SITHERM S140R

SPECIFICATION SHEET

SITHERM S140R is newly developed steel grade with very high thermal conductivity and good toughness within the normal range of hardness for hot-work applications which makes it especially suited for die casting, and hot stamping.

CHEMICAL COMPOSITION (%)

SIJ Metal Ravne	AISI	W.	C	Si	Mo	W	Ni	Co
SITHERM S140R	/	/	0.36	max 0.10	3.20	1.20	2.10	+

TOUGHNESS

KV impact specimens (EN ISO148-1:2017 / ASTM A370-05-17) are used to test impact toughness in transverse direction. Specimens are quenched and tempered to 45+/-1 HRC, and test is performed at 20°C. Average impact toughness of forged quality is higher than 18 Joule for the average forging size of 600 × 300 mm. (NADCA#229-2016)

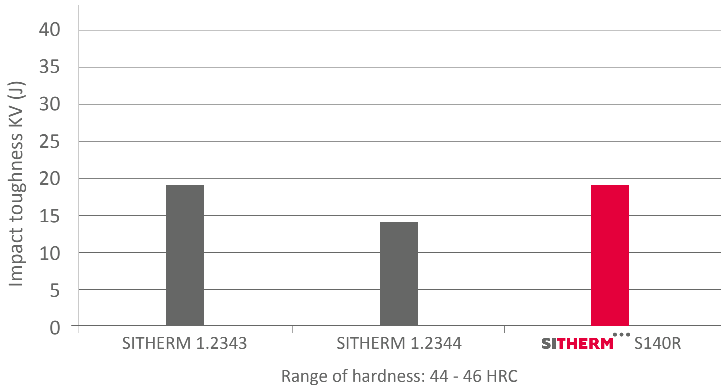

Fig.1: Impact toughness

SITHERM S140R is a supreme hot-work tool steel produced in SIJ Metal Ravne, its most prominent feature is a very high thermal conductivity which is also retained at elevated temperatures. This gives rise to a very high resistance against the formation of thermal fatigue cracks which is especially critical in the field of die casting.
A higher thermal conductivity also enables more rapid cooling of thin-walled work pieces, whereby cycle times during die casting and hot stamping may be significantly shortened. This was achieved without compromising other material properties such as work hardness, wear resistance, toughness, hardenability and resistance against corrosion.

The steels exhibits a high tempering stability and resistance to thermal softening during prolonged exposure to elevated temperatures, making it much suitable for fabrication of die casting tools as well as extrusion dies and die forging tools for press forging.

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APPLICATIONS

SITHERM S140R is meant for:

- production of dies or pressure castings inserts for non-ferrous metals and alloys
- production of hot stamping tools for forming and heat treating high strength sheet materials.
- production of forging dies and parts of forging dies – die forging inserts
- production of extrusion dies
- other areas emphasizing high thermal conductivity (i.e. plastic molding)

SITHERM S140R is supplied in annealed condition, max. 209 HBW (705 N/mm²).

MICROSTRUCTURE IN THE CONDITION AS DELIVERED

SITHERM S140R is delivered in a soft annealed condition according to NADCA#229 standard.

Microstructure of SITHERM S140R steel

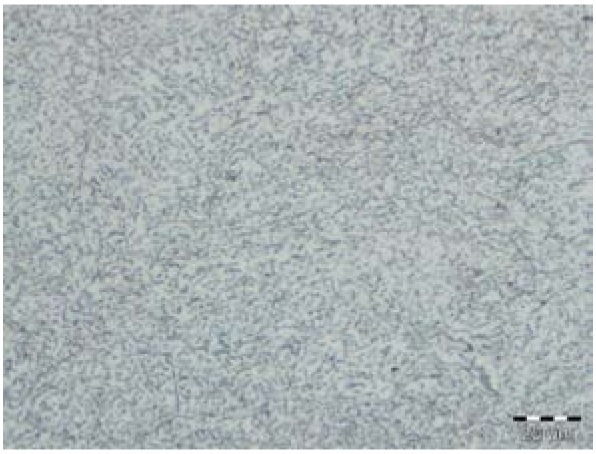


Fig. 2a: Annealed

Fig. 2b: Heat treated (Q+T)

