Our quality – your success

Tool Steel – Mold & Die Steel

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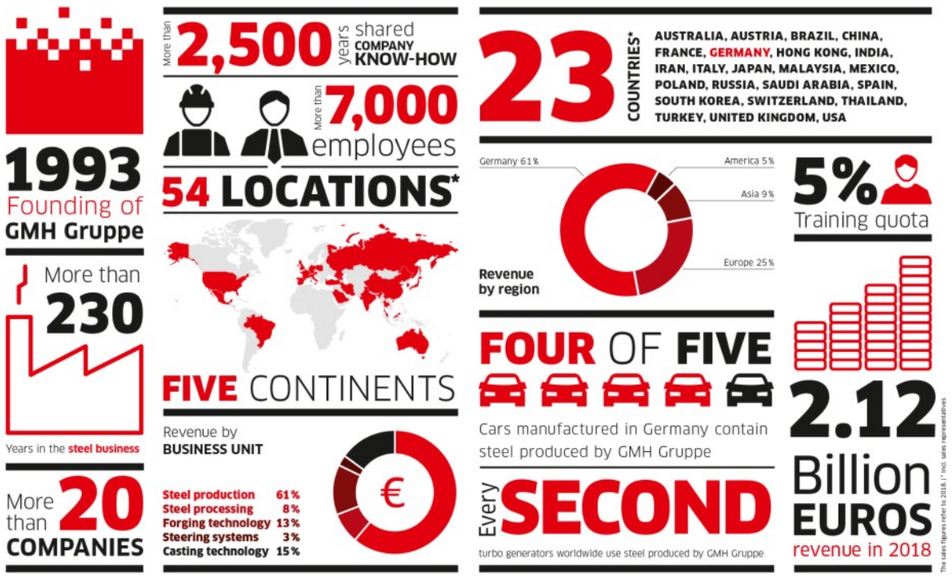
Website

Official SWG distributors are listed on our website.

Schmiedewerke Gröditz
GMH GRUPPE

Content



Steel from Schmiedewerke Gröditz – the basis for your high-tech products

Schmiedewerke Gröditz supplies materials and steel goods that meet specifications and customer requirements with maximum precision. Schmiedewerke Gröditz creates products that meet your standards thanks to expertise gained from more than 240 years producing high quality steel products, sophisticated quality assurance, state-of-the-art plants and new ideas.

With its wide-ranging portfolio, Schmiedewerke Gröditz supplies international industries and markets with the basis for their technological progress. About 300 steel grades produced in more than 2,000 analysis modifications provide customers in many sectors with precisely the application potentials they need. The products are characterized by their precision, dimensional accuracy and special material properties, such as high purity levels, homogeneous microstructures, as well as resistance to wear and corrosion. An ESR plant with maximum ingot weights of 84 tonnes is used to produce high-quality steels. Our steel is produced in extremely efficient processes that have been tried and tested over many years.

Certified quality, dependable delivery

The experts at Schmiedewerke Gröditz always find the best solution for a wide range of customer requirements: precisely needs-oriented and individually customized to specifications and demands. The consistent high quality of the steels is ensured by comprehensive chemical, metallographic and mechanical test processes in line with international standards. Our quality management is certified according to ISO 9001 while our energy and environmental management have ISO 50001 and ISO 14001 certifications. Our constant aspiration is to be the customer's first contact for innovative solutions made of steel.

The new GMH Gruppe – achieving more together

20 other companies worldwide consolidate the expertise, competences and experience of more than 7,000 experts in order to find the best solution for customers.

Steel is one of the most innovative materials of our age. The GMH Gruppe exploits it to help shape the markets and industries of tomorrow. Innovators, specialists and enablers are networked at sites in 24 countries – so they are always present where new markets are developing and customers need us. We drive forward sectors such as mobility, energy and mechanical engineering on five continents – cross-locationally and with short decision-making paths and efficient processes. We develop answers to future questions and exploit the entire potential of steel with our passion for steel and our precise deliveries.

With passion for the future

Innovative power

Together we find new paths where others may find none. For example with our high-strength pre-hardened XPM plastic mold steel, developed by the tool steel specialists of Schmiedewerke Gröditz for the most demanding challenges. It enables the use of large and complex molds economically and more rapidly.

Future-oriented research

Achieving more efficient energy generation whilst preserving resources is one of the greatest challenges of the future. Schmiedewerke Gröditz participates in a multinational research project on a revolutionary solution: the ITER nuclear fusion reactor – the most important of its type for the world's future.

Responsibility

Taking on responsibility is an important attitude throughout the GMH Gruppe. Together we are committed to climate protection, the environment and society; improving our health and safety at work; and promoting education as well as social integration.

material characteristics	material number / grade	**SWG 2311**						
	DIN standard	40CrMnMo7						
	comparable grade	AISI P20						
	chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo		
		0.40	0.30	1.50	2.00	0.20		
	production technology	EAF/LF/VD, forging, Q+T						
	service hardness / strength converted acc. to DIN EN ISO 18265 table B2		HB	HRC	N/mm²			
			280 - 325	28.3 - 34.2	890 - 1030			
	delivery condition	Q+T	280 - 325	28.3 - 34.2	890 - 1030			variation upon request
	maximum dimension	diameter			thickness			
		≤ 600 mm			≤ 400 mm			
	US-specification	EN 10228-3			SEP 1921			
		table 3 - type 1 - qual. class 3			group 3 - class D,d			
	cleanliness	DIN 50602			ASTM E45 method A			
		K4 ≤ 20			A ≤ 1,5; B, C, D ≤ 2			

		0	1	2	3	4	5	comment
technological properties	toughness		■	■				in relation to service hardness
	hot strength at working temp.		■	■	■			
	wear resistance		■	■				
	corrosion resistance	■						
	machinability		■	■	■			Q+T
	polishability		■					ISO/SPI: N3/A-3
	weldability		■	■	■			CET = 0.65 % acc. DIN EN 1011-2
	texturability		■	■				for high texturing reliability: XPM
	nitridability		■	■	■			nitriding hardness 700 - 850 HV1
	chrome-platability		■	■				

rating properties: 0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties	thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
		34.2	33.8	32.0	27.5
	coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
		12.6	12.9	13.4	14.2
	elastic modulus [kN/mm²]	20 °C	200 °C	300 °C	500 °C
		212	207	192	175

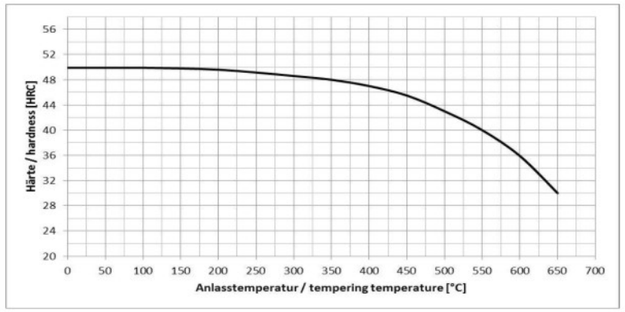
application	technology	mold making, injection molding
	tools	plastic molds, mold frames, mold base, casting tools
	process temperature	< 250 °C
	tool size	small- and medium-sized molds up to 400 mm thickness
	final products	plastic parts without special requirements
	features	quenched and tempered

SWG processing instructions	welding,texturing

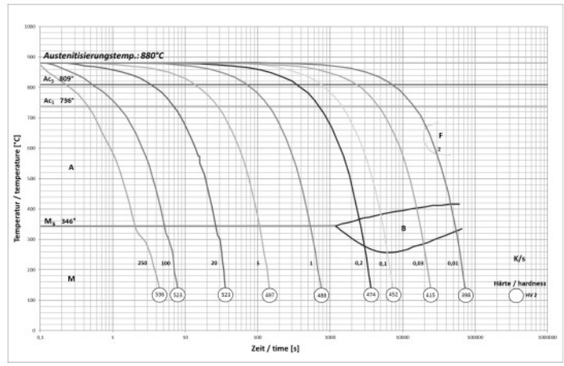
		T min [°C]	T max [°C]	medium / comment
heat treatment	annealing	720	750	air
	hardening	840	870	oil, polymer
	tempering	550	680	air
	stress relieving	500	550	min. 30 °C below tempering temp.
	pre-heating before welding	320	350	
	nitriding	400	550	min. 30 °C below tempering temp.
	PVD-treating	400	550	

diagrams/ structure	CCT-diagram	yes
	tempering diagram	yes
	advice on heat treatment	pre-hardened
	microstructure	mainly bainitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 850 °C in oil



CCT-diagram



material characteristics

material number / grade	**SWG 2312**						
DIN standard	40CrMnMoS8-6						
comparable grade	AISI P20+S						
chemical composition - reference analysis [%]	C	Si	Mn	S	Cr	Mo	
	0.40	0.30	1.50	0.05	1.90	0.20	
production technology	EAF/LF/VD, forging, Q+T						
service hardness / strength converted acc. to DIN EN ISO 18265 table B2		HB	HRC	N/mm²			
		280 - 325	28.3 - 34.2	890 - 1030			
delivery condition	Q+T	280 - 325	28.3 - 34.2	890 - 1030	variation upon request		
maximum dimension	diameter		thickness				
	≤ 800 mm		≤ 700 mm				
US-specification	EN 10228-3		SEP 1921				
	table 3 - type 1 - qual. class 2		group 3 - class C,c				
cleanliness	DIN 50602		ASTM E45 method A				
	K4 ≤ 20 (oxides only)		B, C, D ≤ 2				

technological properties

	0	1	2	3	4	5	comment
toughness		■					in relation to service hardness
hot strength at working temp.		■	■	■			
wear resistance		■	■				
corrosion resistance	■						
machinability		■	■	■	■	■	Q+T
polishability	■						sulfur alloyed
weldability		■	■	■			CET = 0.65 % acc. DIN EN 1011-2
texturability	■						sulfur alloyed
nitridability		■	■	■			nitriding hardness 700 - 850 HV1
chrome-platability	■						sulfur alloyed

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties

thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
	34.2	33.8	32.0	27.5
coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
	12.6	12.9	13.4	14.2
elastic modulus [kN/mm²]	20 °C	200 °C	300 °C	500 °C
	212	207	192	175

application

technology	mold making, injection molding
tools	plastic molds, mold frames, mold base, casting tools
process temperature	< 250 °C
tool size	small- and medium-sized molds up to 400 mm thickness
final products	plastic injection parts
features	sulfur alloyed, not suitable for cavities

