching). Scanning electron micrograph

Photo/captions courtesy of ArcelorMittal

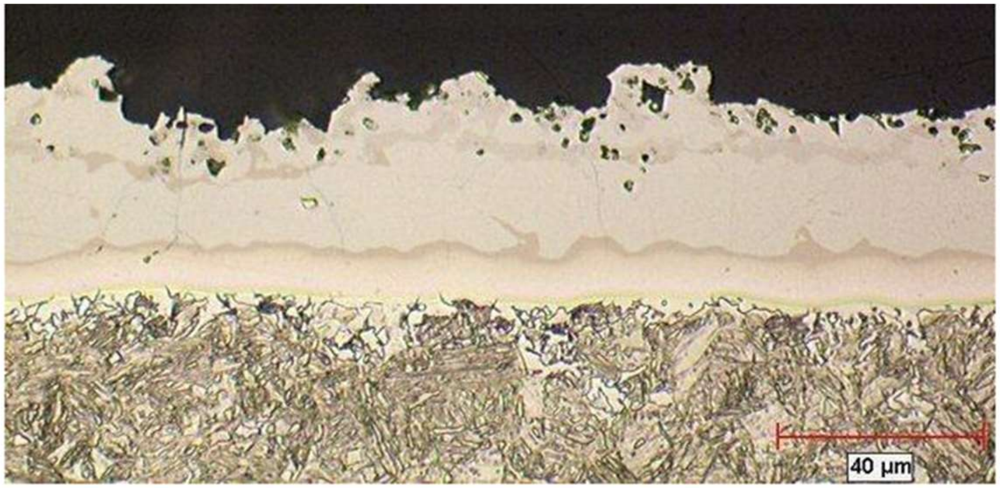
Austenitization
Furnace Heat Treatment Changes Ferrito-Pearlite to Austenite

The Usibor® 1500 Alusi® coating in the delivery condition is split into one ternary layer of alloy at the steel-coating interface and an overlay of binary aluminium-silicon alloy.



Section of Usibor® 1500 coating prior to hot stamping

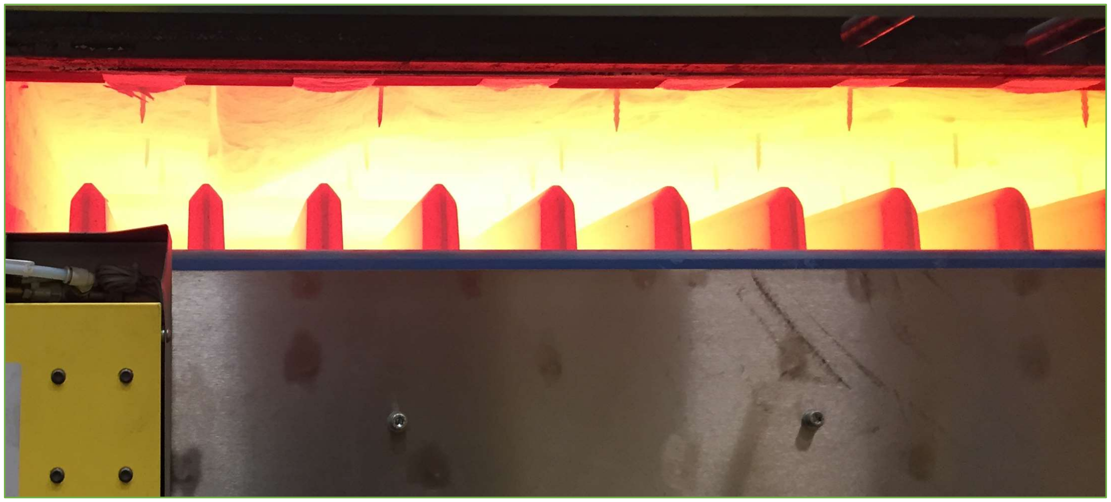
The Usibor® 1500 Al-Si coating is transformed in the furnace (interdiffusion and solidification reactions), forming different intermetal Al-Fe-Si alloy protective layers providing perfect adhesion.



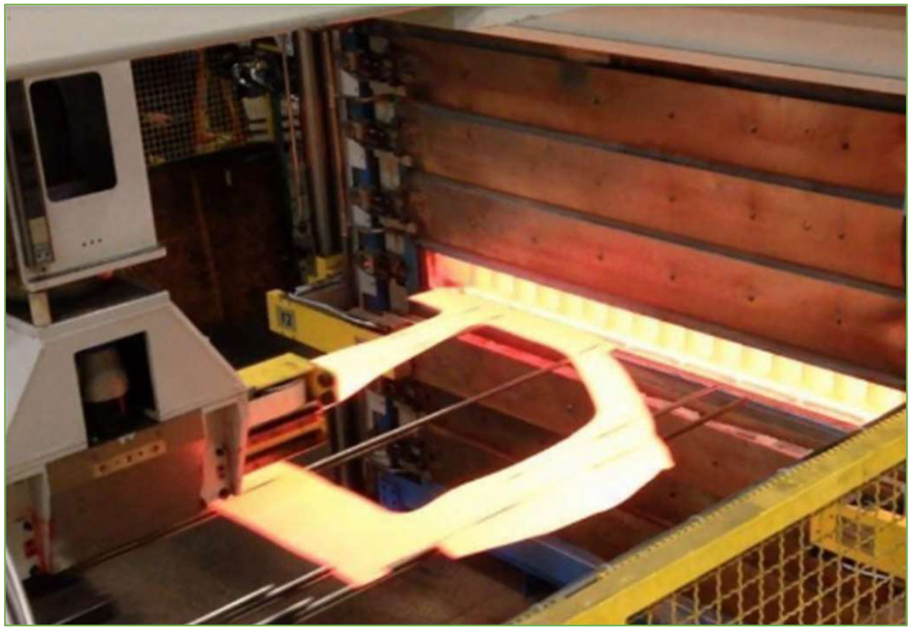
Appearance of the coating after hot stamping (optical microscopy)

Photo/captions courtesy of ArcelorMittal

Austenitizing Multi Layer Furnace



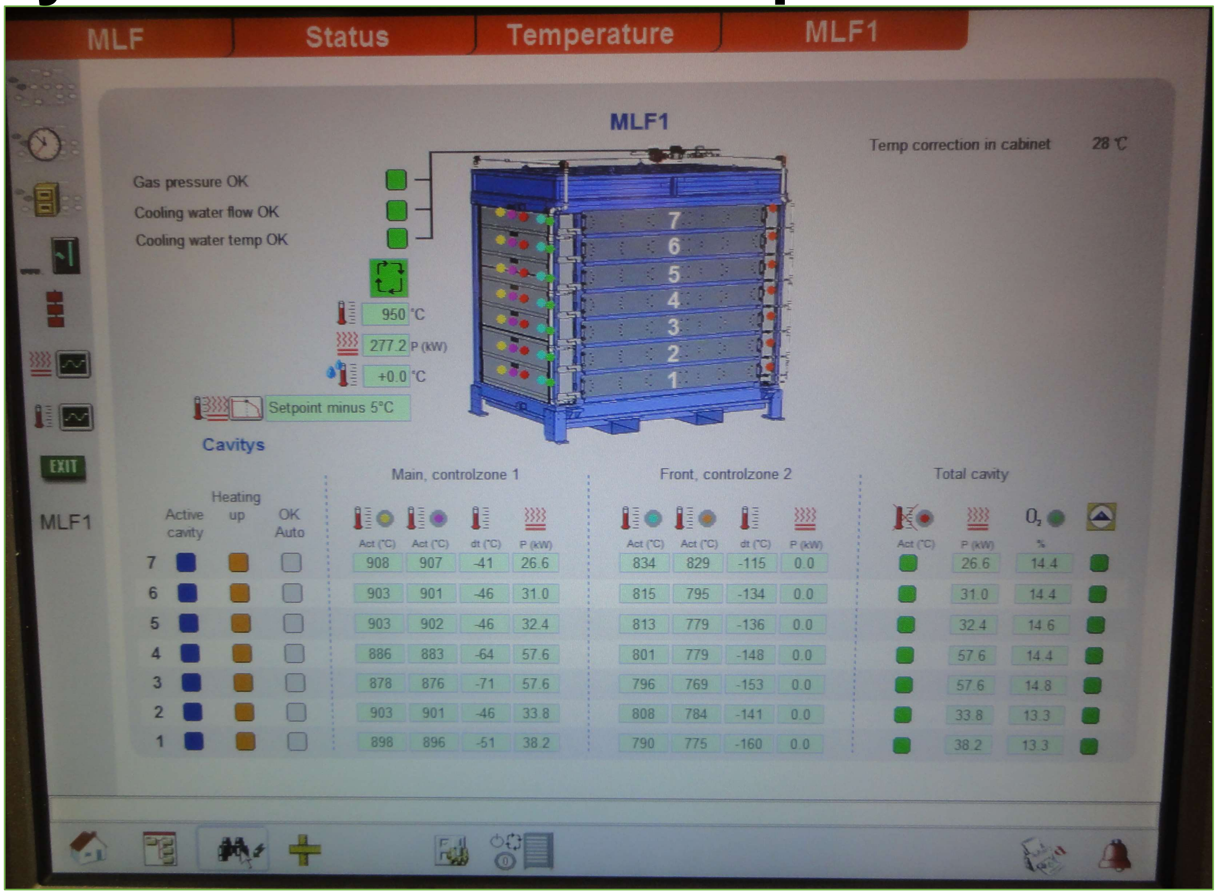
Each of the (7) cavities per furnace are independently powered and controlled to achieve furnace temp setpoint.



Cavities are sized for medium to large parts.

7 Cavity Furnace Thermocouples/Power Control

Each furnace cavity has 2 zones (front and main), each zone is independently powered and controlled



Screen shot taken while furnace is at approx. 900C during ramp up to 950C setpoint.

Typical furnace operating temperature accuracy is +/- 1.5 C degrees from setpoint.

Temperature Uniformity System tests meet required AIAG CQI-9 Process I +/- 15 C degrees.