QUALITY COMPARISON

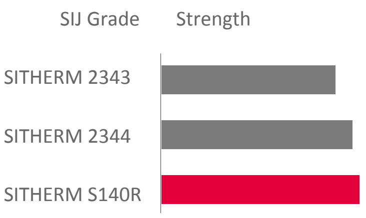


Fig.3: Comparison of strength for hot-work tool steel

Fig.4: Comparison of toughness for hot-work tool steel

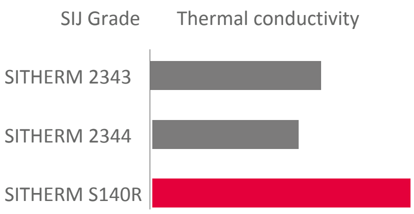


Fig.3: Comparison of thermal conductivity for hot-work tool steel

ADVANTAGES OF USING SITHERM S140R

SITHERM S140R features

- Higher thermal conductivity
- Improved machinability
- Low deformation and distortion during quenching
- Simple single step tempering treatment

Faster cooling of die casting tools has the following benefits:

- Shorter die closing time (faster solidification)
- Shorter time of external cooling time (spray cooling)
- The amount of lubrication required (enables micro lubricating
- Less pollution due to die lubrication
- Longer tool life due to higher thermal fatigue resistance

Die forging tools for press forging made from higher thermal conductivity materials

- Have a lower tool contact temperature
- Reduced softening and wear of the tool surface

Applying SITHER S140R reduces the total cost of the die casting due to increased productivity and tool life.
In applications such as die forging and hot stamping the advantage may be found in less deformation and wear of the tool surface due to lower heating of the tool whereas during extrusion a higher thermal conductivity may act favorably by reducing speed cracking or enable better temperature control and distribution.

PHYSICAL PROPERTIES

Heat treated: hardened and 2× tempered.

Density

DENSITY (g/cm³)				
20 °C	450 °C	500 °C	550 °C	600 °C
7.85	7.80	7.69	7.67	7.65

Thermal conductivity

THERMAL CONDUCTIVITY [W/mK]				
100 °C	450 °C	500 °C	550 °C	600 °C
50	50	50,5	51	50

Electric resistivity

ELECTRIC RESISTIVITY [Ω mm²/m]				
20 °C	450 °C	500 °C	550 °C	600 °C
0.50	0.68	0.86	0.90	0.86

Specific heat capacity

SPECIFIC HEAT CAPACITY [J/gK]				
20 °C	200 °C	400 °C	500 °C	600 °C
0.461	0.498	0.602	0.653	0.714

Modulus of elasticity

MODULUS OF ELASTICITY [10³ N/mm²]				
20 °C	450 °C	500 °C	550 °C	600 °C
215	185	176	171	165

Coefficient of Linear Thermal Expansion

COEFFICIENT OF LINEAR THERMAL EXPANSION BETWEEN 20 °C AND [10^{-6} °C^{-1}]						
100 °C	200 °C	300 °C	400 °C	500 °C	600 °C	700 °C
10.7	11.4	11.7	11.8	11.9	12	12

HEAT TREATMENT

Annealing:

HEATING	ANNEALING TEMPERATURE	COOLING
50 °C/h	800 - 850 °C	20 °C/h
Protect against oxidation, scaling and decarburisation.	Min. 4 hours.	Slow cooling in furnace. Air cooling is possible from 600 °C.

Stress relieving:

HEATING	STRESS RELIEVING	COOLING
100°C/h	600 - 650 °C or 50 °C below the last tempering temperature.	20 °C/h
Protect against oxidation and decarburisation.	Min. 3 hours.	Slow and uniform cooling in furnace to prevent formation of additional residual stress. Air cooling is possible from approximately 200 °C.

Hardening:

Hardness after hardening is 50-54 HRC (1680 - 1916 N/mm²).

HEATING	AUSTENITISING	COOLING
25 - 650 °C, 150-220 °C/h 650 - 850 °C, ≤150 °C/h 850 - 1000 °C, ≤150 °C/h	1040-1060 °C	See CCT diagram
Hold in furnace at T = 650 °C / 850°C until $T_{SURFACE}$-T_{CORE} ≤ 110 °C / 60 °C.	Soaking time: 30 min. after soaking of die surface and core: $T_{SURFACE}$-T_{CORE} ≤ 12 °C (25) F, or 90 minutes maximum after die surface reaches the specified hardening temperature, whichever occurs first.	Fast cooling is recommended in pressurized N_2. For large dimensions of hot-work tooling, see NADCA#207 or GM DC-9999-1Rev.18 specification.