SWG processing instructions	welding

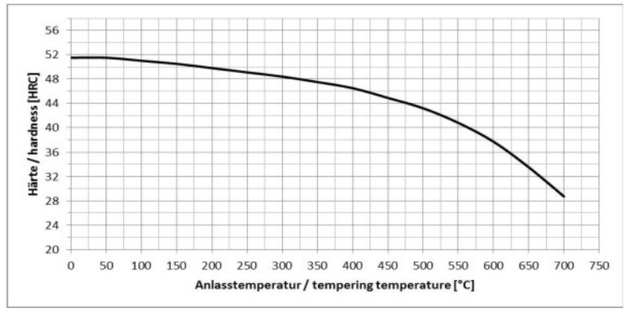
heat treatment

	T min [°C]	T max [°C]	medium / comment
annealing	720	750	air
hardening	840	870	oil, polymer
tempering	550	680	air
stress relieving	500	550	min. 30 °C below tempering temp.
pre-heating before welding	320	350	
nitriding	400	550	min. 30 °C below tempering temp.
PVD-treating	400	550	

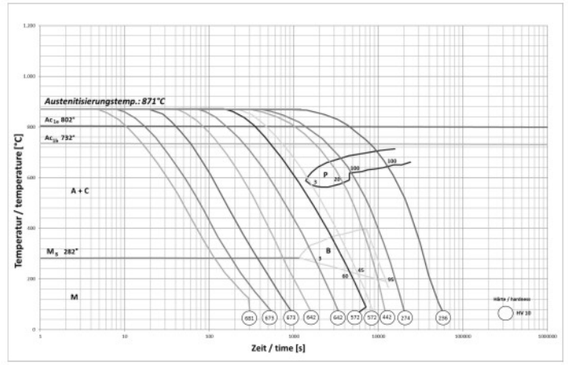
diagrams/ structure

CCT-diagram	yes
tempering diagram	yes
advice on heat treatment	pre-hardened
microstructure	mainly bainitic + manganese sulfides

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 850 °C in oil



CCT-diagram



material characteristics

material number / grade	**SWG 2738 / 2738H / 2738HH**						
DIN standard	40CrMnNiMo8-6-4						
comparable grade	AISI P20+Ni						
chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	Ni	
	0.36	0.25	1.50	1.80	0.20	1.10	
production technology	EAF/LF/VD, forging, Q+T						
service hardness / strength converted acc. to DIN EN ISO 18265 table B2		HB	HRC	N/mm²			
		293-359	30-38	931-1140			
delivery condition	Q+T	293-323	30-34	931-1025	variation upon request		
		308-341	32-36	978-1085			
		324-359	34-38	1029-1140			
maximum dimension	diameter		thickness				
	≤ 1300 mm		≤ 1200 mm				
US-specification	EN 10228-3		SEP 1921				
	table 3 - type 1 - qual. class 3		group 3 - class D,d				
cleanliness	DIN 50602		ASTM E45 method A				
	K4 ≤ 20		A ≤ 1,5; B, C, D ≤ 2				

technological properties

	0	1	2	3	4	5	comment
toughness		■	■	■			in relation to service hardness
hot strength at working temp.		■	■	■			
wear resistance		■	■				
corrosion resistance	■						
machinability		■	■	■			Q+T
polishability		■	■				ISO/SPI: N3/A-3; for higher: 738HH or XPM
weldability		■	■	■			CET = 0.68 % acc. DIN EN 1011-2
texturability		■	■				for high texturing reliability: 738HH or XPM
nitridability		■	■	■			nitriding hardness 700 - 850 HV1
chrome-platability		■	■	■			

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties

thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
	34.2	35.4	34.7	32.5
coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
	11.8	12.9	13.4	14.2
elastic modulus [kN/mm^2]	20 °C	200 °C	300 °C	500 °C
	212	207	192	175

application

technology	mold making, injection molding
tools	plastic molds, large mold frames, die-holder
process temperature	< 250 °C
tool size	medium- and large-sized molds
final products	standard plastic parts
features	quenched and tempered, can be used as replacement for 2311, for high surface requirements use XPM and XPM VICTORY ESR

SWG processing instructions	welding, texturing

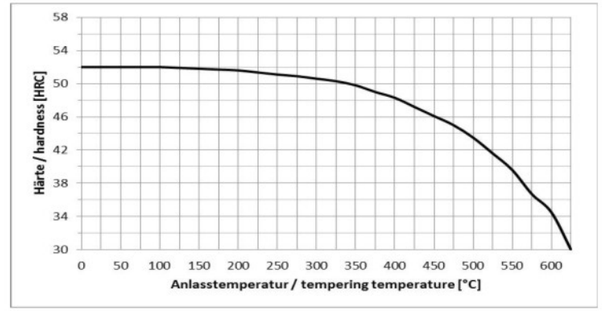
heat treatment

	T min [°C]	T max [°C]	medium / comment
annealing	710	740	air
hardening	850	880	oil, polymer
tempering	520	640	air
stress relieving	490	550	min. 30 °C below tempering temp.
pre-heating before welding	320	350	
nitriding	400	550	min. 30 °C below tempering temp.
PVD-treating	400	550	

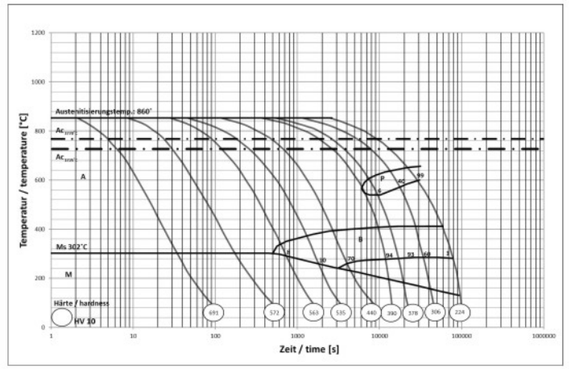
diagrams/ structure

CCT-diagram	yes
tempering diagram	yes
advice on heat treatment	pre-hardened
microstructure	mainly bainitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 880 °C in oil



CCT-diagram



material characteristics	material number / grade	**SWG 738HH**						
	short designation	25MnCrNiMoV6-6-4						
	comparable grade	AISI P20+Ni, 1.2738, 1.2738mod						
	chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	Ni	others
		0.27	0.30	1.55	1.35	alloyed	1.00	alloyed
	production technology	EAF/LF/VD, forging, Q+T						
	service hardness / strength converted acc. to DIN EN ISO 18265 table B2		HB	HRC	N/mm²			
			308 - 359	32 - 38	978-1140			
	delivery condition	Q+T	308 - 341	32 - 36	978-1085	variation upon request		
			324 - 359	34 - 38	1029-1140			
	maximum dimension	diameter		thickness				
		-		≤ 1200 mm				
	US-specification	EN 10228-3		SEP 1921				
		table 3 - type 1 - qual. class 3		group 3 - class D,d				
	cleanliness	DIN 50602		ASTM E45 method A				
		K4 ≤ 20		A ≤ 1,5; B, C, D ≤ 2				

		0	1	2	3	4	5	comment
technological properties	toughness		■	■	■			in relation to service hardness 34 - 38 HCR
	hot strength at working temp.		■	■	■			
	wear resistance		■	■	■			
	corrosion resistance	■						
	machinability		■	■	■			Q+T
	polishability		■	■				ISO/SPI: N2/A-2(34 - 38 HCR); better than 2738
	weldability		■	■	■	■		CET = 0.57 % acc. DIN EN 1011-2
	texturability		■	■	■			
	nitridability		■	■	■			nitriding hardness 550 - 700 HV1
	chrome-platability		■	■	■			

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties	thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
		34.3	36.8	36.6	36.5
	coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
		11.8	12.5	13.1	14.8
	elastic modulus [kN/mm²]	20 °C	200 °C	300 °C	500 °C
		212	207	192	175

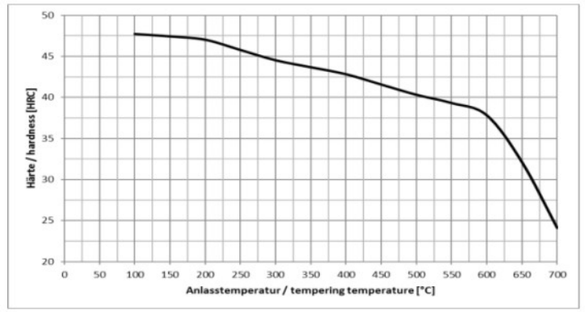
application	technology	mold making, injection molding
	tools	plastic molds, large molds, large mold frames, die-holder
	process temperature	< 250 °C
	tool size	medium- and large-sized molds
	final products	car bumpers, large interior parts, plastic housings
	features	alternative to 2738 for large molds, for high surface requirements: XPM and XPM ESR

SWG processing instructions	welding, texturing

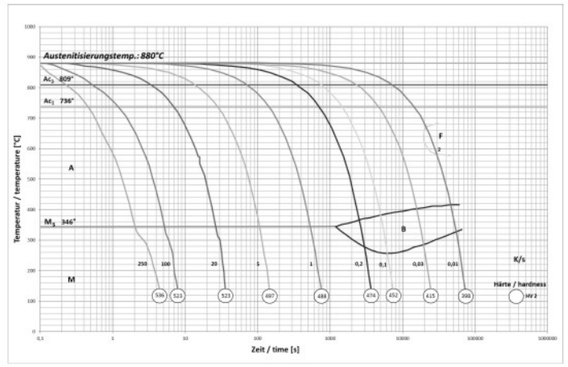
		T min [°C]	T max [°C]	medium / comment
heat treatment	annealing	710	740	air
	hardening	870	920	oil, polymer
	tempering	500	650	air
	stress relieving	450	530	min. 30 °C below tempering temp.
	pre-heating before welding	300	330	
	nitriding	450	530	min. 30 °C below tempering temp.
	PVD-treating	450	530	

diagrams/ structure	CCT-diagram	yes
	tempering diagram	yes
	advice on heat treatment	pre-hardened
	microstructure	mainly bainitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 880 °C in oil



CCT-diagram



material characteristics									
material number / grade	**SWG XPM**								
short designation	25MnCrNiMoV6-6-4								
comparable grade	-								
chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	Ni	others		
	0.27	0.30	1.55	1.35	0.50	1.00	alloyed		
production technology	EAF/LF/VD, forging, Q+T								
service hardness / strength converted acc. to DIN EN ISO 18265 table B2		HB	HRC	N/mm²					
		315 - 400	33 - 42	1000 - 1270					
delivery condition	Q+T	315 - 355	33 - 37.6	1000 - 1128	variation upon request				
		359 - 400	38 - 42	1140 - 1270					
maximum dimension	diameter			thickness					
	-			≤ 1500 mm					
US-specification	EN 10228-3			SEP 1921					
	table 3 - type 1 - qual. class 3			group 3 - class D,d					
cleanliness	DIN 50602			ASTM E45 method A					
	K4 ≤ 20			A ≤ 1,5; B, C, D ≤ 2					

technological properties	0	1	2	3	4	5	comment
toughness		■	■	■			in relation to service hardness 38 - 42 HRC
hot strength at working temp.		■	■	■			
wear resistance		■	■	■			
corrosion resistance	■						
machinability		■	■	■			Q+T
polishability		■	■	■			ISO/SPI: N2/A-2 (38 - 42 HRC); better than 2738
weldability		■	■	■	■		CET = 0.57 % acc. DIN EN 1011-2
texturability		■	■	■	■		
nitridability		■	■	■			nitriding hardness 550 - 700 HV1
chrome-platability		■	■	■	■		

rating properties: 0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties					
thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
	37.0	38.9	38.6	37.2
coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
	11.8	12.5	13.1	14.8
elastic modulus [kN/mm^2]	20 °C	200 °C	300 °C	500 °C
	212	207	192	175