TRB B Pillar Heat Loss During 10 Second Transfer To Die

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780 C+ TRB Blank Temperatures Just Prior to Press Closing

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Finished Hot Stamp B Pillar Draw Shells On Air Cooling Conveyor

Austenitization and Quench/Cool Thermal Trace Example 1.6 mm 22MnB5 with AlSi Coating

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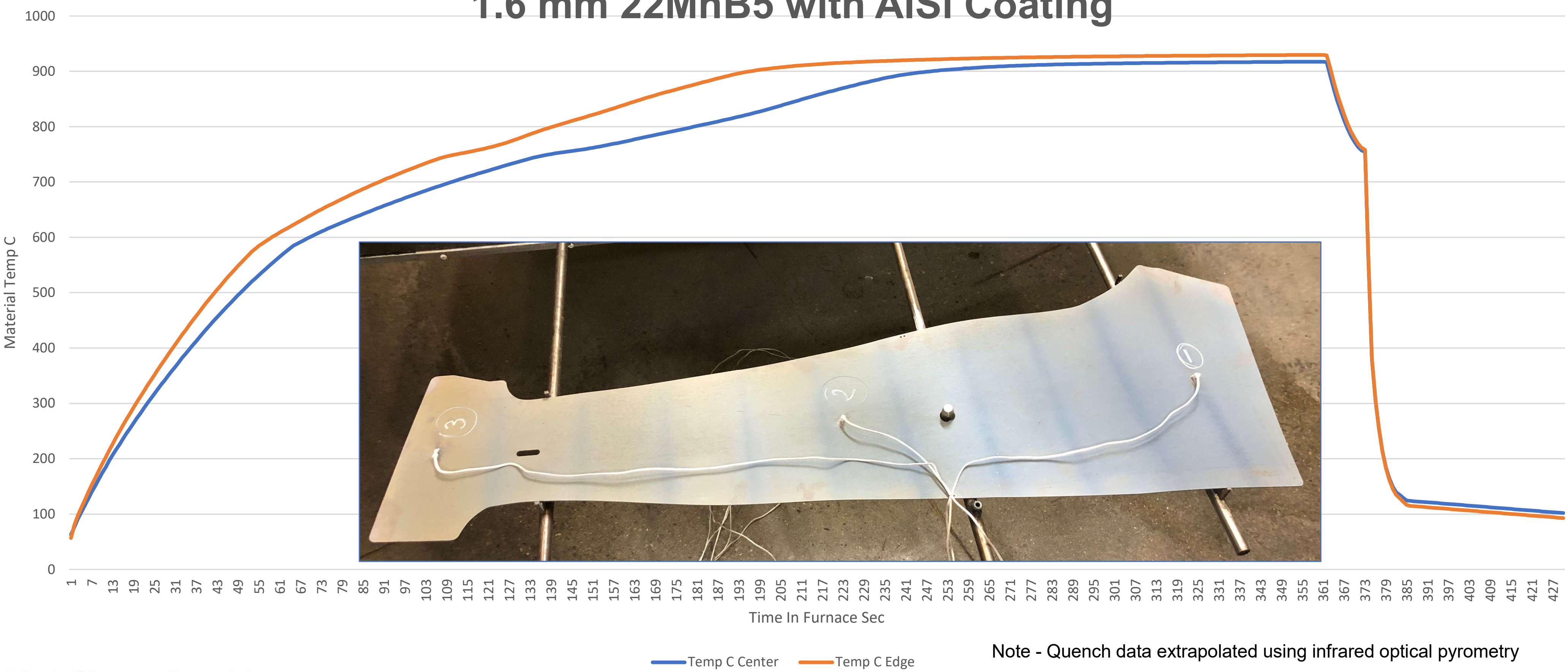

Note - Quench data extrapolated using infrared optical pyrometry

Quench Cooling Treatment to Change Austenite to Martensite (During Hot Stamping)

- As austenite cools, the carbon diffuses out of the austenite and forms carbon-rich iron-carbide (cementite) and leaves behind carbon-poor ferrite. Depending on alloy composition, a layering of ferrite and cementite, called pearlite, may form. [2]
- If the rate of cooling is very swift, the carbon does not have sufficient time to diffuse, and the alloy may experience a large lattice distortion known as martensitic transformation in which it transforms into martensite, a body centered tetragonal structure (BCT). [2]

Quench Cooling Treatment to Change Austenite to Martensite (During Hot Stamping)

- The rate of cooling determines the relative proportions of martensite, ferrite, and cementite, and therefore determines the mechanical properties of the resulting steel, such as hardness and tensile strength. [2]

[2] Wikipedia - Austenite

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Hot Stamping Issues and Standards

- Hot Stampers readily see and grasp the concept of how to control the process to achieve part geometric physical objectives but may lack the commercial heat-treatment background or capabilities for tightly controlling the two-step process.
- Addressing this challenge has fallen to the Automotive Industry Action Group (AIAG), which previously issued standard CQI-9 governing general heat-treatment requirements, and a substandard, “Special Process: Heat Treat System Assessment," for determining if specialized automotive heat-treatment process equipment and systems can meet unique process quality requirements.
- These standards cover commonly used heat-treatment processes and address tasks such as temperature measurement (thermocouples, pyrometry), system testing (accuracy and temperature uniformity), and controlling time and atmospheric conditions. Process Table I addresses the Hot Stamping process, and was updated in the June 2020 CQI-9 Fourth Edition.

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AIAG CQI-9 Process Table I - June 2020

PROCESS TABLE I – Hot Stamping

"Hot Stamping" is also known as dry contact press hardening, high strength metal sheet hardening, press hardening, or die press quenching. This process first austenitizes and then simultaneously quenches and forms a part. Quenching is achieved by direct contact with a die that is internally cooled with a suitable medium. The die is used in conjunction with a high tonnage press and relatively short heat treat cycles are used.

All requirements given below are subordinate to customer specific requirements.

The Customer may have additional requirements, e.g. inspection testing, greater frequencies. When performing the job audit, the auditor shall verify heat treater is conforming to the Customer's requirements.

OK - Complies to requirement
NOK - Does not comply to requirement (Explain noncompliance in 'Related HTSA Question #')
NA - Requirement not applicable

Item #	Related HTSA Question #	Category/Process Steps	
1.0		**PROCESS AND TEST EQUIPMENT REQUIREMENTS**	**OK / NOK / NA**
I1.1	3.1 3.7	Recording instruments are required for temperature controlling devices and protective atmosphere monitoring unit, e.g. dew point, oxygen probe, or other atmosphere controlling devices.	
I1.2	3.2	To avoid double layer loading, furnace loading device and control elements shall be verified and maintained per maintenance plan.	
I1.3	3.2	Dew pointers, gas analyzers, spectrometers, and carbon IR combustion analyzers (shim stock/foil analysis), used to verify protective atmosphere in furnaces, shall be calibrated annually at a minimum.	
I1.4	3.2	Oxygen probe controllers shall be calibrated quarterly (single-point or multi-point calibration). A six month calibration interval is allowed if multi-point calibration is utilized.	
I1.5	3.2	Verification of spectrometers and carbon IR combustion analyzers (shim stock/foil analysis) shall be performed daily or prior to use.	
I1.6	3.2	Verification of gas analyzers with zero gas and span gas when used as the back-up verification shall be performed weekly at a minimum. When used for primary control of the carbon-bearing atmospheres, verification shall be daily.	
I1.7	2.16	Laboratory and Test equipment used for product and process testing shall be calibrated annually at a minimum, per the applicable national standard (e.g. ASTM, EN, JIS) or approved equivalent standard, and verified per internal procedure if not specified in the applicable standard.	
2.0		**PYROMETRY**	**OK / NOK / NA**
I2.1	3.2 3.3	Thermocouples and calibration of thermocouples shall conform to Section P3.1.	
I2.2	3.2 3.3	Calibration of instrumentation shall conform to Section P3.2.	
I2.3	3.2 3.3	System Accuracy Test (SAT) for all control, monitoring, and recording thermocouples shall conform to Section P3.3.	
I2.4	3.4	Temperature Uniformity Survey (TUS) shall be performed annually and after major rebuild per Section P3.4 Temperature uniformity tolerance for hardening furnaces shall be +/- 15°C (or +/- 25°F).	
I2.5	3.5	Process temperature(s) shall be controlled within +/- 10°C (or +/- 15°F) of the set point as evidenced by recording instruments. Furnace temperature shall be controlled with soak times starting at the lower tolerance limit (as defined above). **For Continuous Furnaces, this requirement applies to the Qualified Work Zone.**	
I2.6	3.2	Non-contact thermometry devices used for temperature monitoring (e.g. infrared pyrometer, thermal imaging camera) shall be calibrated annually at a minimum in the temperature range to be used utilizing a blackbody device or per the manufacturer's recommended procedure.	

Item #	Related HTSA Question #	Category/Process Steps					
3.0		**PROCESS MONITORING PARAMETERS**	**REQUIREMENTS / FREQUENCY** **BOX Type Furnace (Single-Chamber)**	**BOX Type Furnace (Multi-Chamber)**	**Continuous Furnace**	**Atmosphere Generation**	**OK / NOK / NA**
I3.1	1.4 2.14	Monitor primary temperature control instrument(s).	Continuous recording with alarm system set per limits in I2.5. In absence of alarm system, sign-off every 2 hours satisfies this requirement.	For each chamber, continuous recording with alarm system set per limits in I2.5. In absence of alarm system, sign-off every 2 hours for each chamber satisfies this requirement.	Continuous recording with alarm system set per limits in I2.5. In absence of alarm system, sign-off every 2 hours satisfies this requirement.	Generators shall be continuously monitored and recorded. Sign-off required for each shift for generators. An alarm system will satisfy the sign-off requirement.	
I3.2	1.4 2.14 3.7	Monitor atmosphere generation as applicable.				Dried air or nitrogen systems may either be continuously monitored and alarmed, or sign-off every 2 hours.	
I3.3	1.4 2.14 3.7	Monitor primary furnace atmosphere control(s), as applicable	Continuous recording with alarm system. In absence of alarm system, sign-off every 2 hours satisfies this requirement.	For each chamber, continuous recording with alarm system. In absence of alarm system, sign-off every 2 hours for each chamber satisfies this requirement.	Continuous recording with alarm system. In absence of alarm system, sign-off every 2 hours satisfies this requirement.		
I3.4	1.4 2.14	Monitor time in furnace.	System monitoring of time in furnace (ex. Robot, PLC, etc.). Alarm for times outside of process window.	For each chamber, system monitoring of time in furnace (ex. Robot, PLC, etc.). Alarm for times outside of process window.	System monitoring of time in furnace (ex. Roller speed). Alarm for times outside of process window.		
I3.5		Press cycle parameter (e.g. dwell time, tonnage)	System monitoring of applicable press cycle parameters. There shall be an alarm for conditions outside of process window.				
		Quench Process Parameters					
I3.6	1.4 2.12	Monitor part temperature in die.	System to monitor part temperature in the die and immediately prior to quenching (infrared, thermal camera, or other suitable non-contact thermometry device).				
I3.7	1.4 2.12	Temperature of die cooling system.	Continuous recording. Alarm for temperature control systems are required.				
I3.8	1.4 2.12	Cooling system flow control.	Monitoring of die cooling system flow. Alarm for flow control systems are required.				
I3.9	1.4 2.12	Supplemental Cooling Water - Temperature	Continuous recording. Alarm for temperature control systems are required.				
I3.10	1.4 2.12	Supplemental Cooling Water – Flow Rate	Monitoring of quenchant system flow. Alarm for flow control systems are required.				

Item #	Related HTSA Question #	Category/Process Steps					
4.0		**IN-PROCESS/ FINAL TEST PARAMETERS**	**REQUIREMENTS / FREQUENCY** **BOX Type Furnace (Single-Chamber)**	**BOX Type Furnace (Multi-Chamber)**	**Continuous Furnace**	**Atmosphere Generation**	**OK / NOK / NA**
I4.1	1.4 2.15	Microstructure shall be checked at a low magnification of 100X and a high magnification of 400X or above. Microstructure visual references shall be available.	Daily per furnace.	Daily per furnace (chamber). May rotate chambers but minimum each chamber per week.	Daily per furnace.		
I4.2	1.4 2.15	Decarburization (for bare steel only).	Daily per furnace.	Daily per furnace (chamber). May rotate chambers but minimum each chamber per week.	Daily per furnace.		
I4.3	1.4 2.15	Coating Thickness, Layer Evaluation (for coated material).	Daily per furnace.	Daily per furnace (chamber). May rotate chambers but minimum each chamber per week.	Daily per furnace.		
I4.4	1.4 2.15	Hardness	At start up (per cavity) and every 4 hours minimum (per cavity).	At start up (per cavity) and every 4 hours minimum (per cavity). May rotate chambers but minimum each chamber every 48 hours.	At start up (per cavity) and every 4 hours minimum (per cavity).		
I4.5	1.4 2.15	Mechanical (Tensile, Yield, % Elongation) - when specified.	As required by Customer.	As required by Customer.	As required by Customer.		
5.0		**PRESS AND QUENCH TEST PARAMETERS**	**REQUIREMENTS / FREQUENCY** **BOX Type Furnace (Single-Chamber)**	**BOX Type Furnace (Multi-Chamber)**	**Continuous Furnace**	**Atmosphere Generation**	**OK / NOK / NA**
		Press and Quenching					
I5.1	2.15 3.14	Die - Segment Wear managed to maintain desired properties.	Per maintenance and equipment plan.				
I5.2	2.15 3.14	Cooling System check. Cooling media contamination. Cleaning/maintenance of cooling system and cooling channels in the die.	Per maintenance and equipment plan (tubes, channels, filters etc.).				