Guidelines:

Optimal heat treatment involves rapid cooling into the bainite region and a short isothermal holding at 400°C. This serves to fully complete the bainite formation and to equalize the temperatures of surface and central region of tool. Quenching rates can be high as bainite produces distortions which are up to an order of magnitude smaller compared to martensite. The volume change from the initial spheroidized pearlite is considered to be negligible. After the equalization step at 400°C, steel is further cooled to 200°C or lower. The Bf temperature as indicated in the CCT diagram is at approx. 350°C, however, one should keep in mind that all such data are essentially dependent on the resolution of the measurement equipment. Accordingly, a higher undercooling is recommended to achieve a retained austenite content below 1% which is common for this steel, after which we proceed with tempering.

TEMPERING DIAGRAM AND IMPACT TOUGHNESS:

Tempering must start immediately after quenching is completed (when part reaches below 250 ˚C).
Three tempering treatments are recommended. First tempering destabilizes the retained austenite.
Second tempering tempers newly formed microstructure constituents.

HEATING	TEMPERING TEMPERATURE	COOLING
150 °C/h – 250 °C/h	1st: 20-590 °C 2nd: choose working hardness (see tempering diagram).	Cool in air or in the furnace to room temperature between tempering cycles.
Protect against oxidation, scaling and decarburisation.	1 hour per 25 mm wall thickness based on furnace temperature. Minimum 5 hours.	