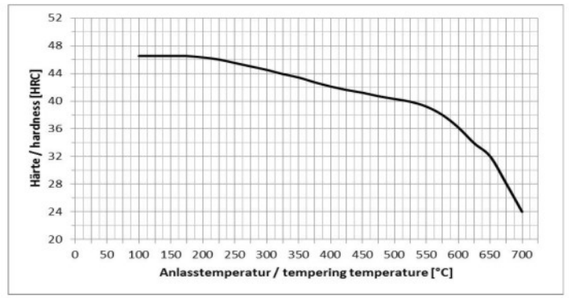
application	
technology	mold making, injection molding, press-molding
tools	large plastic molds, cavities, with high surface requirement
process temperature	< 250 °C
tool size	medium- and large-sized molds
final products	TV housing, bumpers, interior car parts, car lights
features	good texturing reliability

SWG processing instructions	welding, texturing, polishing, deep-hole drilling

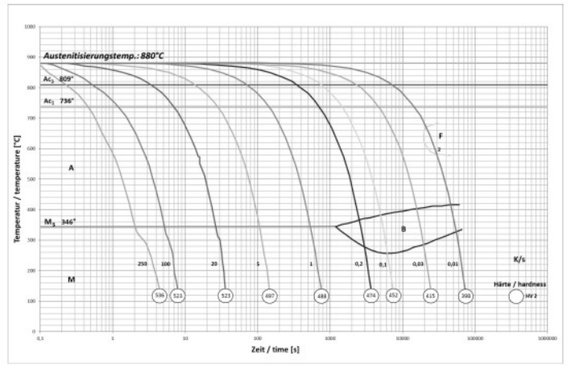
heat treatment		T min [°C]	T max [°C]	medium / comment
	annealing	710	740	air
	hardening	870	920	oil, polymer
	tempering	540	650	air
	stress relieving	500	530	min. 30 °C below tempering temp.
	pre-heating before welding	300	330	
	nitriding	450	530	min. 30 °C below tempering temp.
	PVD-treating	450	530	

diagrams/ structure	
CCT-diagram	yes
tempering diagram	yes
advice on heat treatment	pre-hardened
microstructure	mainly bainitic

Tempering diagram: Average values on samples dia 25 mm × length 50 mm; hardened at 880 °C in oil



CCT-diagram



material characteristics	material number / grade	SWG XPM VICTORY ESR						
	short designation	25MnCrNiMoV6-6-4						
	comparable grade	-						
	chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	Ni	others
		0.30	0.30	1.55	1.35	0.70	1.00	alloyed
	production technology	EAF/LF/VD, ESR, forging, Q+T						
	service hardness / strength converted acc. to DIN EN ISO 18265 table B2		HB	HRC	N/mm²			
			359 - 400	38 - 42	1140-1270			
	delivery condition	Q+T	359 - 400	38 - 42	1140-1270	variation upon request		
	maximum dimension	diameter		thickness				
		-		≤ 1500 mm				
	US-specification	EN 10228-3		SEP 1921				
		table 3 - type 1 - qual. class 4 (t ≤ 800 mm)		group 3 - class E,e (t ≤ 800 mm)				
	cleanliness	DIN 50602		ASTM E45 method A				
		K1 ≤ 10		A ≤ 0,5; B, C, D ≤ 1				

		0	1	2	3	4	5	comment
technological properties	toughness		■	■	■	■		in relation to service hardness
	hot strength at working temp.		■	■	■			
	wear resistance		■	■	■	■		
	corrosion resistance	■						
	machinability		■	■	■			Q+T
	polishability		■	■	■	■		ISO/SPI: N1/A-1
	weldability		■	■	■			CET = 0.57 % acc. DIN EN 1011-2
	texturability		■	■	■	■	■	
	nitridability		■	■	■			nitriding hardness 550 - 700 HV1
	chrome-platability		■	■	■	■	■	

rating properties: 0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties	thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
		37.1	39.0	38.5	37.1
	coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
		12.2	12.5	13.1	14.8
	elastic modulus [kN/mm²]	20 °C	200 °C	300 °C	500 °C
		212	207	192	175

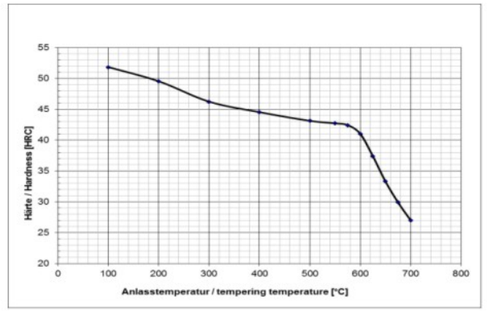
application	technology	mold making, injection molding, press-molding
	tools	plastic molds and cavities, with highest surface requirements
	process temperature	< 250 °C
	tool size	small-, medium- and large-sized molds
	final products	transparent plastic parts, high gloss parts, car lights
	features	high homogeneity and cleanliness

SWG processing instructions	welding, texturing, polishing, deep-hole drilling

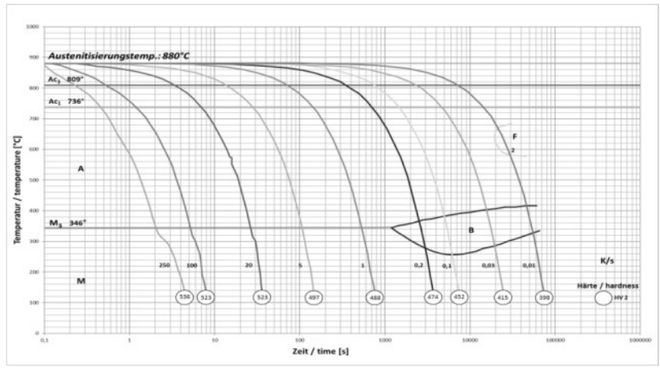
		T min [°C]	T max [°C]	medium / comment
heat treatment	annealing	710	740	air
	hardening	870	920	oil, polymer
	tempering	540	650	air
	stress relieving	500	530	min. 30 °C below tempering temp.
	pre-heating before welding	300	330	
	nitriding	450	530	min. 30 °C below tempering temp.
	PVD-treating	450	530	

diagrams/ structure	CCT-diagram	yes
	tempering diagram	yes
	advice on heat treatment	pre-hardened
	microstructure	mainly bainitic

Tempering diagram: Average values on samples dia 25 mm × length 50 mm; hardened at 880 °C in oil



CCT-diagram



material characteristics	material number / grade	**SWG 2711**						
	DIN standard	54NiCrMoV6						
	comparable grade	-						
	chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	Ni	V
		0.55	0.25	0.70	0.70	0.30	1.70	0.10
	production technology	EAF/LF/VD, forging, Q+T						
	service hardness / strength converted acc. to DIN EN ISO 18265 table G.2		HB	HRC	N/mm²			
			295 - 401	30.4 - 41.6	935 - 1305			
	delivery condition	Q+T	295 - 401	30.4 - 41.6	935 - 1305	variation upon request		
	maximum dimension	diameter			thickness			
		≤ 600 mm			≤ 400 mm			
	US-specification	EN 10228-3			SEP 1921			
		table 3 - type 1 - qual. class 3			group 3 - class D,d			
	cleanliness	DIN 50602			ASTM E45 method A			
		K4 ≤ 30			A ≤ 1,5; B, C, D ≤ 2			

		0	1	2	3	4	5	comment
technological properties	toughness			■	■	■					in relation to service hardness 370 - 401 HB
	hot strength at working temp.			■	■	■					
	wear resistance			■	■	■	■				
	corrosion resistance	■									
	machinability			■	■						Q+T
	polishability			■	■						ISO/SPI: N2/A-2; 370 - 401 HB
	weldability			■	■						CET = 0.73 % acc. DIN EN 1011-2
	texturability			■	■						for high texturing reliability: XPM
	nitridability			■	■						nitriding hardness 550 - 700 HV1
	chrome-platability			■	■						

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties	thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
		37.5	39.7	39.0	36.1
	coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
		11.8	12.7	13.3	14.3
	elastic modulus [kN/mm²]	20 °C	200 °C	300 °C	500 °C
		212	199	192	175

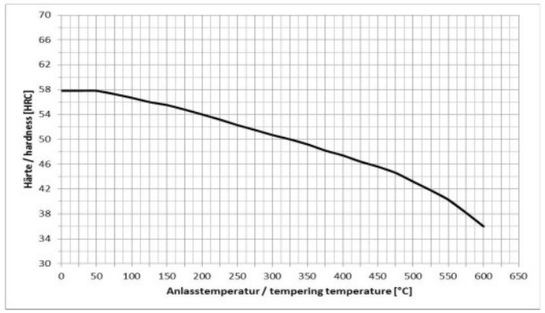
application	technology	mold making, injection molding, press-molding
	tools	plastic molds, die-holder
	process temperature	< 250 °C
	tool size	medium-sized molds
	final products	injection plastic parts, press-forming plastic parts
	features	pre-hardened, high hard, for high surface requirements: XPM and XPM ESR

SWG processing instructions	welding, texturing

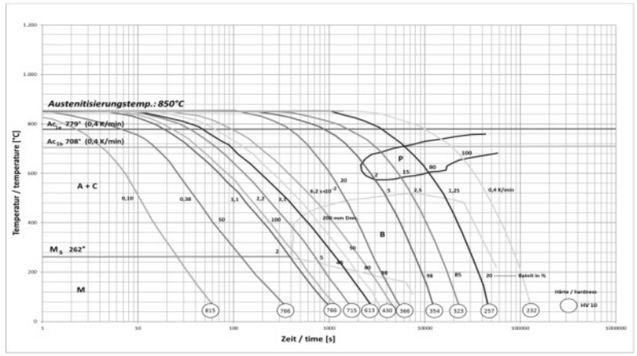
		T min [°C]	T max [°C]	medium / comment
heat treatment	annealing	720	750	air
	hardening	840	870	oil, polymer
	tempering	550	680	air
	stress relieving	500	550	min. 30 °C below tempering temp.
	pre-heating before welding	300	320	
	nitriding	400	500	min. 30 °C below tempering temp.
	PVD-treating	400	500	

diagrams/ structure	CCT-diagram	yes
	tempering diagram	yes
	advice on heat treatment	pre-hardened
	microstructure	martensitic/bainitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 850 °C in oil