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Controlling Heating & Cooling Cycles During Hot Stamping

- How to establish minimum/maximum austenitizing temperatures and times
- Typical hot stamping issues with austenitizing
- Balancing thorough austenitizing with excessive coating growth
- Typical austenitizing process windows
- Atmospheric control - typical issues
- Obtaining repeatable blank temperatures prior to forming
- Forming velocity and its impact on quench rate and formability
- Determining minimum quench force and time
- Quench-variation detection and control
- Developing quench-force process windows

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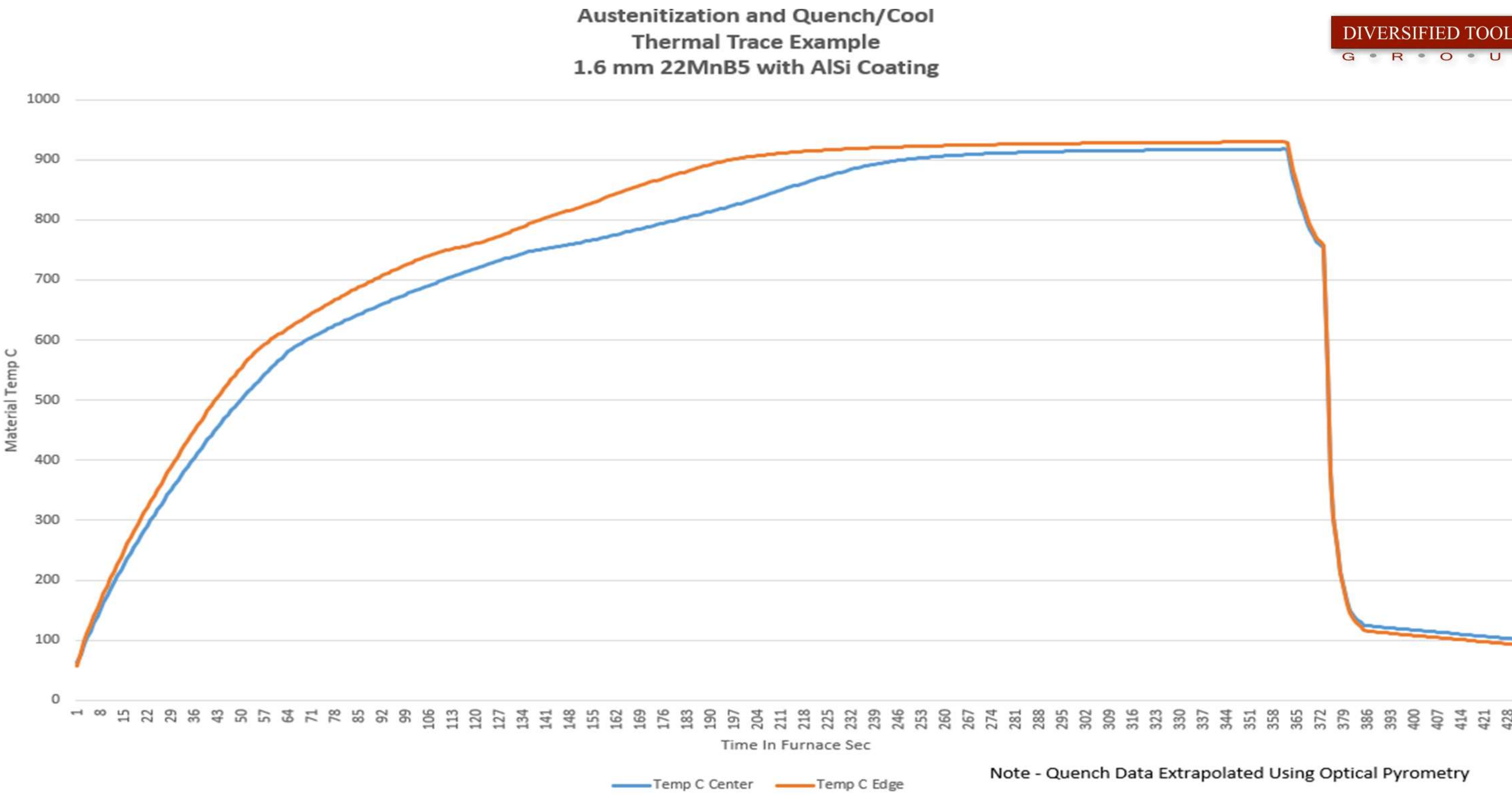
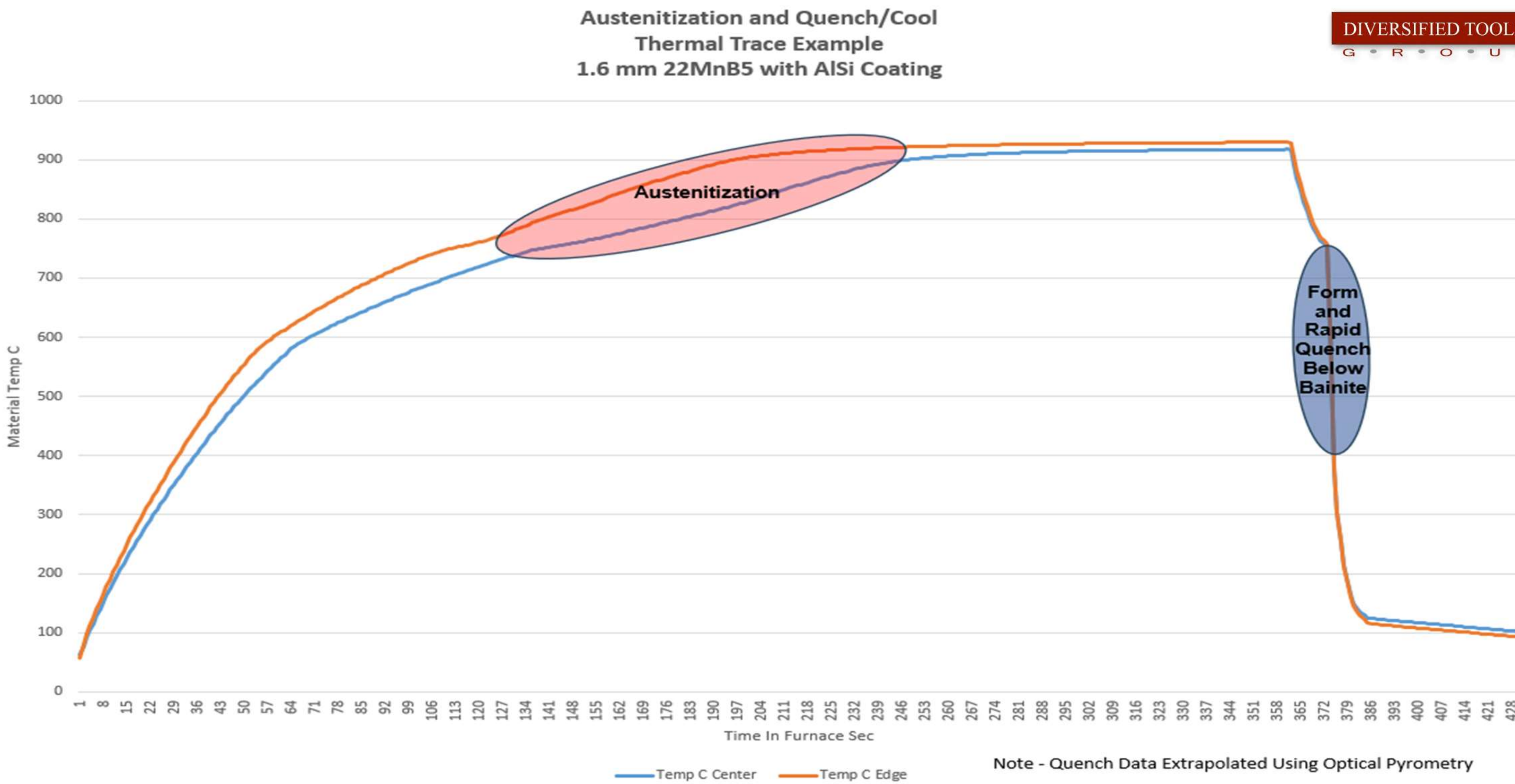
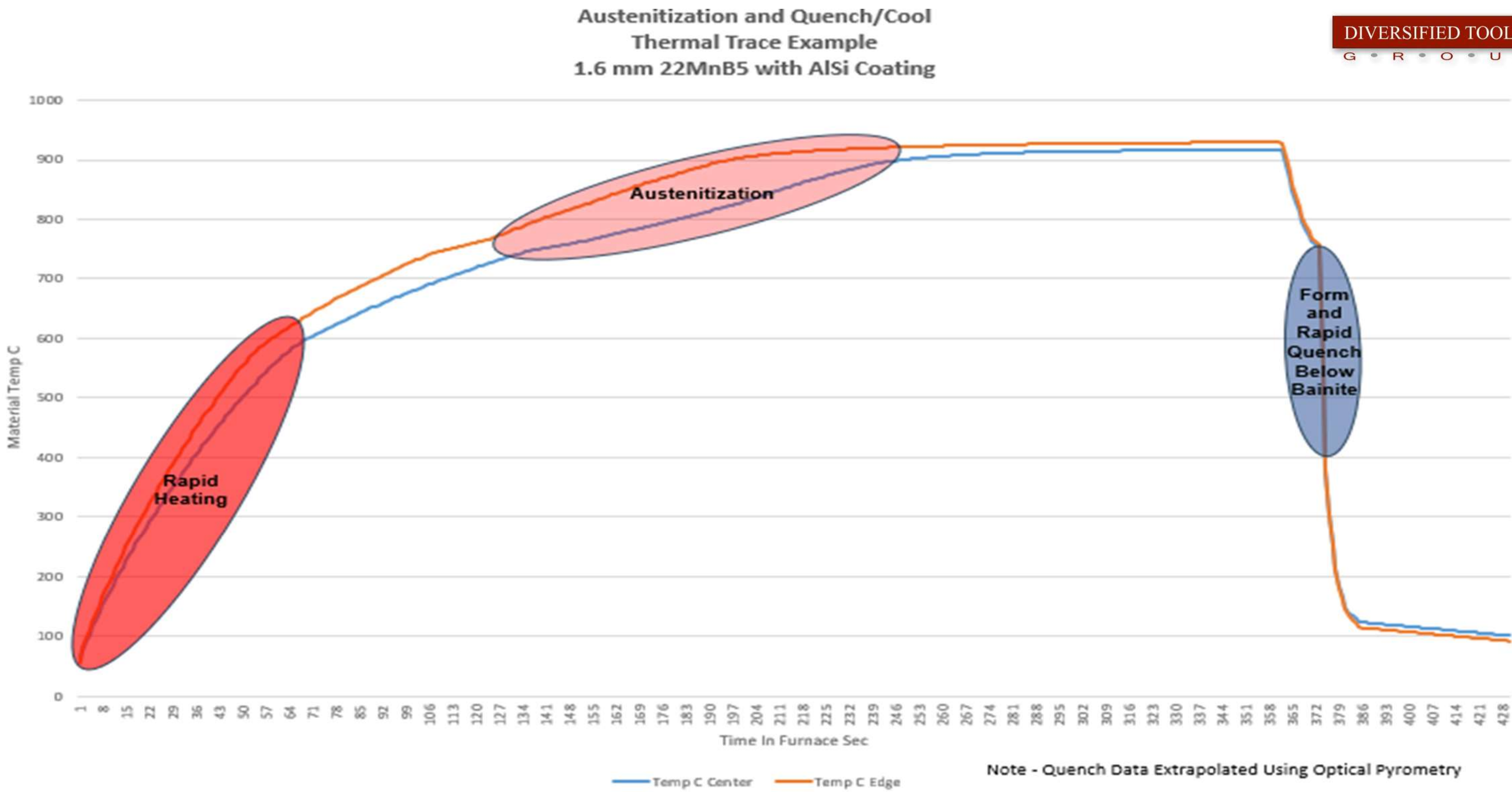
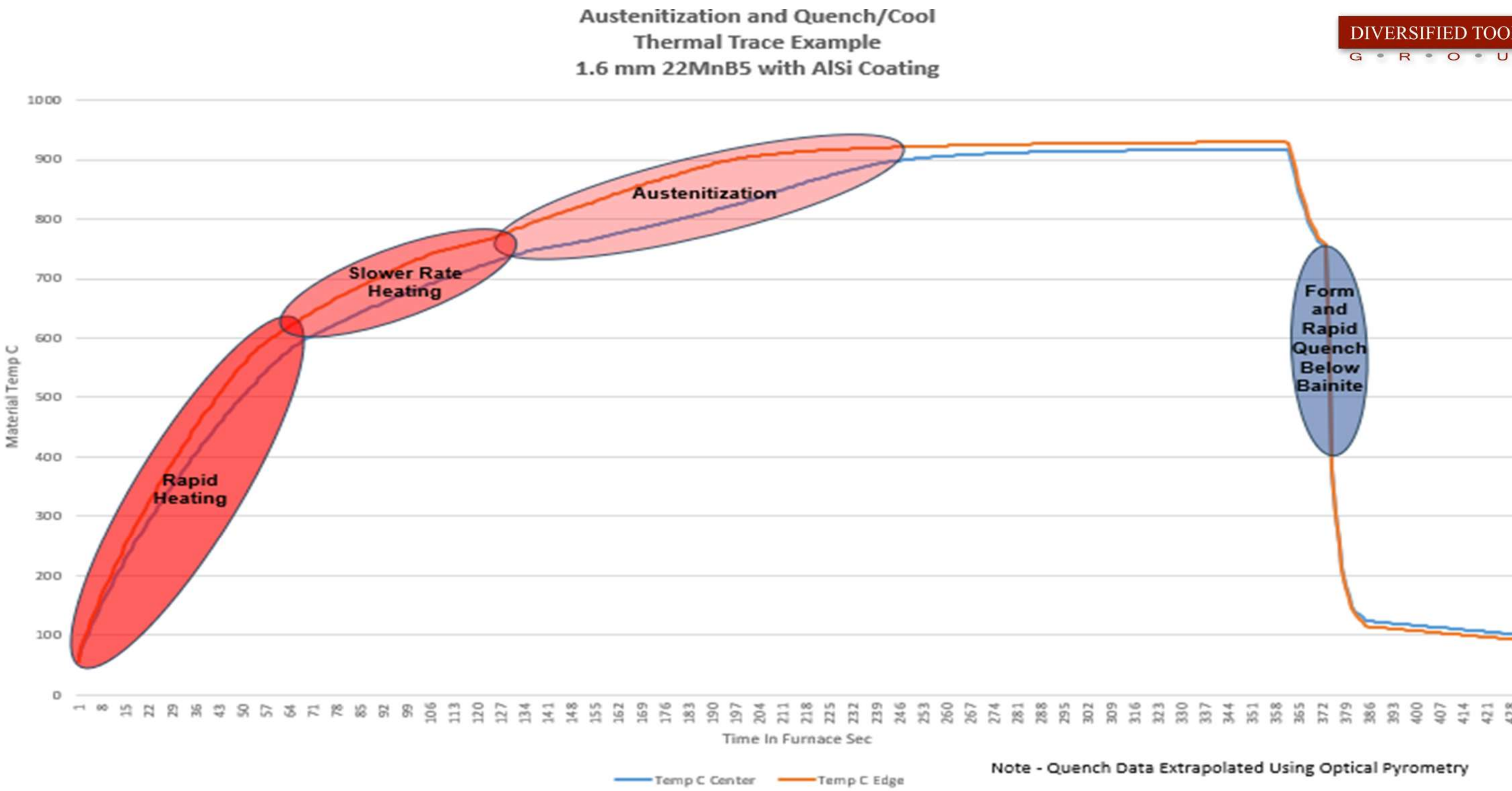
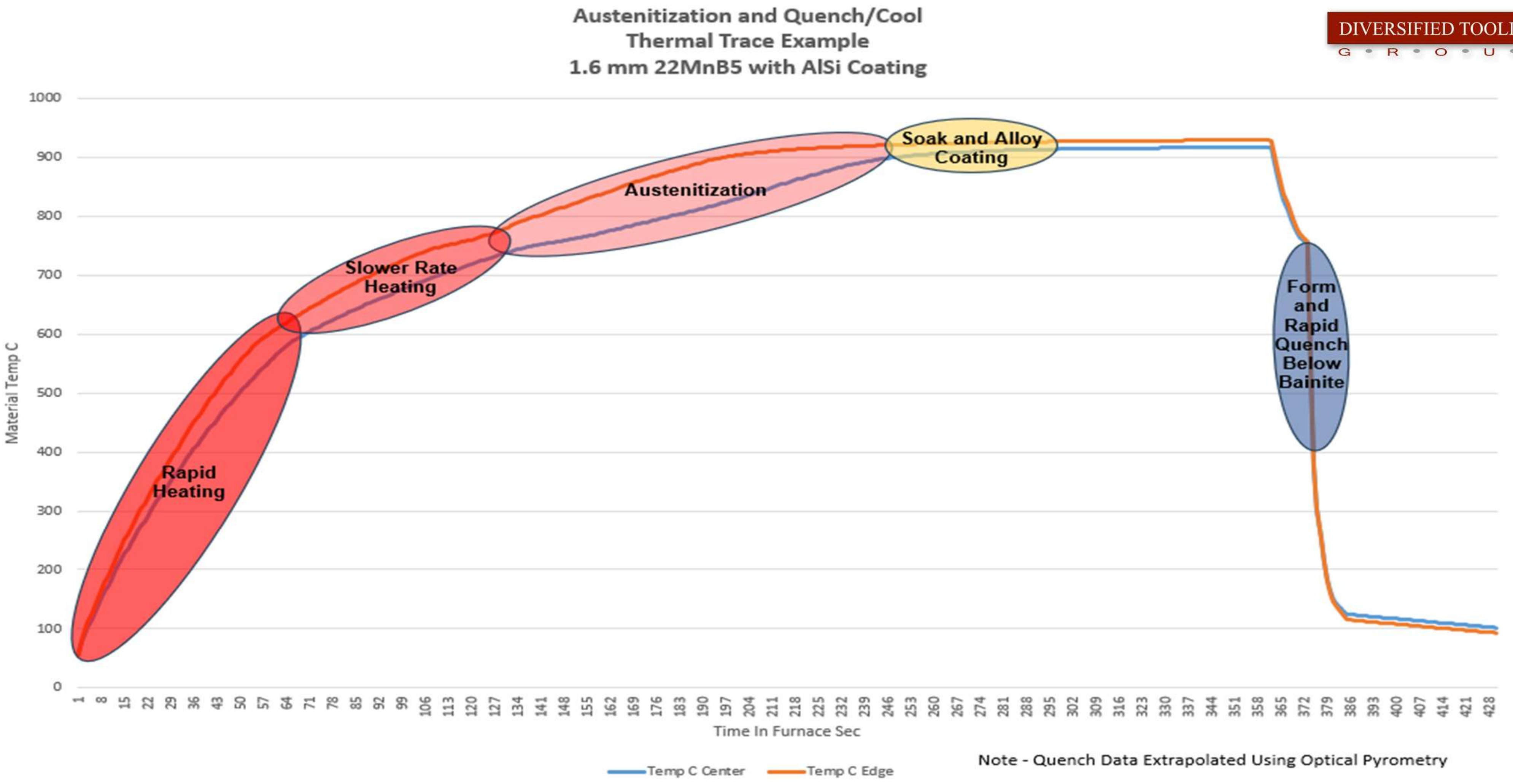
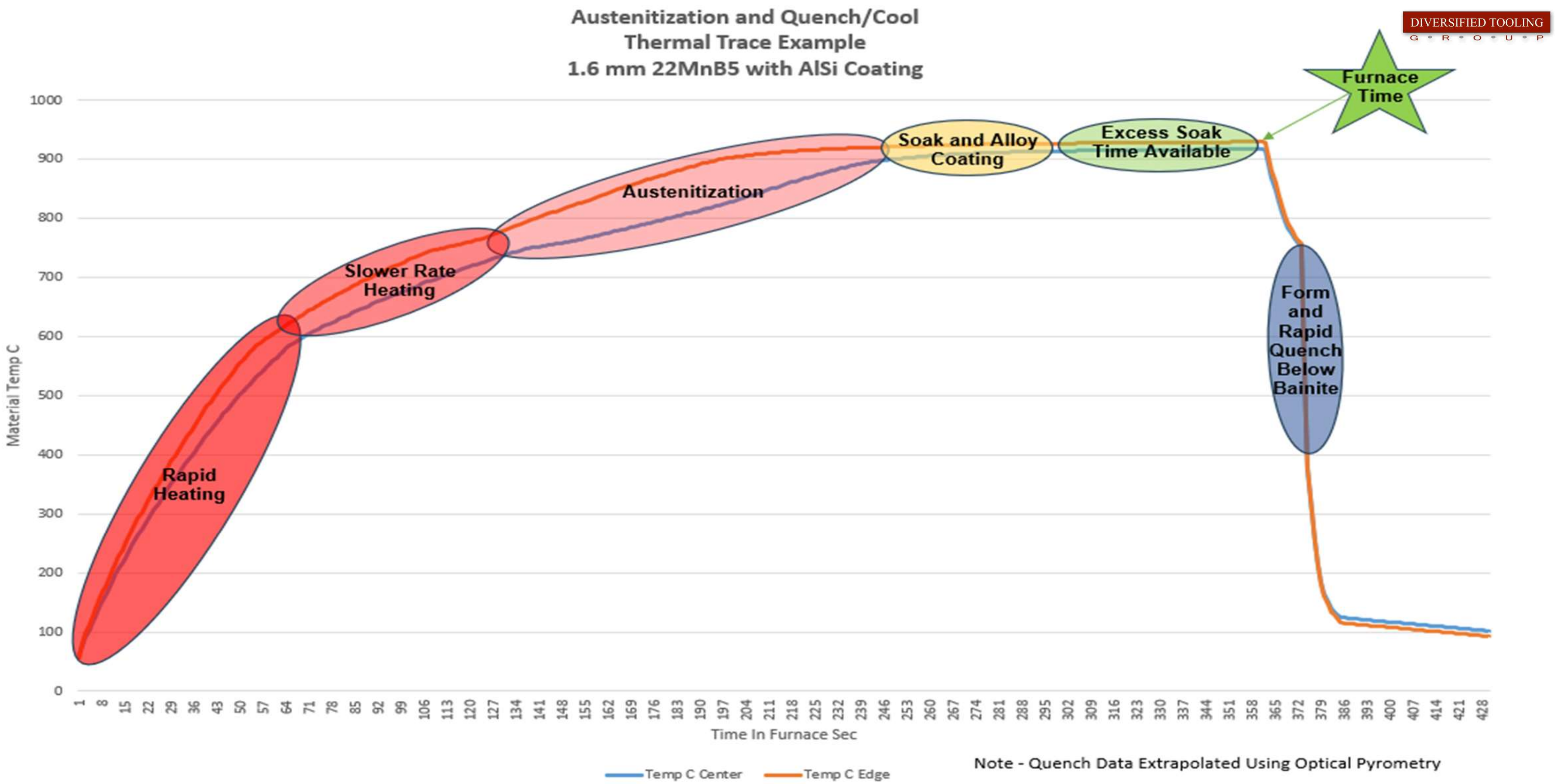