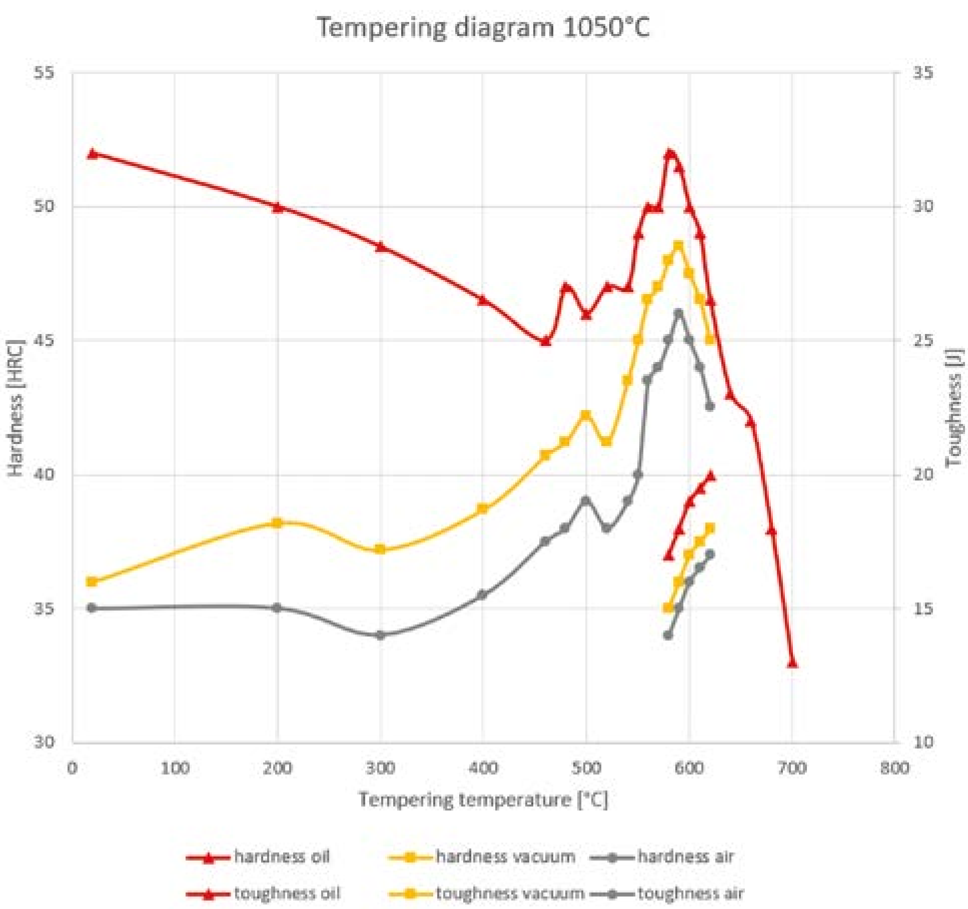
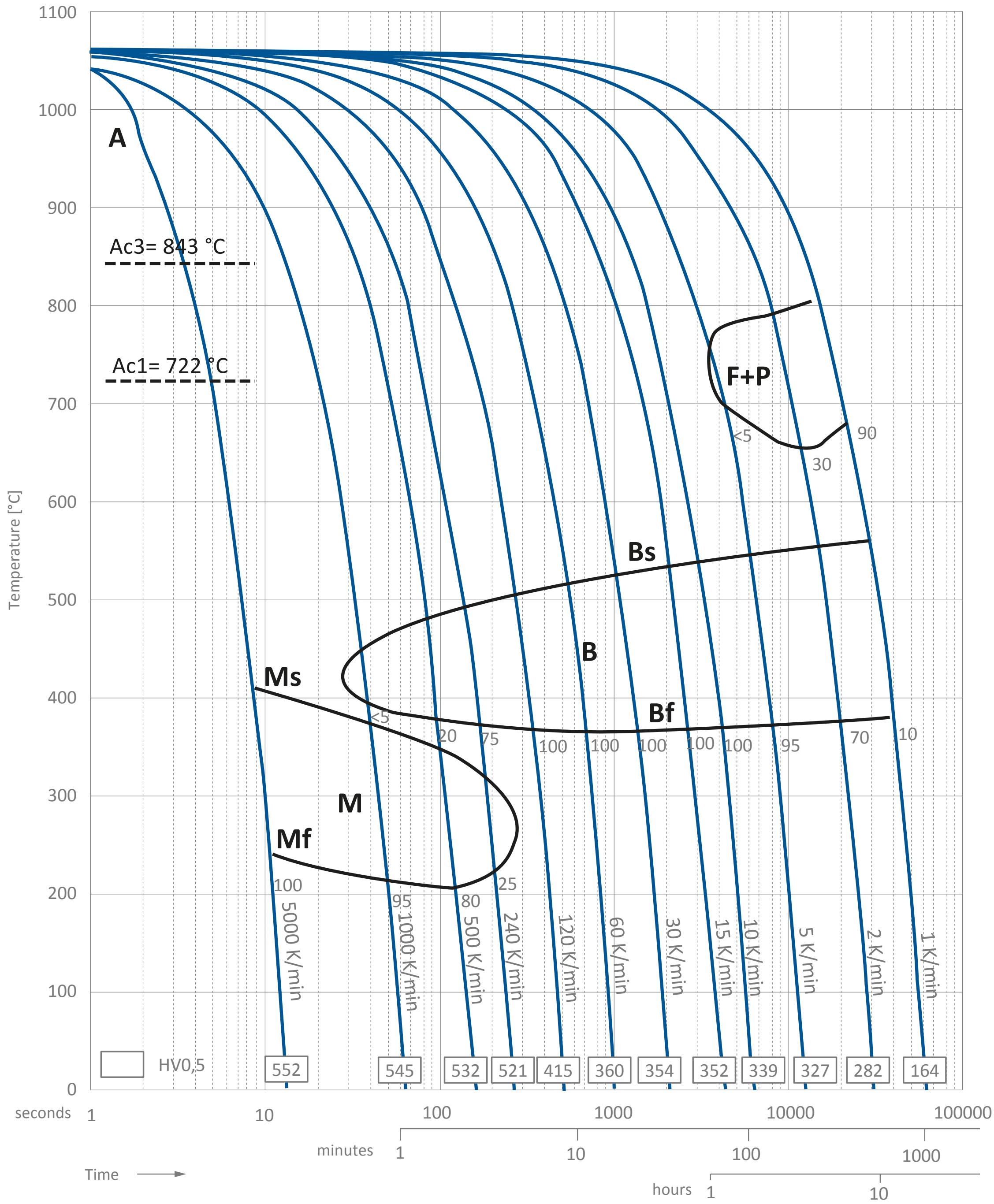


Fig. 5: Tempering diagram

Dimensional changes during hardening and tempering

It is recommended to leave machining allowance before hardening of
minimum 0.2 % per dimension, equal in all three directions.