CCT-diagram



material characteristics	material number / grade	**SWG 2711mod**						
	short designation	54NiCrMoV6mod						
	comparable grade	-						
	chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	Ni	V
		0.55	0.25	1.00	1.10	0.80	2.00	0.10
	production technology	EAF/LF/VD, forging, Q+T						
	service hardness / strength converted acc. to DIN EN ISO 18265 table G.2		HB	HRC	N/mm²			
			340 - 383	36 - 40.4	1093 - 1255			
	delivery condition	Q+T	295 - 383	30.4 - 40.4	935 - 1255	variation upon request		
	maximum dimension	diameter			thickness			
		≤ 1200 mm			≤ 1000 mm			
	US-specification	EN 10228-3			SEP 1921			
		table 3 - type 1 - qual. class 3			group 3 - class D,d			
	cleanliness	DIN 50602			ASTM E45 method A			
		K4 ≤ 20			A ≤ 1,5; B, C, D ≤ 2			

		0	1	2	3	4	5	comment
technological properties	toughness		■	■	■			in relation to service hardness
	hot strength at working temp.		■	■	■			
	wear resistance		■	■	■	■		
	corrosion resistance	■						
	machinability		■	■				Q+T
	polishability		■	■				ISO/SPI: N2/A-2
	weldability		■	■				CET = 0.84 % acc. DIN EN 1011-2
	texturability		■	■				for high texturing reliability: XPM
	nitridability		■	■				nitriding hardness 550 - 700 HV1
	chrome-platability		■	■				

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties	thermal conductivity [W · m^{-1} · K^{-1}]	20 °C	200 °C	300 °C	500 °C
		37.5	39.7	39.0	36.1
	coefficient of thermal expansion between 20 °C and ... [10^{-6} · K^{-1}]	100 °C	200 °C	300 °C	500 °C
		12.5	13.1	13.4	14.0
	elastic modulus [kN/mm^2]	20 °C	200 °C	300 °C	500 °C
		212	199	192	175

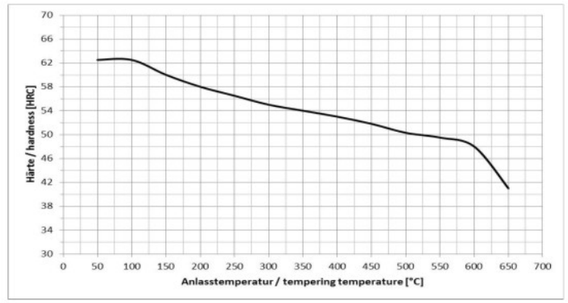
application	technology	mold making, injection molding, press-molding
	tools	large plastic molds, large die-holder
	process temperature	< 250 °C
	tool size	large-sized molds up to 650 mm thickness
	final products	injection plastic parts, press-forming plastic parts
	features	pre-hardened, high hard, for high surface requirements: XPM and XPM VICTORY ESR

SWG processing instructions	welding, texturing

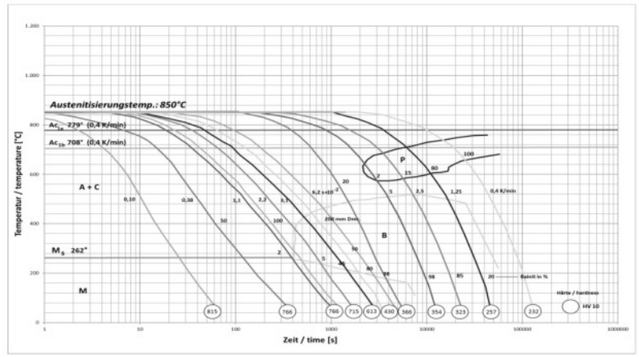
		T min [°C]	T max [°C]	medium / comment
heat treatment	annealing	720	750	air
	hardening	840	870	oil, polymer
	tempering	550	680	air
	stress relieving	500	550	min. 30 °C below tempering temp.
	pre-heating before welding	300	320	
	nitriding	400	500	min. 30 °C below tempering temp.
	PVD-treating	400	500	

diagrams/ structure	CCT-diagram	yes
	tempering diagram	yes
	advice on heat treatment	pre-hardened
	microstructure	martensitic/bainitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 850 °C in oil



CCT-diagram



material characteristics

material number / grade	**SWG 2714**							
DIN standard	56NiCrMoV7							
comparable grade	AISI L6							
chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	Ni	V	
	0.55	0.25	0.70	1.10	0.50	1.70	0.10	
production technology	EAF/LF/VD, forging, Q+T							
service hardness / strength converted acc. to DIN EN ISO 18265 table G.2		HB	HRC	N/mm²				
		370 - 415	39.1 - 43.3	1170 - 1310				
delivery condition	Q+T	370 - 415	39.1 - 43.3	1170 - 1310	variation upon request			
	annealed	≤ 248 HB	-	-				
maximum dimension	diameter		thickness					
	≤ 1200 mm		≤ 1000 mm					
US-specification	EN 10228-3		SEP 1921					
	table 3 - type 1 - qual. class 3		group 3 - class D,d					
cleanliness	DIN 50602		ASTM E45 method A					
	K4 ≤ 30		A ≤ 1,5; B, C, D ≤ 2					

technological properties

	0	1	2	3	4	5	comment
toughness		■	■	■			in relation to service hardness
hot strength at working temp.		■	■	■			
wear resistance		■	■	■	■		
corrosion resistance	■						
machinability		■	■				Q+T
polishability		■	■				ISO/SPI: N2/A-2
weldability		■	■				CET = 0.77 % acc. DIN EN 1011-2
texturability		■	■				for high texturing reliability: XPM
nitridability		■	■				nitriding hardness 550 - 700 HV1
chrome-platability		■	■				

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties

thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
	37.5	39.7	39.0	36.1
coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
	11.8	12.7	13.3	14.3
elastic modulus [kN/mm^2]	20 °C	200 °C	300 °C	500 °C
	212	199	192	175

application

technology	die-making
tools	forging dies, die-holder
process temperature	< 500 °C
tool size	small- and medium-sized dies
final products	die forgings
features	pre-hardened, high hard, for sizes > 450 mm 2714mod, even for replacing of 2711 (due to better hardenability)

SWG processing instructions	welding

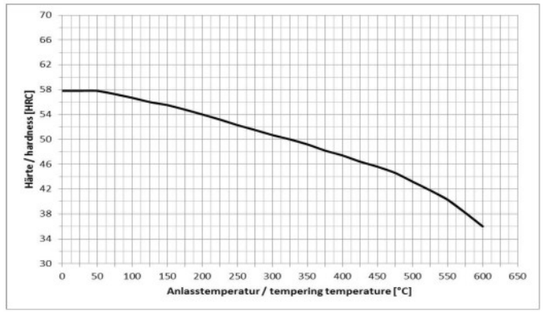
heat treatment

	T min [°C]	T max [°C]	medium / comment
annealing	720	750	air
hardening	840	870	oil, polymer
tempering	550	680	air
stress relieving	500	550	min. 30 °C below tempering temp.
pre-heating before welding	300	320	
nitriding	400	500	min. 30 °C below tempering temp.
PVD-treating	400	500	

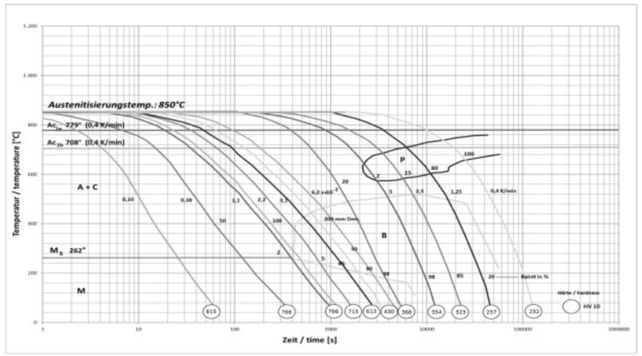
diagrams/ structure

CCT-diagram	yes
tempering diagram	yes
advice on heat treatment	pre-hardened
microstructure	martensitic/bainitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 850 °C in oil



CCT-diagram



material characteristics	material number / grade	**SWG 2767**						
	DIN standard	45NiCrMo16						
	comparable grade	-						
	chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	Ni	
		0.45	0.25	0.35	1.25	0.20	3.90	
	production technology	EAF/LF/VD, forging, annealing						
	service hardness / strength		HB	HRC	N/mm²			
			-	48.9 - 53.0	-			
	delivery condition	annealed	≤ 285	-	-	variation upon request		
	maximum dimension	diameter		thickness				
		≤ 750 mm		≤ 500 mm				
	US-specification	EN 10228-3		SEP 1921				
		table 3 - type 1 - qual. class 3		group 3 - class D,d				
	cleanliness	DIN 50602		ASTM E45 method A				
		K4 ≤ 30		A ≤ 1,5; B, C, D ≤ 2				

		0	1	2	3	4	5	comment
technological properties	toughness		■	■	■			in relation to service hardness
	hot strength at working temp.		■	■	■			
	wear resistance		■	■	■	■	■	
	corrosion resistance	■						
	machinability		■	■	■	■		annealed
	polishability		■	■	■			ISO/SPI: N3/A-3
	weldability		■	■				CET = 0.67 % acc. DIN EN 1011-2
	texturability		■	■	■	■		
	nitridability		■	■				nitriding hardness 550 - 700 HV1
	chrome-platability		■	■	■			

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties	thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
		30.0	32.0	32.0	30.0
	coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
		11.3	12.5	12.8	13.4
	elastic modulus [kN/mm^2]	20 °C	200 °C	300 °C	500 °C
		207	196	189	172

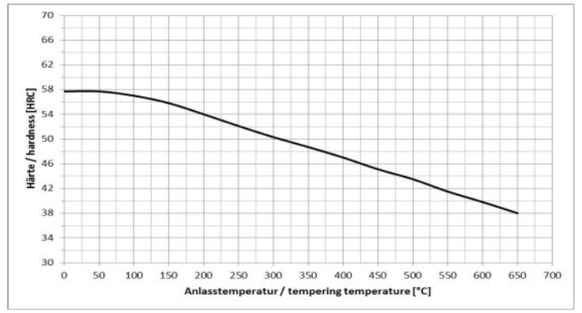
application	technology	mold making, steel cold forming
	tools	stamping tools, cutting tools, plastic molds high hard
	process temperature	< 300 °C
	tool size	small- and medium-sized molds
	final products	steel sheets, strip steel, plastic injection parts
	features	low hardening distortion, high hardness, high toughness