Austenitization and Quench/Cool
Thermal Trace Example
1.6 mm 22MnB5 with AlSi Coating
Material Temp C
1000
900
800
700
600
500
400
300
200
100
0
1 8 15 22 29 36 43 50 57 64 71 78 85 92 99 106 113 120 127 134 141 148 155 162 169 176 183 190 197 204 211 218 225 232 239 246 253 260 267 274 281 288 295 302 309 316 323 330 337 344 351 358 365 372 379 386 393 400 407 414 421 428
Time In Furnace Sec
Austenitization
Form and Rapid Quench Below Bainite
Temp C Center
Temp C Edge
Note - Quench Data Extrapolated Using Optical Pyrometry


Austenitization and Quench/Cool
Thermal Trace Example
1.6 mm 22MnB5 with AlSi Coating
Material Temp C
Time In Furnace Sec
Rapid Heating
Austenitization
Form and Rapid Quench Below Bainite
Temp C Center
Temp C Edge
Note - Quench Data Extrapolated Using Optical Pyrometry


Austenitization and Quench/Cool
Thermal Trace Example
1.6 mm 22MnB5 with AlSi Coating
Material Temp C
Time In Furnace Sec
Rapid Heating
Slower Rate Heating
Austenitization
Form and Rapid Quench Below Bainite
Temp C Center
Temp C Edge
Note - Quench Data Extrapolated Using Optical Pyrometry


Austenitization and Quench/Cool
Thermal Trace Example
1.6 mm 22MnB5 with AlSi Coating
Material Temp C
1000
900
800
700
600
500
400
300
200
100
0
Rapid Heating
Slower Rate Heating
Austenitization
Soak and Alloy Coating
Form and Rapid Quench Below Bainite
Time In Furnace Sec
Temp C Center
Temp C Edge
Note - Quench Data Extrapolated Using Optical Pyrometry


Austenitization and Quench/Cool
Thermal Trace Example
1.6 mm 22MnB5 with AlSi Coating
DIVERSIFIED TOOLING
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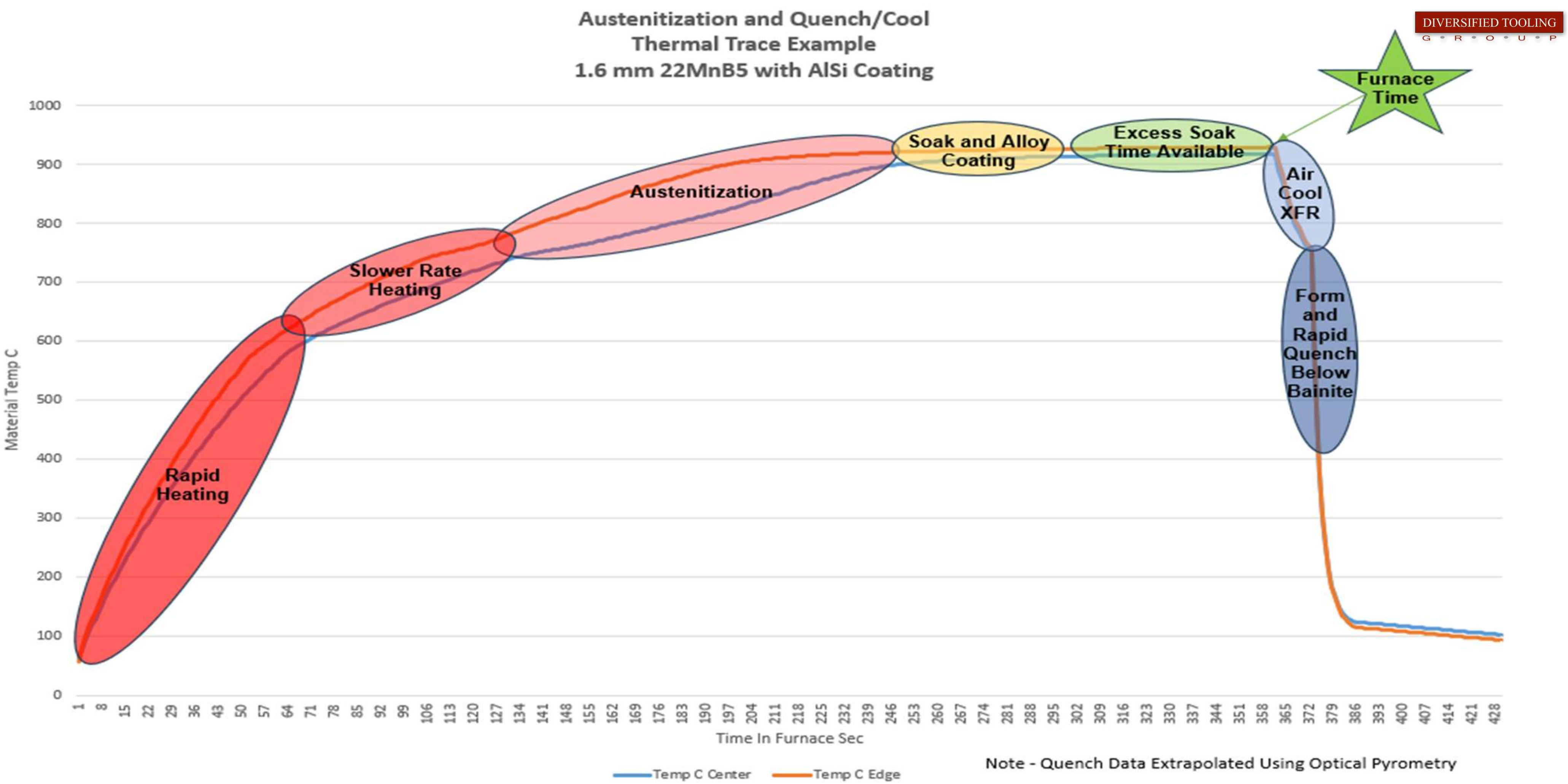
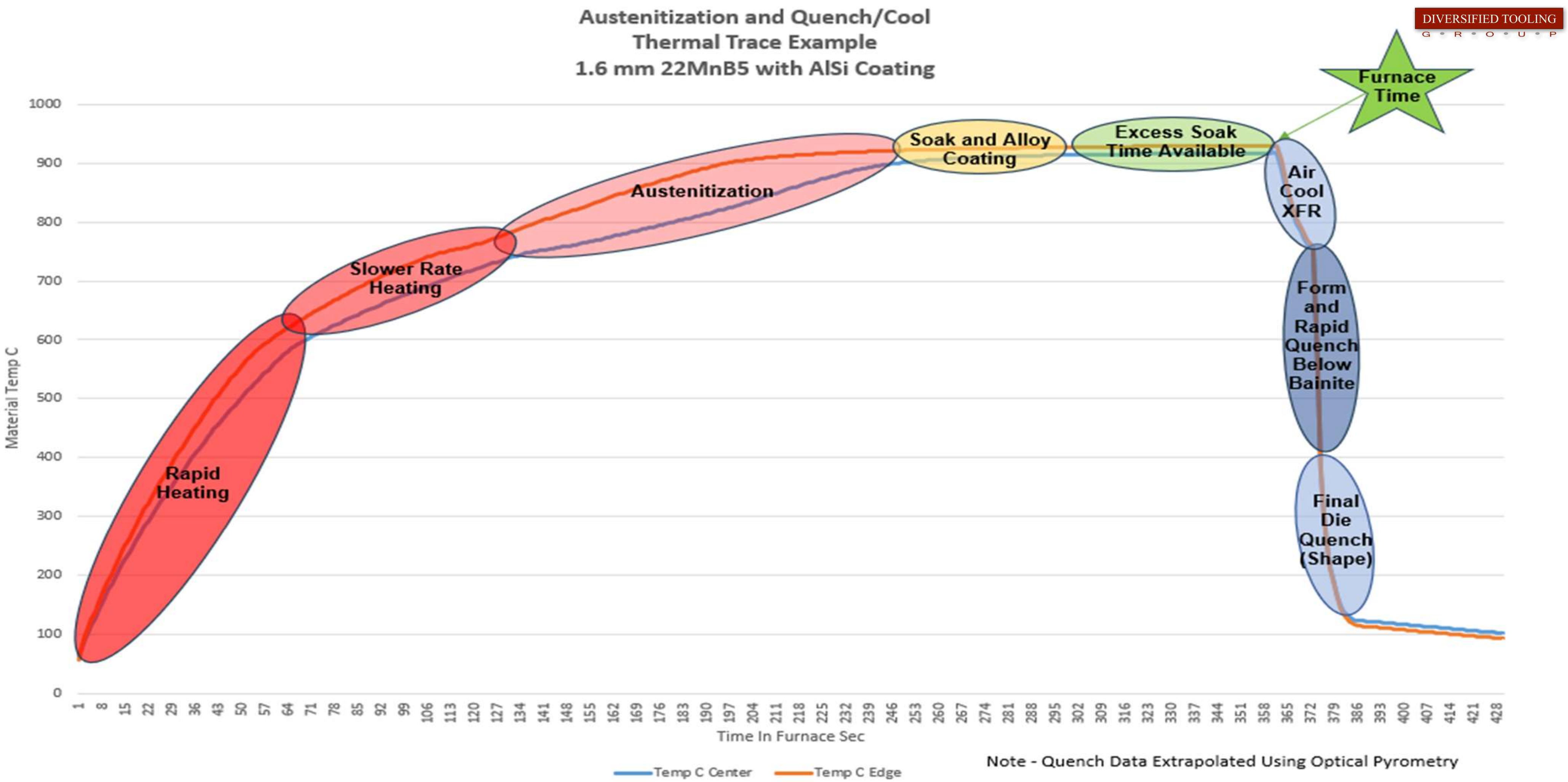
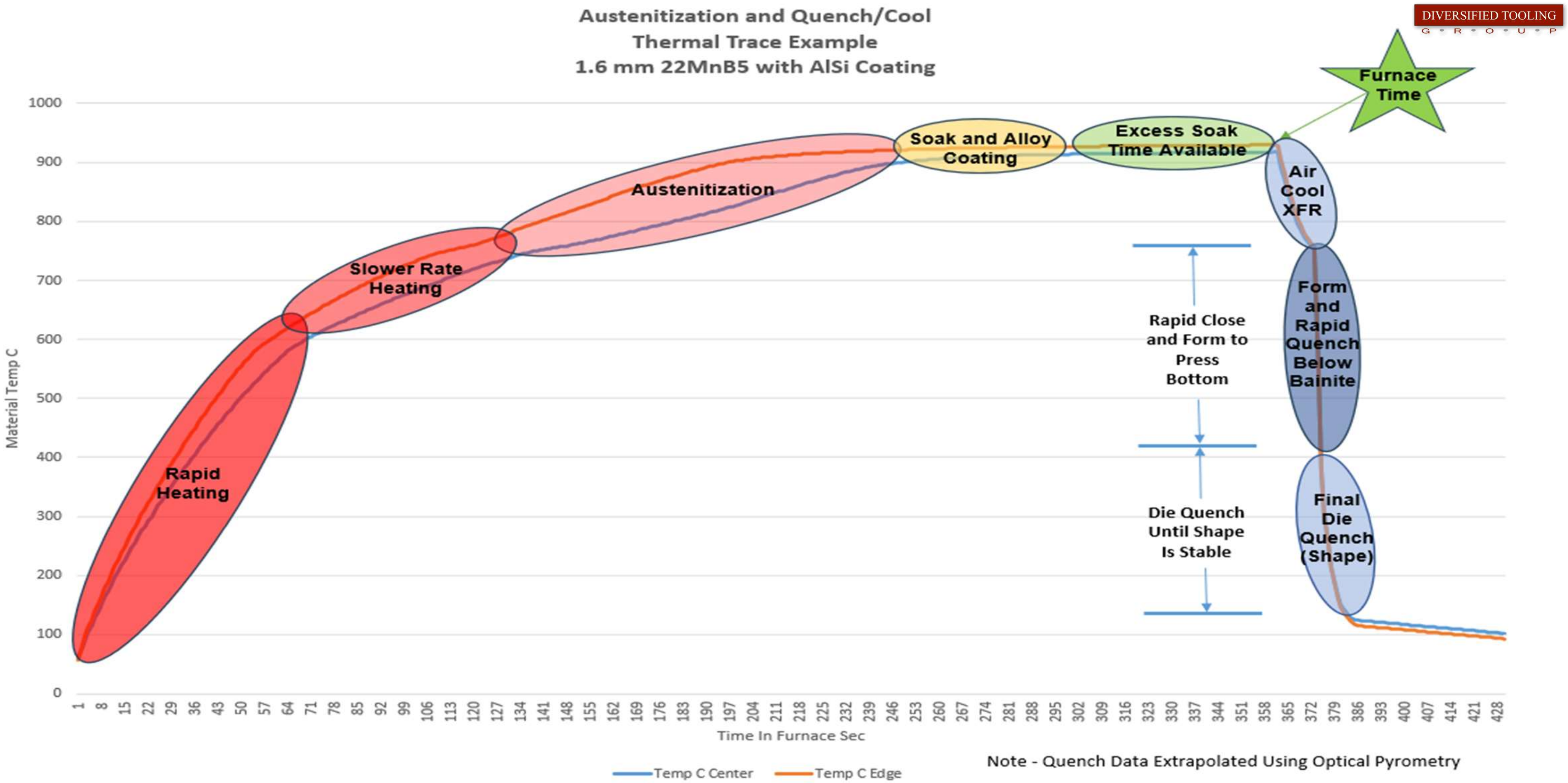
Furnace Time
Soak and Alloy Coating
Excess Soak Time Available
Austenitization
Slower Rate Heating
Rapid Heating
Form and Rapid Quench Below Bainite
Material Temp C
Time In Furnace Sec
Note - Quench Data Extrapolated Using Optical Pyrometry
Temp C Center
Temp C Edge