CONTINUOUS COOLING TRANSFORMATION (CCT) DIAGRAM



Austenitising temperature: 1060 °C; soaking time: 15 min

Legend:
A - Austenite
K - Carbide
P - Pearlite
M - Martensite
B - Bainite

Obtainable hardness upon tempering:

Cooling rate (°K/min]	5000	1000	500	240	120	60	30	15	10
Hardness after quenching [HV0.5]	552	545	532	521	415	360	354	352	339
Hardness after tempering [HV0.5]	539	566	548	545	515	511	484	463	448
Obtainable work hardness [HRC]*	**51.6**	**53.3**	**52.1**	**51.9**	**50.2**	**49.9**	**47.9**	**46.4**	**45.2**
Tempering temperature (°C]	580	580	580	580	590	590	590	590	590

* Estimated from Vickers hardness

CASE STUDY IN HIGH PRESSURE DIE CASTING

Tests were performed on a tool produced from SITHERM 2343 with four inserts, three of which were produced from 1.2367mod, whereas one was from the new steel SITHERM S140R. The inserts were numbered 2-4 and 1 for 1.2367mod and SITHERM S140R respectively as shown in Fig. 7. It was determined by means of optical measurements that the surface of the insert made from SITHERM S140R reached its targeted work temperature of 220°C after just 3 casting cycles whereas during prolonged casting under regular conditions the tool surface was 50-70°C cooler when compared to those produced from 1.2367mod or the frame made from SITHERM 2343. The temperature difference was even more pronounced when internal cooling was switched of as can be seen in Fig. 8.

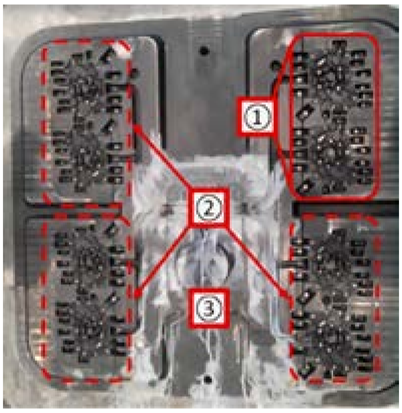


Fig. 7: HPDC tool assembly;

1: Insert made from SITHERM S140R
2: Inserts made from superiour grade 1.2367mod
3: Tool frame and runner made from Wr. Nr 2343

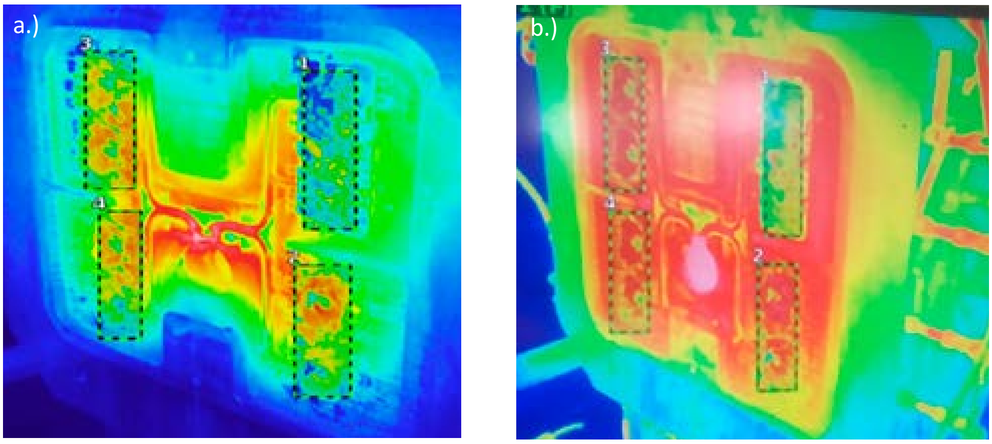


Fig. 8: Thermo-optical measurement of die surface temperature

a.) Using internal cooling, ROI 1 164.1 °C, ROI 2 212.5 °C ROI 3 206.9 °C, ROI 4 202.1 °C

b.) Without internal cooling ROI1: 234°C, ROI2: 276°C ROI3 272°C, ROI 4 273°C.

DISCLAIMER

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RAVNE QUALITY

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