SWG processing instructions	welding

		T min [°C]	T max [°C]	medium / comment
heat treatment	annealing	610	650	air
	hardening	840	870	vacuum, air, oil, polymer
	tempering	200	300	air
	stress relieving	550	600	before hardening only
	pre-heating before welding	280	320	
	nitriding	400	450	with lower hardness only
	PVD-treating	400	450	

diagrams/ structure	CCT-diagram	yes
	tempering diagram	yes
	advice on heat treatment	air or vacuum
	microstructure	martensitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 850 °C in oil



CCT-diagram

material characteristics								
	material number / grade	**SWG 2357 (AISI S7)**						
	DIN standard	50CrMoV13-14						
	comparable grade	AISI S7						
	chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	V	
		0.50	0.30	0.60	3.30	1.50	0.25	
	production technology	EAF/LF/VD, forging, annealing						
	service hardness / strength		HB	HRC	N/mm²			
			-	52 - 56	-			
	delivery condition	annealed	≤ 285	-	-			variation upon request
	maximum dimension	diameter			thickness			
		≤ 600 mm			≤ 400 mm			
	US-specification	EN 10228-3			SEP 1921			
		table 3 - type 1 - qual. class 3			group 3 - class D,d			
	cleanliness	DIN 50602			ASTM E45 method A			
		K4 ≤ 30			A ≤ 1,5; B, C, D ≤ 2			

technological properties		0	1	2	3	4	5	comment
	toughness		■	■				in relation to service hardness
	hot strength at working temp.		■	■	■			
	wear resistance		■	■	■	■		
	corrosion resistance	■						
	machinability		■	■	■	■		soft annealed
	polishability		■	■	■			ISO/SPI: N3/A-3
	weldability		■					CET = 0.89 % acc. DIN EN 1011-2
	texturability		■	■				
	nitridability		■	■	■	■		nitriding hardness 550 - 700 HV1
	chrome-platability		■	■	■			

rating properties: 0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties						
	thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	400 °C	500 °C
		31.1	32.1	31.9	31.1	30.7
	coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	400 °C	500 °C
		11.6	12.1	12.6	13.0	13.3
	elastic modulus [kN/mm^2]	20 °C	200 °C	300 °C	500 °C	
		210	199	191	172	

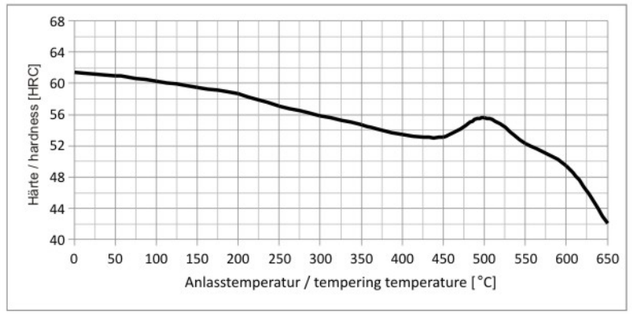
application		
	technology	mold making, steel cold forming, hot stamping
	tools	hot and cold stamping tools, cutting tools, plastic molds high hard
	process temperature	< 500 °C
	tool size	small- and medium-sized molds
	final products	steel sheets, strip steel, plastic injection parts
	features	low hardening distortion, high hardness, proper toughness

SWG processing instructions	welding, vacuum hardening

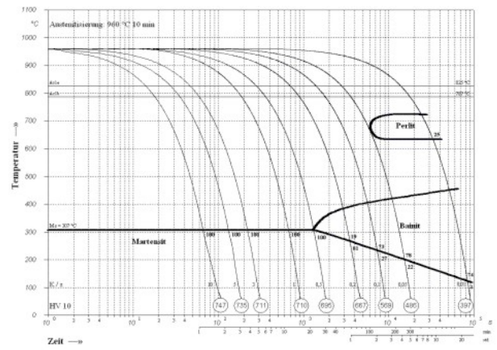
heat treatment		T min [°C]	T max [°C]	medium / comment
	annealing	800	840	furnace until min. 600°C, air
	hardening	950	1010	oil, vacuum
	tempering	200	600	air
	stress relieving	600	650	before hardening
	pre-heating before welding	350	-	
	nitriding	480	550	min. 30 °C below tempering temp.
	PVD-treating	480	550	

diagrams/ structure		
	CCT-diagram	yes
	tempering diagram	yes
	advice on heat treatment	air or vacuum
	microstructure	martensitic

Tempering diagram: Average values on samples dia 25 mm × length 50 mm; hardened at 960 °C in oil



CCT-diagram



material characteristics

material number / grade	**SWG GPM58 VICTORY ESR**							
short designation	X50CrMoV5-2							
comparable grade	-							
chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	V	Ni	
	0.5	≤ 0.5	0.5	5.0	2.2	0.7	+	
production technology	EAF/LF/VD/ESR, forging, annealing							
service hardness / strength		HB	HRC	N/mm²				
		-	54 - 58	-				
delivery condition	annealed	≤ 250	-	-				variation upon request
maximum dimension	diameter			thickness				
	-			≤ 400 mm				
US-specification	EN 10228-3			SEP 1921				
	table 3 - type 1 - qual. class 4			group 3 - class E,e				
cleanliness	DIN 50602			ASTM E45 method A				
	K1 ≤ 10			A ≤ 0,5; B, C, D ≤ 1				

technological properties

	0	1	2	3	4	5	comment
toughness		■	■	■			in relation to service hardness 54 - 58 HRC
hot strength at working temp.		■	■	■	■	■	
wear resistance		■	■	■	■	■	
corrosion resistance	■						
machinability		■	■				annealed
polishability		■	■	■	■		ISO/SPI: N1/A-1
weldability		■					CET = 1.03 % acc. DIN EN 1011-2
texturability		■	■	■			
nitridability		■	■	■	■	■	nitriding hardness 900 - 1250 HV1
chrome-platability		■	■	■	■	■	high cleanliness

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties

thermal conductivity [W · m^{-1} · K^{-1}]	20 °C	200 °C	300 °C	400 °C	500 °C
	23.5	27.3	28.2	28.7	29.3
coefficient of thermal expansion between 20 °C and ... [10^{-6} · K^{-1}]	100 °C	200 °C	300 °C	400 °C	
	12.6	12.7	13.0	13.4	
elastic modulus [kN/mm²]	20 °C	200 °C	300 °C	500 °C	
	195	-	-	-	

application

technology	mold making for plastic injection, cold and hot working applications
tools	molds and inserts for reinforced plastic injection, press forming, cutting, stamping, thread rolling, hot shears, die casting
process temperature	< 600 °C
tool size	small- and medium-sized dies
final products	high strength plastic parts, clippings, thread bolts, structure parts
features	for high requirements on strength and toughness, wear resistance, lasting series tools

SWG processing instructions	vacuum hardening

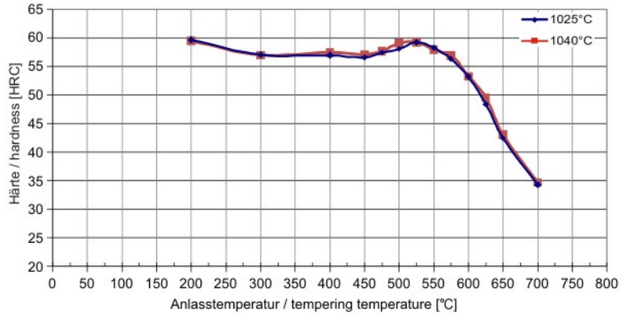
heat treatment

	T min [°C]	T max [°C]	medium / comment
annealing	800	850	furnace until 650 °C, air
hardening	1010	1040	vacuum, oil
tempering	530	600	air, protective gas
stress relieving	500	600	min. 30 °C below tempering temp.
pre-heating before welding	300	320	
nitriding	480	550	min. 30 °C below tempering temp.
PVD-treating	480	550	

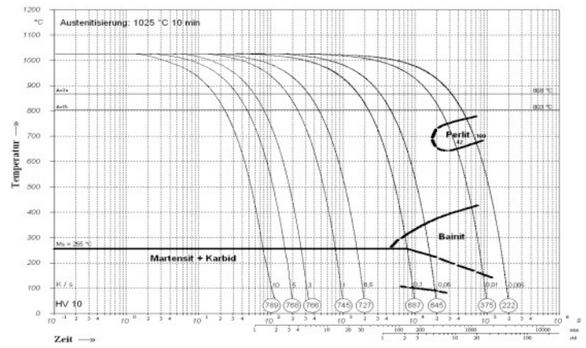
diagrams/ structure

CCT-diagram	yes
tempering diagram	yes
advice on heat treatment	vacuum hardening after pre-machining
microstructure	martensitic

Tempering diagram: Average values on samples 20mm×28mm×36mm, hardened at 1025 °C and 1040°C (1h), fan cooling



CCT-diagram



material characteristics						
material number / grade	**SWG 2083**					
DIN standard	X40Cr14					
comparable grade	AISI 420					
chemical composition - reference analysis [%]	C	Si	Mn	Cr		
	0.40	0.40	0.70	13.00		
production technology	EAF/LF/VD/ forging, Q+T or annealing					
service hardness / strength converted acc. to DIN EN ISO 18265 table B2		HB	HRC	N/mm²		
		-	32 - 52	-		
delivery condition	Q+T	308-341	32 - 36	980-1085		variation upon request
	annealed	≤ 250		-		
maximum dimension	diameter		thickness			
	≤ 650 mm		≤ 450 mm			
US-specification	EN 10228-3		SEP 1921			
	table 3 - type 1 - qual. class 3		group 3 - class D,d			
cleanliness	DIN 50602		ASTM E45 method A			
	K4 ≤ 20		A ≤ 1,5; B, C, D ≤ 2			

technological properties	0	1	2	3	4	5	comment
toughness		■	■				in relation to service hardness 48 - 52 HRC
hot strength at working temp.		■	■	■			
wear resistance		■	■	■	■		
corrosion resistance		■	■	■			polished surface for best corrosion resistance
machinability		■	■	■			annealed
polishability		■	■	■			ISO/SPI: N2/A-2; 48 - 52 HRC
weldability		■					CET = 1.12 % acc. DIN EN 1011-2
texturability		■	■				
nitridability		■	■	■	■		nitriding hardness 900 - 1200 HV1
chrome-platability		■	■				

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties					
thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
	20.0	23.0	24.0	25.0
coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
	10.5	11.0	11.0	11.6
elastic modulus [kN/mm^2]	20 °C	200 °C	300 °C	500 °C
	218	206	198	180