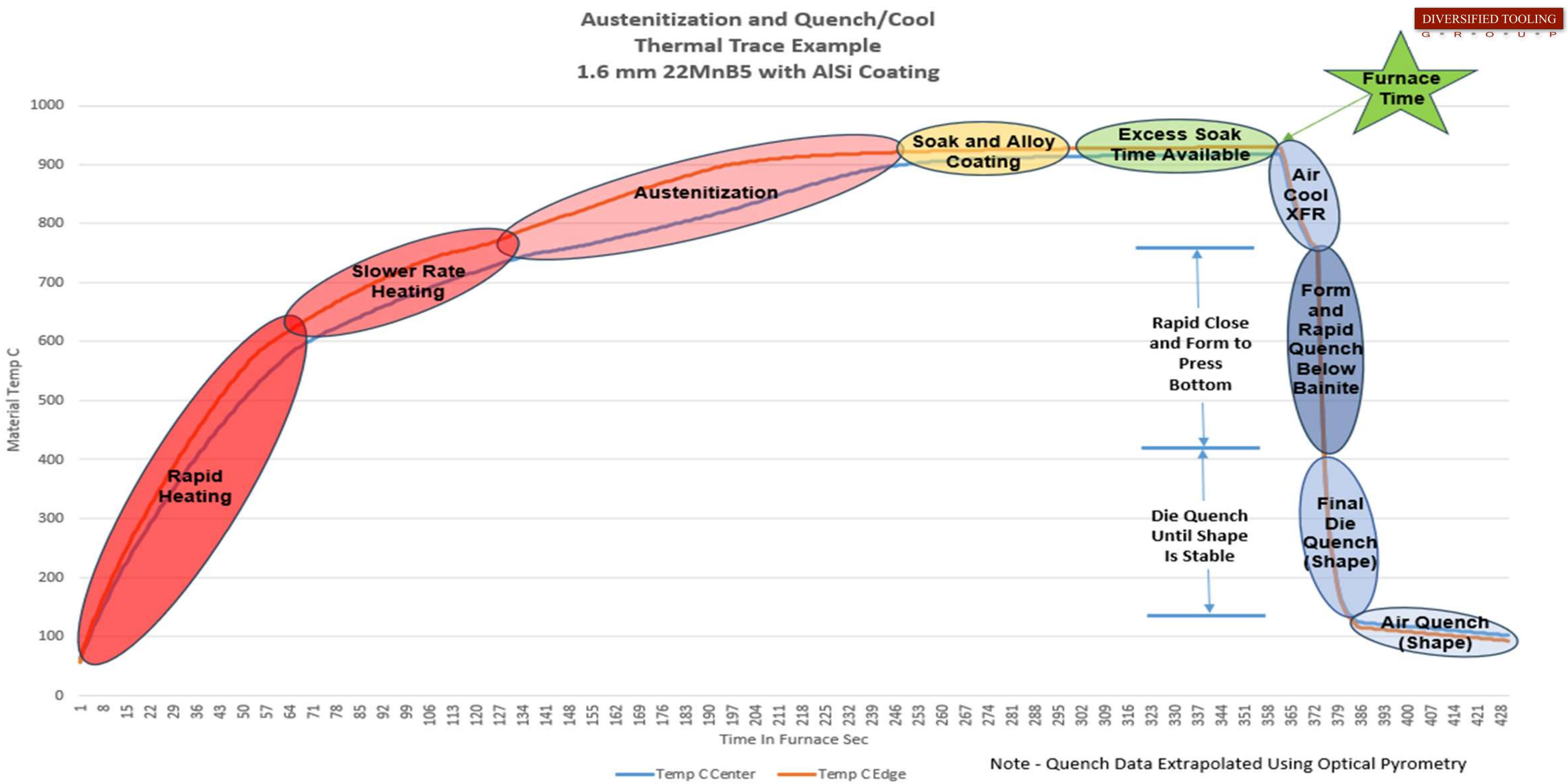
Austenitization and Quench/Cool
Thermal Trace Example
1.6 mm 22MnB5 with AlSi Coating
DIVERSIFIED TOOLING GROUP
Furnace Time
Rapid Heating
Slower Rate Heating
Austenitization
Soak and Alloy Coating
Excess Soak Time Available
Air Cool XFR
Form and Rapid Quench Below Bainite
Material Temp C
Time In Furnace Sec
Temp C Center
Temp C Edge
Note - Quench Data Extrapolated Using Optical Pyrometry



Austenitization and Quench/Cool
Thermal Trace Example
1.6 mm 22MnB5 with AlSi Coating
DIVERSIFIED TOOLING
G • R • O • U • P
Furnace Time
Material Temp C
Time In Furnace Sec
Rapid Heating
Slower Rate Heating
Austenitization
Soak and Alloy Coating
Excess Soak Time Available
Air Cool XFR
Form and Rapid Quench Below Bainite
Final Die Quench (Shape)
Temp C Center
Temp C Edge
Note - Quench Data Extrapolated Using Optical Pyrometry



Note - Quench Data Extrapolated Using Optical Pyrometry


Austenitization and Quench/Cool
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Furnace Time
Material Temp C
Rapid Heating
Slower Rate Heating
Austenitization
Soak and Alloy Coating
Excess Soak Time Available
Air Cool XFR
Form and Rapid Quench Below Bainite
Final Die Quench (Shape)
Air Quench (Shape)
Rapid Close and Form to Press Bottom
Die Quench Until Shape Is Stable
Time In Furnace Sec
Temp C Center
Temp C Edge
Note - Quench Data Extrapolated Using Optical Pyrometry

Establishing Minimum/Nominal/Maximum Times

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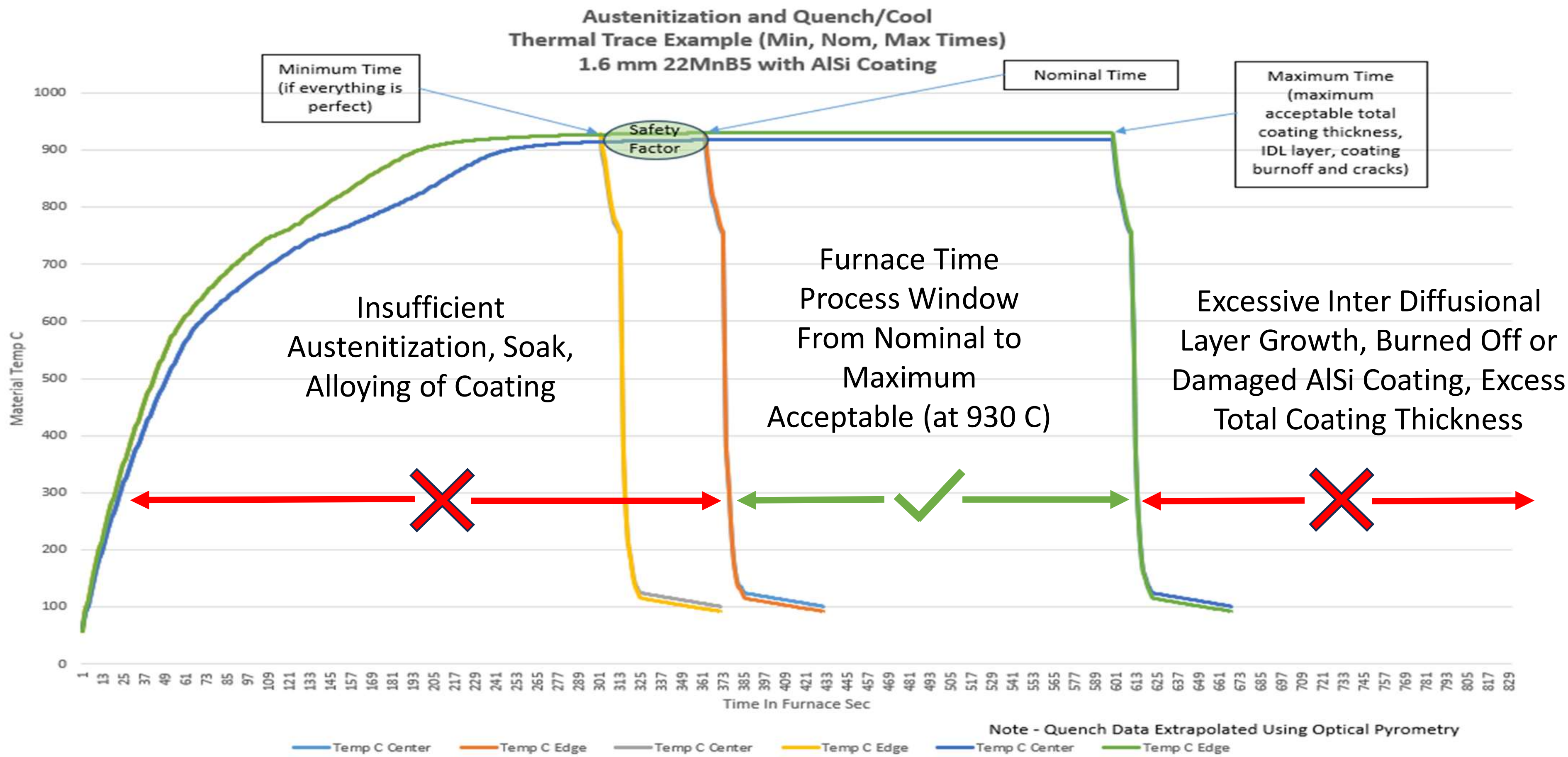