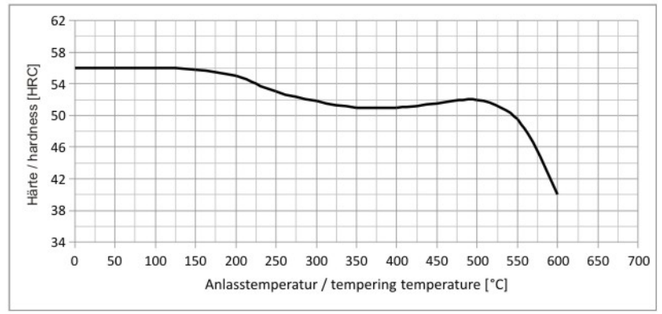
application	
technology	mold making, injection molding, corrosion resistant
tools	plastic molds, corrosion resistant
process temperature	< 300 °C
tool size	small- and medium-sized molds
final products	plastic injection parts (medicine, compact discs)
features	pre-hardened up to 36 HRC delivery hardness

SWG processing instructions	welding, texturing, vacuum hardening

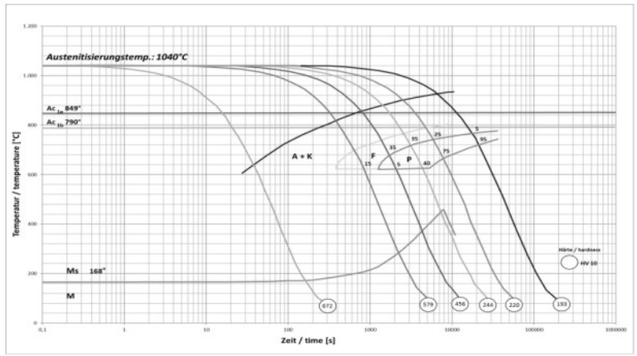
heat treatment		T min [°C]	T max [°C]	medium / comment
	annealing	760	800	furnace, air
	hardening	1000	1030	vacuum, oil
	tempering	250	600	furnace, air
	stress relieving	450	500	min. 30 °C below tempering temp.
	pre-heating before welding	320	350	
	nitriding	400	500	min. 30 °C below tempering temp.
	PVD-treating	400	500	

diagrams/ structure	
CCT-diagram	yes
tempering diagram	yes
advice on heat treatment	pre-hardened, annealing before new-hardening
microstructure	martensitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 1020 °C in oil



CCT-diagram



material characteristics						
	material number / grade	**SWG 2083 VICTORY ESR**				
	DIN standard	X40Cr14				
	comparable grade	AISI 420 ESR				
	chemical composition - reference analysis [%]	C	Si	Mn	Cr	
		0.40	0.40	0.70	13.00	
	production technology	EAF/LF/VD/ESR, forging, Q+T (annealing)				
	service hardness / strength converted acc. to DIN EN ISO 18265 table B2		HB	HRC	N/mm²	
			-	32 - 52	-	
	delivery condition	Q+T	308 - 341	32 - 36	980-1085	variation upon request
		annealed	≤ 250	-	-	
	maximum dimension	diameter		thickness		
		≤ 700 mm		≤ 500 mm		
	US-specification	EN 10228-3		SEP 1921		
		table 3 - type 1 - qual. class 4		group 3 - class E,e		
	cleanliness	DIN 50602		ASTM E45 method A		
		K1 ≤ 10		A ≤ 0,5; B, C, D ≤ 1		

technological properties		0	1	2	3	4	5	comment
	toughness		■	■				in relation to service hardness 48 - 52 HRC
	hot strength at working temp.		■	■	■			
	wear resistance		■	■	■	■		
	corrosion resistance		■	■	■	■		polished surface for best corrosion resistance
	machinability		■	■	■			annealed
	polishability		■	■	■	■	■	ISO/SPI: N0/A-1; 48 - 52 HRC
	weldability		■					CET = 1.12 % acc. DIN EN 1011-2
	texturability		■	■	■	■		
	nitridability		■	■	■	■		nitriding hardness 900 - 1200 HV1
	chrome-platability		■	■	■	■		high cleanliness

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties					
	thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
		20.0	23.0	24.0	25.0
	coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
		10.5	11.0	11.0	11.6
	elastic modulus [kN/mm^2]	20 °C	200 °C	300 °C	500 °C
		218	206	198	180

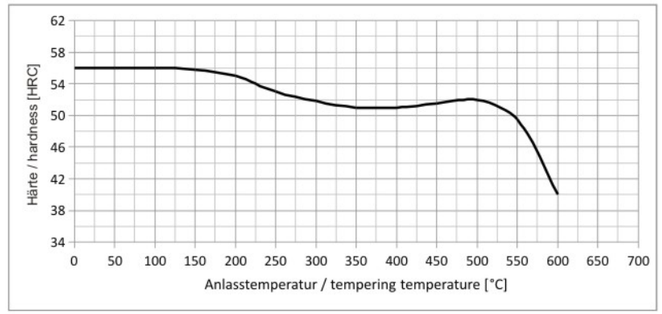
application		
	technology	mold making, injection molding, corrosion resistant
	tools	plastic molds, corrosion resistant, high surface quality
	process temperature	< 300 °C
	tool size	small- and medium-sized molds
	final products	plastic injection parts, high gloss, transparent
	features	pre-hardened up to 36 HRC delivery hardness

SWG processing instructions	welding, texturing, polishing,vacuum hardening

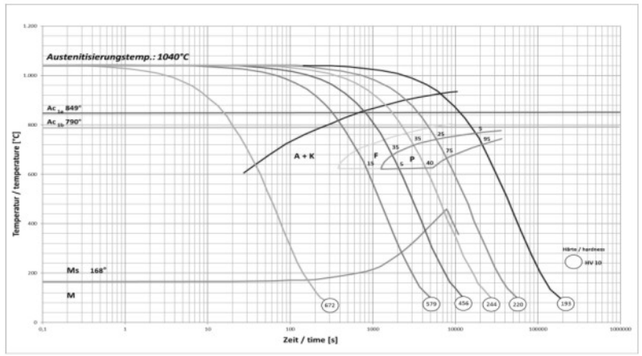
heat treatment		T min [°C]	T max [°C]	medium / comment
	annealing	760	800	furnace
	hardening	1000	1030	vacuum, oil
	tempering	250	600	furnace, air
	stress relieving	450	500	min. 30 °C below tempering temp.
	pre-heating before welding	320	350	
	nitriding	400	500	min. 30 °C below tempering temp.
	PVD-treating	400	500	

diagrams/ structure		
	CCT-diagram	yes
	tempering diagram	yes
	advice on heat treatment	pre-hardened, annealing before new-hardening
	microstructure	martensitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 1020 °C in oil



CCT-diagram



material characteristics							
material number / grade	**SWG 2083mod VICTORY ESR**						
short designation	X40Cr14						
comparable grade	AISI 420 mod ESR						
chemical composition - reference analysis [%]	C	Si	Mn	Cr	V		
	0.38	1.00	0.50	13.00	0.25		
production technology	EAF/LF/VD/ESR, forging, Q+T or annealing						
service hardness / strength converted acc. to DIN EN ISO 18265 table B2		HB	HRC	N/mm²			
		-	29 - 52	-			
delivery condition	Q+T	285 - 332	29 - 35	905 - 1055	variation upon request		
	annealed	≤ 241	-	-			
maximum dimension	diameter		thickness				
	≤ 700 mm		≤ 500 mm				
US-specification	EN 10228-3		SEP 1921				
	table 3 - type 1 - qual. class 4		group 3 - class E,e				
cleanliness	DIN 50602		ASTM E45 method A				
	K1 ≤ 10		A ≤ 0,5; B, C, D ≤ 1				

technological properties	0	1	2	3	4	5	comment
toughness		■	■				in relation to service hardness 48 - 52 HRC
hot strength at working temp.		■	■	■	■		
wear resistance		■	■	■	■		
corrosion resistance		■	■	■	■	■	polished surface for best corrosion resistance
machinability		■	■	■			annealed
polishability		■	■	■	■	■	ISO/SPI: N0/A-1; 48 - 52 HRC
weldability		■					CET = 1.12 % acc. DIN EN 1011-2
texturability		■	■	■	■		
nitridability		■	■	■	■		nitriding hardness 900 - 1200 HV1
chrome-platability		■	■	■	■		high cleanliness

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties					
thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
	21.0	23.0	25.0	24.0
coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
	11.0	11.3	11.6	12.0
elastic modulus [kN/mm^2]	20 °C	200 °C	300 °C	500 °C
	218	206	198	180

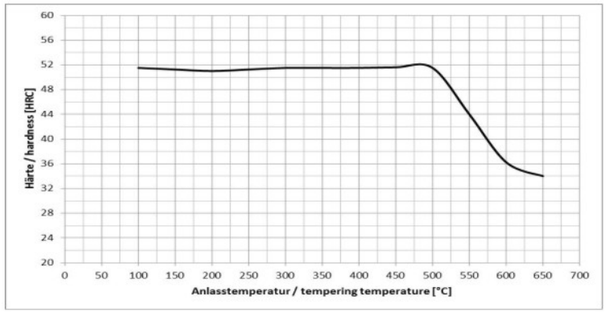
application	
technology	mold making, injection molding, corrosion resistant
tools	plastic molds, corrosion resistant, high surface quality
process temperature	< 300 °C
tool size	small- and medium-sized molds
final products	plastic injection parts, high gloss, transparent (e.g optical and electronical parts)
features	pre-hardened up to 35 HRC delivery hardness, high cleanliness

SWG processing instructions	welding, texturing, polishing,vacuum hardening

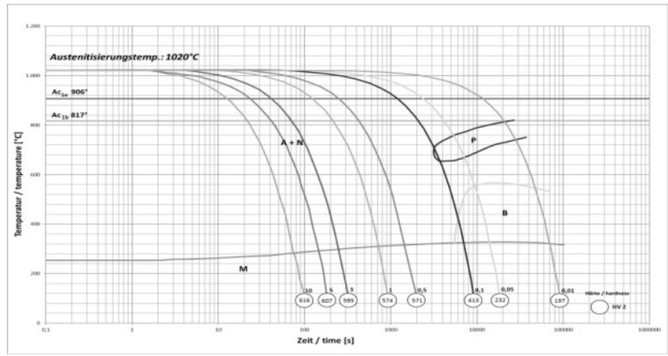
heat treatment		T min [°C]	T max [°C]	medium / comment
	annealing	760	800	furnace
	hardening	1000	1030	vacuum, oil
	tempering	250	600	furnace, air
	stress relieving	450	500	max. 30 °C below tempering temp.
	pre-heating before welding	320	350	
	nitriding	400	500	max. 30 °C below tempering temp.
	PVD-treating	400	500	

diagrams/ structure	
CCT-diagram	yes
tempering diagram	yes
advice on heat treatment	pre-hardened, annealing before new-hardening
microstructure	martensitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 1020 °C in oil