Caution – 950C is the highest recommended temp.
950C Process Windows are shorter and can be difficult

Establishing Minimum/Nominal/Maximum Times

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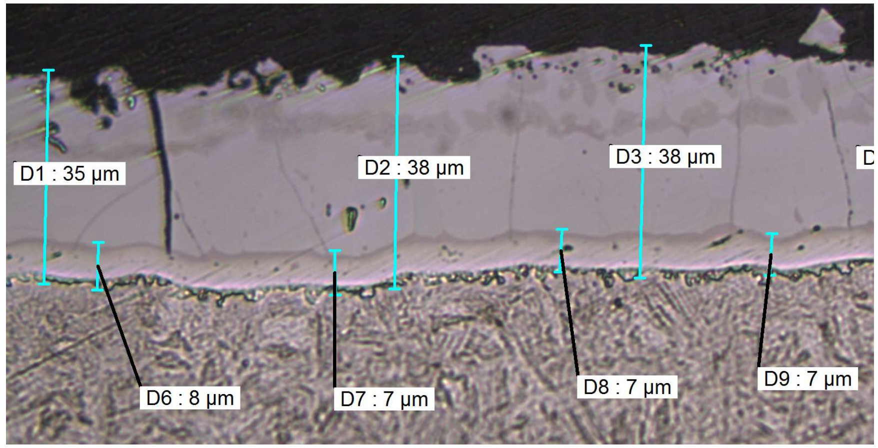
35 µm Total Coating Thickness

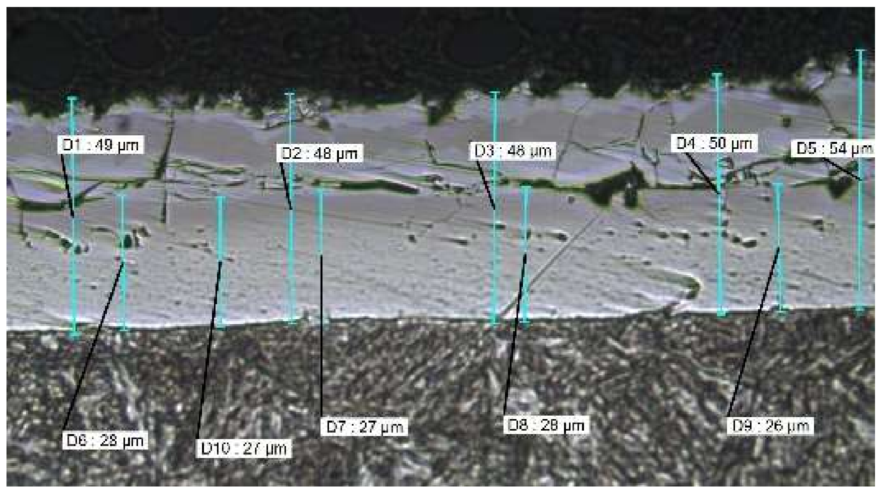
8 µm Interdiffusion Layer Thickness



Nominal Furnace Temp and Time

50 µm Total Coating Thickness

28 µm Interdiffusion Layer Thickness



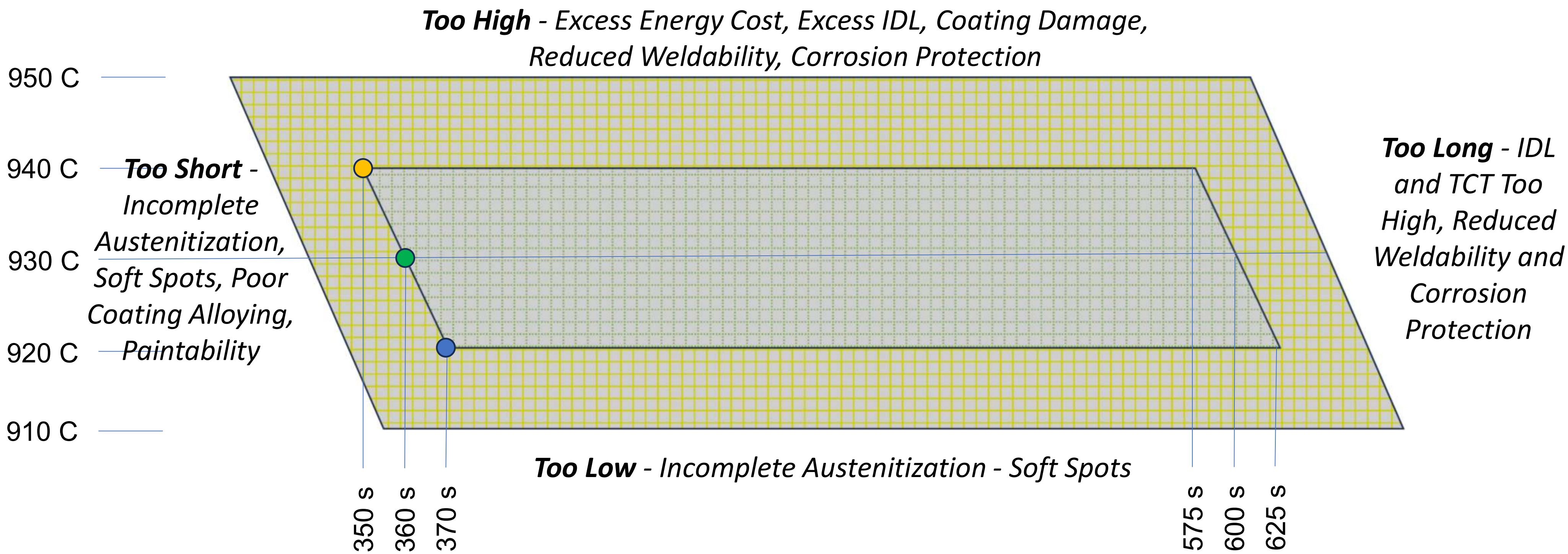
High Furnace Temp with Excessive Time

Source: American Tooling Center Metallurgical Test Lab

Establishing Temp-Time Process Windows

- The previous slide showed that the furnace trace for a 22MnB5 AlSi material with a 930 C furnace temp required heating for a minimum of 300 seconds (the time needed to complete the Soak/Alloy step). A 60 second safety factor was applied, establishing 360 seconds as the nominal furnace time.
- Maximum time was established at 600 seconds, which was tested and showed acceptable levels of IDL growth, Total Coating Thickness, and Coating Roughness.
- To complete the task of establishing the Temp-Time 2D Process Window, the process is repeated at the lowest and highest temperatures planned to be used for the furnace (920C and 940C).
- Typically the 940 C Nominal time will be less than 930 C Nominal time.
- The 940 C Maximum time will typically be disproportionately less than 930 C Maximum time since the higher temperature tends to grow IDL and Coating more quickly than 930 C.
- The opposite is generally true for 920 C versus 930 C, it usually has a longer Nominal time and a disproportionally longer Maximum time.
- Stable processes with rare momentary stoppages due to misfeeds or other issues can often benefit from running at higher temperatures, whereas fragile processes usually benefit from running at lower temperatures due to longer time windows.

Establishing Temp-Time Process Windows



- High Temp - 940 C – 350 Sec to 575 Sec (225 Sec Window)
- Nominal Temp - 930 C – 360 Sec to 600 Sec (240 Sec Window)
- Low Temp - 920 C – 370 Sec to 625 Sec (255 Sec Window)

Typical Austenitization Issues

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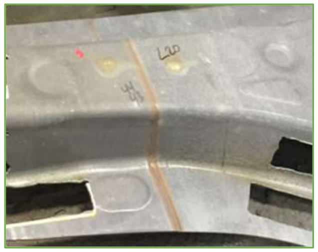
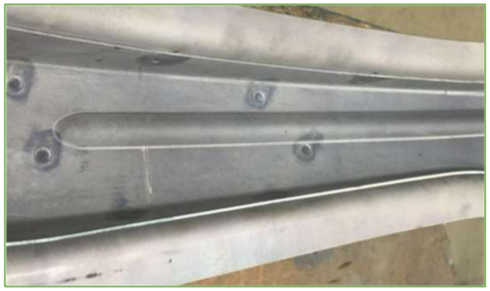
- Material gage/furnace soak time tables are often used instead of thermal traces
  - Different grades may require different times
  - Blank shapes heat differently, thermocouples may show excessive heating on corners of shaped blanks or ends of rails
- TRBs and LWB/TWBs with multiple gages can overheat thin gages before heating thick gages, process windows may be very small.
- Patched blanks can overheat thin gages before heating patches, Process windows may be very small, welds may be fragile



Typical Austenitization Issues

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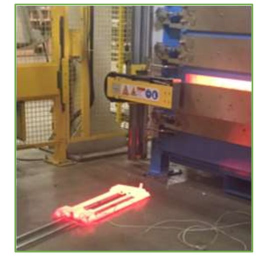
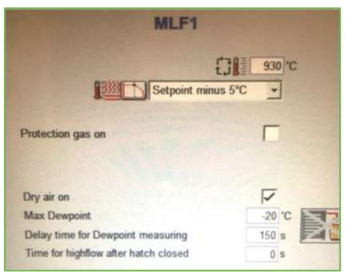
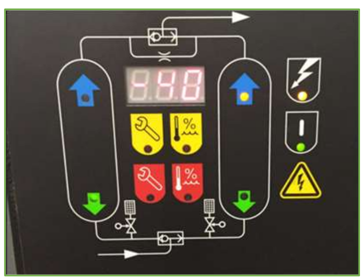
- Excess furnace temp is often used, shortening process window, causing overbaked and damaged coatings