CCT-diagram



material characteristics	material number / grade	**SWG CRMHP VICTORY ESR**						
	short designation	X28CrNi13						
	comparable grade	1.4021mod ESR, AISI 420mod ESR						
	chemical composition - reference analysis [%]	C	Si	Mn	Cr	Ni	N	
		0.25	0.30	0.40	14.00	0.60	alloyed	
	production technology	EAF/LF/VD/ESR, forging, annealing						
	service hardness / strength		HB	HRC	N/mm²			
			-	50 - 52	-			
	delivery condition	annealed	≤ 250	-	-	variation upon request		
	maximum dimension	diameter			thickness			
		-			≤ 500 mm			
	US-specification	EN 10228-3			SEP 1921			
		table 3 - type 1 - qual. class 4			group 3 - class E,e			
	cleanliness	DIN 50602			ASTM E45 method A			
		K1 ≤ 10			A ≤ 0,5; B, C, D ≤ 1			

		0	1	2	3	4	5	comment
technological properties	toughness		■	■				in relation to service hardness
	hot strength at working temp.		■	■	■			
	wear resistance		■	■	■	■		
	corrosion resistance		■	■	■	■	■	polished surface for best corrosion resistance
	machinability		■	■	■			annealed
	polishability		■	■	■	■	■	ISO/SPI: N0/A-1
	weldability		■					CET = 1.00 % acc. DIN EN 1011-2
	texturability		■	■	■	■		
	nitridability		■	■	■	■		nitriding hardness 900 - 1200 HV1
	chrome-platability		■	■	■	■	■	high cleanliness

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties	thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
		20.0	21.0	-	-
	coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
		10.5	11.0	11.0	-
	elastic modulus [kN/mm²]	20 °C	200 °C	300 °C	500 °C
		218	206	198	180

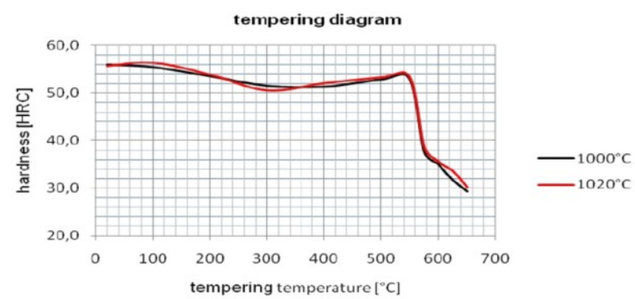
application	technology	mold making, corrosion resistant
	tools	corrosion resistant plastic molds with high requirements on surface quality
	process temperature	< 300 °C
	tool size	small- and medium-sized molds
	final products	transparent plastic parts, high gloss parts, lenses, optical parts, electronic covers
	features	for very high surface quality

SWG processing instructions	welding, texturing, polishing, vacuum hardening

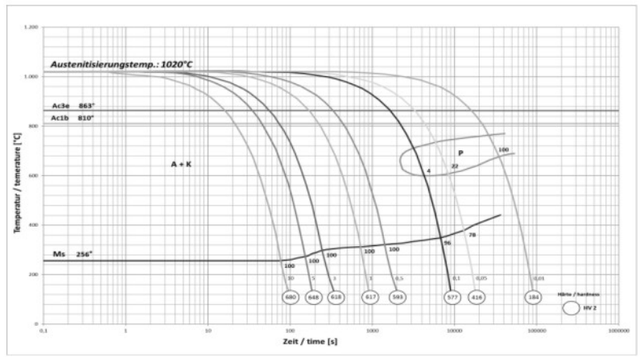
		T min [°C]	T max [°C]	medium / comment
heat treatment	annealing	760	800	furnace
	hardening	1000	1030	vacuum, oil
	tempering	250	600	furnace
	stress relieving	450	500	min. 30 °C below tempering temp.
	pre-heating before welding	320	350	
	nitriding	400	500	min. 30 °C below tempering temp.
	PVD-treating	400	500	

diagrams/ structure	CCT-diagram	yes
	tempering diagram	yes
	advice on heat treatment	vacuum hardening after pre-machining
	microstructure	martensitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 1000°C and 1020°C in oil



CCT-diagram



material characteristics	material number / grade	**SWG CPM50 VICTORY ESR**						
	short designation	X28CrNiMo13						
	comparable grade	1.4021mod, AISI 420mod						
	chemical composition - reference analysis [%]	C	Si	Mn	Cr	Ni	N	
		0.28	0.30	0.40	14.00	0.60	alloyed	
	production technology	EAF/LF/VD/ESR, forging, Q+T						
	service hardness / strength converted acc. to DIN EN ISO 18265 table B2		HB	HRC	N/mm²			
			360 - 400	38 - 42	1145 - 1265			
	delivery condition	Q+T	360 - 400	38 - 42	1145 - 1265	variation upon request		
	maximum dimension	diameter			thickness			
		-			≤ 400 mm			
	US-specification	EN 10228-3			SEP 1921			
		table 3 - type 1 - qual. class 4			group 3 - class E,e			
	cleanliness	DIN 50602			ASTM E45 method A			
		K1 ≤ 10			A ≤ 0,5; B, C, D ≤ 1			

		0	1	2	3	4	5	comment
technological properties	toughness		■	■				in relation to service hardness
	hot strength at working temp.		■	■	■			
	wear resistance		■	■	■			
	corrosion resistance		■	■	■	■		polished surface for best corrosion resistance
	machinability		■	■				Q+T
	polishability		■	■	■	■		ISO: N1/A-1
	weldability		■					CET = 1.00 % acc. DIN EN 1011-2
	texturability		■	■	■	■		
	nitridability		■	■	■	■		nitriding hardness 900 - 1200 HV1
	chrome-platability		■	■	■	■	■	high cleanliness

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties	thermal conductivity [W · m⁻¹· K⁻¹]	20 °C	200 °C	300 °C	500 °C
		24.7	25.7	26.3	26.6
	coefficient of thermal expansion between 20 °C and ... [10⁻⁶· K⁻¹]	100 °C	200 °C	300 °C	500 °C
		10.5	11.0	11.0	-
	elastic modulus [kN/mm²]	20 °C	200 °C	300 °C	500 °C
		218	202	198	180

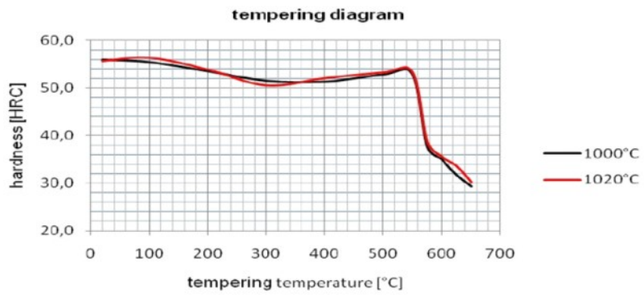
application	technology	plastic injection molding, rapid heat cycle molding
	tools	plastic molds, corrosion resistant for "weldless molding"
	process temperature	< 300 °C
	tool size	small- and medium-sized molds
	final products	injection molding parts, high gloss, transparent
	features	pre-hardened ~ 40 HRC delivery hardness, corrosion resistant

SWG processing instructions	welding, texturing, polishing

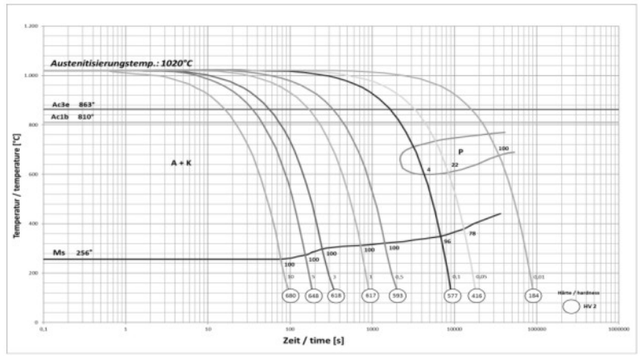
		T min [°C]	T max [°C]	medium / comment
heat treatment	annealing	760	800	furnace
	hardening	1000	1030	vacuum, oil
	tempering	250	600	air, protective atmosphere
	stress relieving	450	500	min. 30 °C below tempering temp.
	pre-heating before welding	320	350	
	nitriding	400	500	min. 30 °C below tempering temp.
	PVD-treating	400	500	

diagrams/ structure	CCT-diagram	yes
	tempering diagram	yes
	advice on heat treatment	pre-hardened
	microstructure	martensitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 1000°C and 1020°C in oil



CCT-diagram



material characteristics								
	material number / grade	SWG OPTI N+						
	short designation	X15CrNi13						
	comparable grade	1.4024mod PESR, AISI 420mod PESR						
	chemical composition - reference analysis [%]	C	Si	Mn	Cr	Ni	N	
		0.15	0.30	0.40	14.00	0.60	alloyed	
	production technology	EAF/LF/VD/PESR, forging, annealing						
	service hardness / strength		HB	HRC	N/mm²			
			-	50 - 57	-			
	delivery condition	annealed	≤ 260	-	-			variation upon request
	maximum dimension	diameter			thickness			
		-			≤ 500 mm			
	US-specification	EN 10228-3			SEP 1921			
		table 3 - type 1 - qual. class 4			group 3 - class E,e			
	cleanliness	DIN 50602			ASTM E45 method A			
		K1 ≤ 10			A ≤ 0,5; B, C, D ≤ 1			

technological properties		0	1	2	3	4	5	comment
	toughness		■	■				in relation to service hardness
	hot strength at working temp.		■	■	■			
	wear resistance		■	■	■	■		
	corrosion resistance		■	■	■	■	■	polished surface for best corrosion resistance
	machinability		■	■				Q+T
	polishability		■	■	■	■	■	ISO/SPI: N0/A-1
	weldability		■					CET = 0.91 % acc. DIN EN 1011-2
	texturability		■	■	■	■		
	nitridability		■	■	■	■		nitriding hardness 900 - 1200 HV1
	chrome-platability		■	■	■	■	■	high cleanliness

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties							
	thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C	-	
		19.9	23.5	24.4	25.1	-	
	coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	20 °C	50 °C	100 °C	120 °C	140 °C	150 °C
		10.356	10.434	10.584	10.644	10.704	10.734
		160 °C	180 °C	200 °C	220 °C	240 °C	260 °C
		10.764	10.824	10.884	10.944	11.004	11.064
		280 °C	300 °C	400 °C	-	-	-
		11.124	11.184	11.484	-	-	-
	elastic modulus [kN/mm²]	20 °C	200 °C	300 °C	500 °C	-	
		218	206	198	180	-	