- Lack of furnace maintenance, CQI-9 SAT/TUS testing, thermocouple, optical spot pyrometer/laser scanner calibrations, optical emissivity calibrations
- Not allowing adequate safety margin for establishing nominal time
- Maximum furnace times not tested to verify acceptable coatings
- Inadequate dry air injection, high humidity when running HE sensitive material





DewCav Meas	DewCav Limit W	TimeCav ActTotInCav	TimeCav Setp
-47	-5	30	30
-47	-5	30	30
-47	-5	33	33
-47	-5	33	33
-47	-5	33	33
-47	-5	33	33
-47	-5	33	33

Atmospheric Controlled Austenitization Furnaces

- When austenitizing uncoated material with no protection against decarburization and scale formation, the furnace must have adequate atmospheric control to avoid excessive decarburization and weakened material surfaces.
- Typically this requires N2 + CH4 injection (even if some blank scale is permitted in the die/press when hot stamping the part, with subsequent part shot blasting).
- Atmospheric controlled furnaces can also use methane injection to reduce the amount of hydrogen to assist in reducing HE
- Cost of atmospheric gases remains a roadblock

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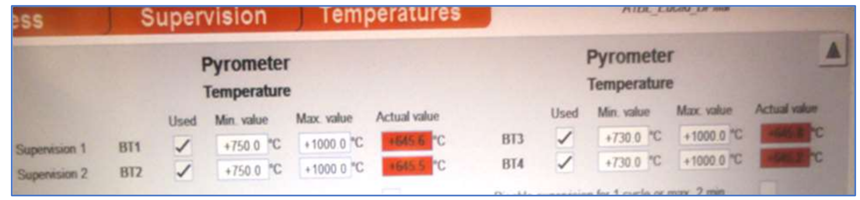
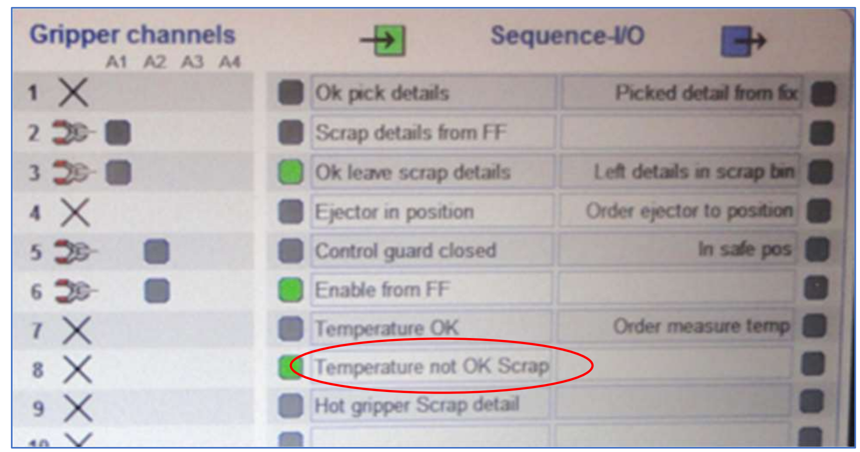
Repeatable Blank Temperatures

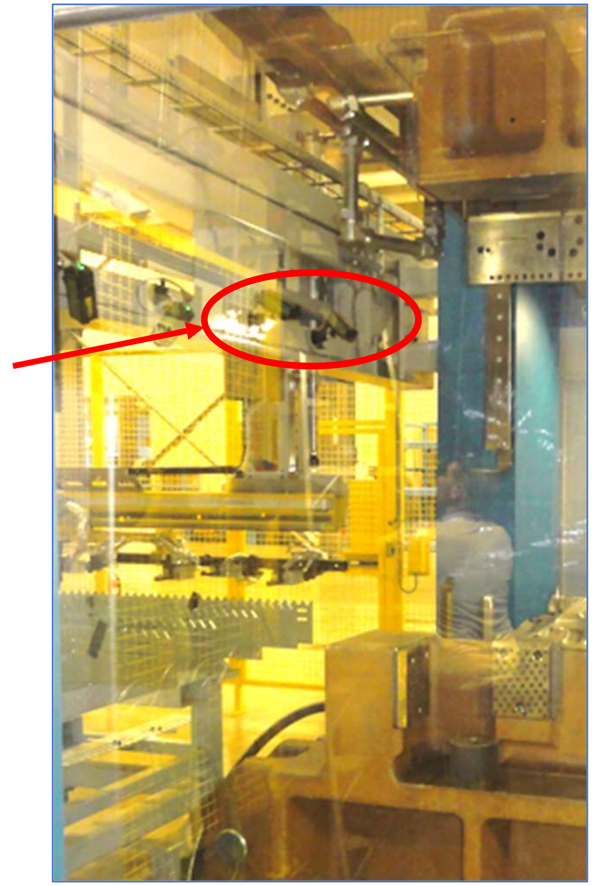
- Blank temperature variation happens primarily due to either furnace temperature or time fluctuation, inadequate soak time to uniformly heat the blank, or variation in ‘air time’ during blank transfer to the die
- Blank optical spot pyrometers must be used to verify blank temp is within an acceptable range after loading the die, before die closes





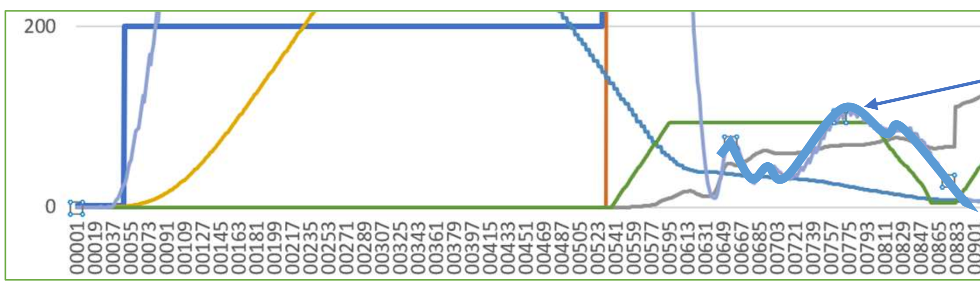
Repeatable Blank Temperatures

- Blank temps out of range can cause variation in formability and martensitic phase transformation, especially when processing quench sensitive material
- Spot pyrometers must be accurately aimed and adjusted to emissivity of material surface and coating for accurate temps
- A laser scanner checking blank temps when exiting the furnace helps verify spot pyrometer emissivity calibration



Forming Velocity Impact On Quench Rates

- Forming velocity primarily impacts formability but also can impact quench rates and material coatings
- High speed quenching requires minimal gap from part to die surface and reasonably good contact for conductive heat transfer
- Slow forming velocity can cause material to prematurely harden as it is formed, causing waviness in the part surface if material is too hard to iron out at die bottoming, reducing heat transfer effectiveness



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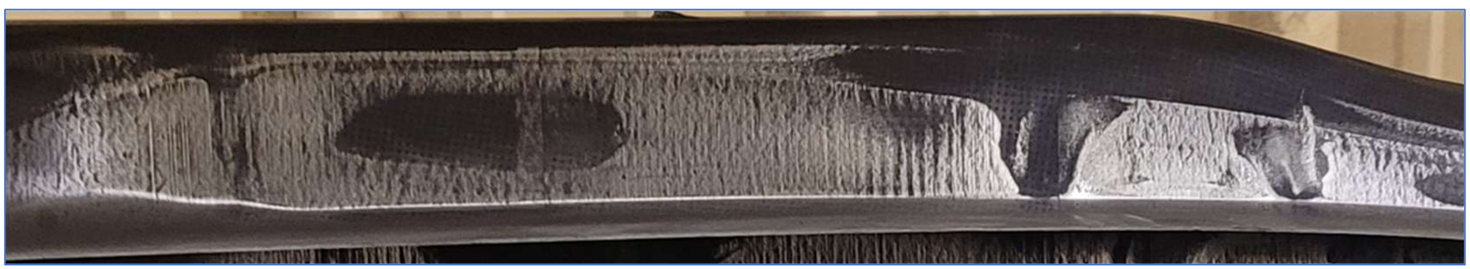
Forming Velocity Impact On Quench Rates

- It can also increase wear on tooling, increasing gaps from part to die
- Excess velocity at bottom tends to embed the coating into the die surface, increasing gaps and reducing thermal transfer efficiency. It also makes it more difficult to clean the die, which tends to compound the problem by reducing cleaning frequency since it requires more production downtime.
- Excess velocity can cause excessive scraping off of coating, and die impact at die bottoming, both causing excessive coating pickup in die



Determining Minimum Quench Force and Time

- Quenching the part also has a process window: Force and Time
- For reduced energy cost, improved die cleaning and die wear, the quench force and time should be reduced to the lowest amount needed. Quenching must reduce part temp so subsequent air quench will not create excessive part geometry variation. High quench force uses large amounts of energy!
- Longer quench time should be used whenever it is not possible to stop production for die cleaning or repair
- Higher quench force should not be used except in emergency. This causes excessive coating pickup and related gaps, slower thermal transfer, die deflection and die wear.

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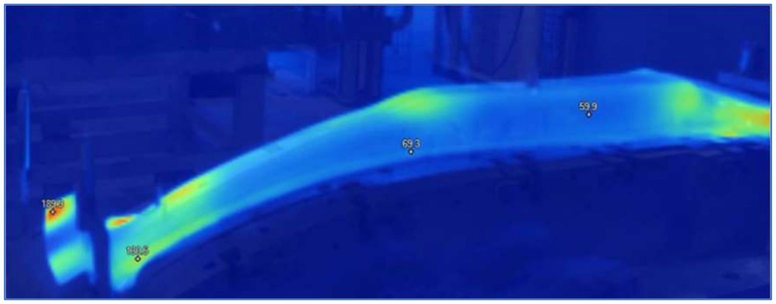
Determining Minimum Quench Force and Time

- Determining quench process windows is similar to austenitizing furnace process window development but is easier to accomplish
- Start with a low quench force and low time. Check part temp with optical spot pyrometer and hand held thermal imager.
- Increase quench time and check part temp. Repeat process.
- After measuring part temps at low force at various quench times, increase force and repeat process to establish optimal force/time.
- Generally, if parts are below 200 C part temp, most parts will air cool without distortion, but capability studies and mechanical testing should validate quench force.



Determining Minimum Quench Force and Time

- Balance quench force against quench time to select optimal force and time settings that repeatedly produce parts below the temp threshold that produces repeatable part geometry.
- Use the lowest possible quench force with a reasonable quench time that does not significantly reduce gross production rate. This may extend duration between die cleanings, offsetting the slower cycle rate.
- Limit ability to increase quench force unless it’s an emergency.
- Capture part temps and establish thresholds for warnings (and alarms that shut down production if limit are exceeded), triggering increasing quench times, or shutdowns for die cleaning or repair.
- Consider laser line scanners for measuring part temps to capture more data
- Publish quench force process window with approved time increases and limited or no force increases, set limits in press recipes

Summary

- Hot stamping combines heat treatment with stamping. Effective Hot Stampers must understand and manage the heat treatment process
- Adopt AIAG CQI-9 Process Table I – Hot Stamping and incorporate into your hot stamping operation. Train operators and setup/maintenance.
- Fully understand austenitization and its impact on part paintability, weldability, corrosion, and mechanical strength/ductility
- Establish process windows for production parts. For high volume parts try to run with lower temperatures and longer furnace time. Assess if there are significant energy savings available at lower furnace temps or if shorter times at higher temps uses less energy.
- Don't limit process window development to austenitizing. Adopt quench process windows to reduce cleaning downtime, increase tool life and reduce tool cost, while reducing energy cost.