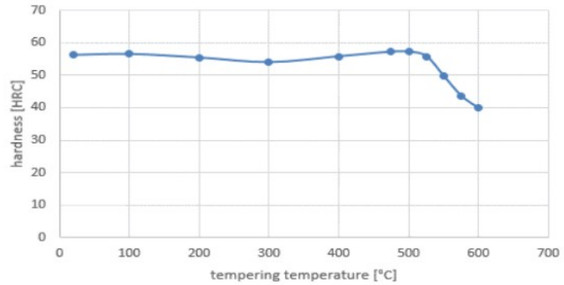
application		
	technology	mold making, corrosion resistant
	tools	corrosion resistant plastic molds with high requirements on surface quality
	process temperature	< 300 °C
	tool size	small- and medium-sized molds
	final products	transparent plastic parts, high gloss parts, lenses, optical parts, electronic covers
	features	for very high surface quality

SWG processing instructions	welding, texturing, polishing, vacuum hardening

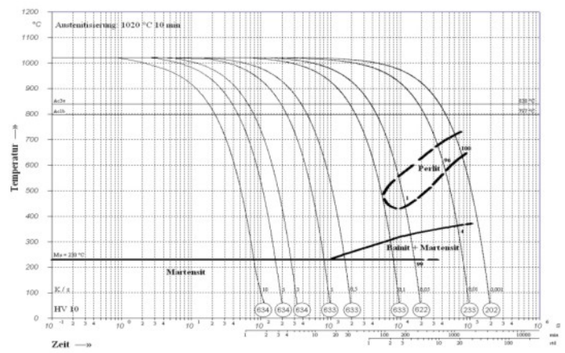
heat treatment		T min [°C]	T max [°C]	medium / comment
	annealing	760	800	furnace
	hardening	1000	1030	vacuum, oil
	tempering	250	600	furnace
	stress relieving	450	500	min. 30 °C below tempering temp.
	pre-heating before welding	320	350	
	nitriding	400	500	min. 30 °C below tempering temp.
	PVD-treating	400	500	

diagrams/ structure		
	CCT-diagram	yes
	tempering diagram	yes
	advice on heat treatment	vacuum hardening after pre-machining
	microstructure	martensitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 1020°C in oil



CCT-diagram



material characteristics								
	material number / grade	**SWG CRM13S**						
	short designation	X10CrMnS13						
	comparable grade	1.2085mod						
	chemical composition - reference analysis [%]	C	Si	Mn	S	Cr	others	
		≤ 0.10	0.25	1.30	0.14	12.50	alloyed	
	production technology	EAF/LF/VOD, forging, Q+T						
	service hardness / strength converted acc. to DIN EN ISO 18265 table B2		HB	HRC	N/mm²			
			278 - 308	28 - 32	885 - 980			
	delivery condition	Q+T	278 - 308	28 - 32	885 - 980	variation upon request		
	maximum dimension	diameter			thickness			
		-			≤ 400 mm			
	US-specification	EN 10228-3			SEP 1921			
		table 3 - type 1 - qual. class 2			group 3 - class C,c			
	cleanliness	DIN 50602			ASTM E45 method A			
		K4 ≤ 40 (oxides only)			B, C, D ≤ 2			

technological properties		0	1	2	3	4	5	comment
	toughness		■					in relation to service hardness
	hot strength at working temp.		■	■	■			
	wear resistance		■	■				
	corrosion resistance		■	■	■			
	machinability		■	■	■	■	■	
	polishability	■						sulphur alloyed
	weldability		■					CET = 0.83 % acc. DIN EN 1011-2
	texturability	■						
	nitridability		■	■	■	■		nitriding hardness 900 - 1200 HV1
	chrome-platability	■						

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties					
	thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
		24.7	25.7	26.3	26.6
	coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
		11.0	11.6	11.9	12.4
	elastic modulus [kN/mm²]	20 °C	200 °C	300 °C	500 °C
		218	202	198	180

application		
	technology	mold making, injection molding, corrosion resistant
	tools	plastic molds: mold base, frames, cores
	process temperature	< 300 °C
	tool size	small- and medium-sized molds
	final products	plastic injection parts
	features	to be used for chemically aggressive plastics, not for cavities and parts with surface requirements

SWG processing instructions	welding

heat treatment		T min [°C]	T max [°C]	medium / comment
	annealing	720	750	air
	hardening	1020	1040	oil
	tempering	550	600	air
	stress relieving	500	530	min. 30 °C below tempering temp., air
	pre-heating before welding	320	350	
	nitriding	400	530	min. 30 °C below tempering temp.
	PVD-treating	400	530	

diagrams/ structure		
	CCT-diagram	no
	tempering diagram	no
	advice on heat treatment	pre-hardened
	microstructure	martensitic + manganese sulfides

material characteristics

material number / grade	**SWG 2316**						
DIN standard	X38CrMo16						
comparable grade	-						
chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	Ni	
	0.35	0.35	0.70	15.50	1.00	0.50	
production technology	EAF/LF/VD, forging, Q+T or annealing						
service hardness / strength converted acc. to internal hardness table		HB	HRC	N/mm²			
		276 - 335	28 - 34	872 - 1059			
delivery condition	Q+T	276 - 335	28 - 34	872 - 1059	variation upon request		
	annealed	≤ 248HB	-	-			
maximum dimension	diameter		thickness				
	≤ 750 mm		≤ 500 mm				
US-specification	EN 10228-3		SEP 1921				
	table 3 - type 1 - qual. class 3		group 3 - class D,d				
cleanliness	DIN 50602		ASTM E45 method A				
	K4 ≤ 20		A ≤ 1,5; B, C, D ≤ 2				

technological properties

	0	1	2	3	4	5	comment
toughness		■	■	■			in relation to service hardness 276 - 335 HB
hot strength at working temp.		■	■	■			
wear resistance		■	■				
corrosion resistance		■	■	■			polished surface for best corrosion resistance
machinability		■	■				Q+T
polishability		■	■				ISO/SPI: N3/A-3
weldability		■					CET = 1.33 % acc. DIN EN 1011-2
texturability		■	■				
nitridability		■	■	■	■		nitriding hardness 900 - 1200 HV1
chrome-platability		■	■				

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties

thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
	23.5	24.2	24.3	23.2
coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
	10.3	10.8	11.2	11.9
elastic modulus [kN/mm^2]	20 °C	200 °C	300 °C	500 °C
	218	206	198	180

application

technology	mold making PVC processing, corrosion resistant
tools	corrosion resistant plastic molds for PVC, extrusion tools, matrices
process temperature	< 300 °C
tool size	small- and medium-sized molds
final products	PVC tubes, PVC profiles, PVC plastic parts
features	processing of chemically aggressive plastics with chloride atmosphere

SWG processing instructions	welding, texturing

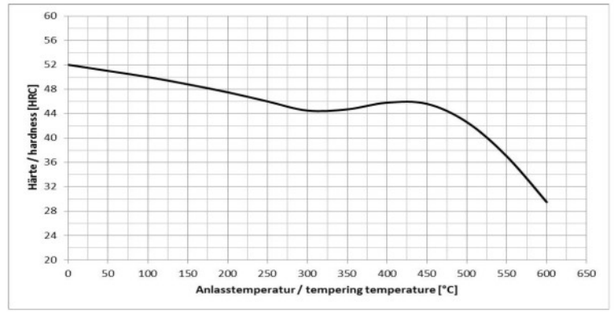
heat treatment

	T min [°C]	T max [°C]	medium / comment
annealing	780	820	furnace
hardening	1000	1040	vacuum, oil
tempering	580	700	air, protective atmosphere
stress relieving	520	550	min. 30 °C below tempering temp.
pre-heating before welding	220	250	
nitriding	450	550	min. 30 °C below tempering temp.
PVD-treating	450	550	

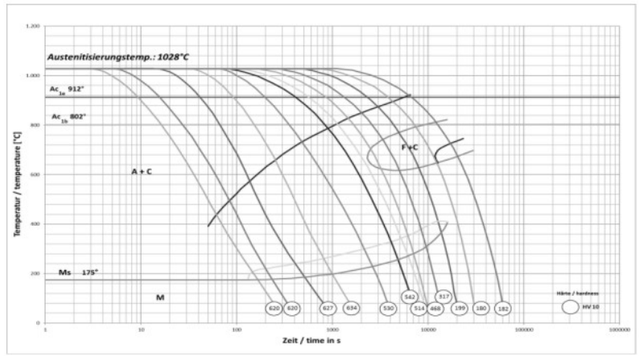
diagrams/ structure

CCT-diagram	yes
tempering diagram	yes
advice on heat treatment	soft annealing before new hardening
microstructure	martensitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 1010 °C in oil



CCT-diagram



material characteristics

material number / grade	**SWG 2316 VICTORY ESR**						
DIN standard	X38CrMo16						
comparable grade	-						
chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	Ni	
	0.35	0.35	0.70	15.50	1.00	0.50	
production technology	EAF/LF/VD, ESR, forging, Q+T or annealing						
service hardness / strength converted acc. to internal hardness table		HB	HRC	N/mm²			
		276 - 335	28 - 34	872 - 1059			
delivery condition	Q+T	276 - 335	28 - 34	872 - 1059	variation upon request		
	annealed	≤ 248HB	-	-			
maximum dimension	diameter		thickness				
	≤ 750 mm		≤ 500 mm				
US-specification	EN 10228-3		SEP 1921				
	table 3 - type 1 - qual. class 4		group 3 - class E,e				
cleanliness	DIN 50602		ASTM E45 method A				
	K1 ≤ 10		A ≤ 0,5; B, C, D ≤ 1				

technological properties

	0	1	2	3	4	5	comment
toughness		■	■	■			in relation to service hardness 276 - 335 HB
hot strength at working temp.		■	■	■			
wear resistance		■	■				
corrosion resistance		■	■	■	■		polished surface for best corrosion resistance
machinability		■	■	■	■		annealed
polishability		■	■	■	■		ISO/SPI: N2/A-2; 30 - 34 HRC
weldability		■					CET = 1.33 % acc. DIN EN 1011-2
texturability		■	■	■			
nitridability		■	■	■	■		nitriding hardness 900 - 1200 HV1
chrome-platability		■	■	■	■		ESR: high cleanliness

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties

thermal conductivity [W · m⁻¹· K⁻¹]	20 °C	200 °C	300 °C	500 °C
	23.5	24.2	24.3	23.2
coefficient of thermal expansion between 20 °C and ... [10⁻⁶· K⁻¹]	100 °C	200 °C	300 °C	500 °C
	10.3	10.8	11.2	11.9
elastic modulus [kN/mm²]	20 °C	200 °C	300 °C	500 °C
	218	206	198	180

application

technology	mold making PVC processing, corrosion resistant
tools	corrosion resistant plastic molds for PVC, extrusion tools, matrices
process temperature	< 300 °C
tool size	small- and medium-sized molds
final products	PVC tubes, PVC profiles, PVC plastic parts
features	processing of chemically aggressive plastics with chloride atmosphere for high surface quality

SWG processing instructions	welding, texturing, vacuum hardening

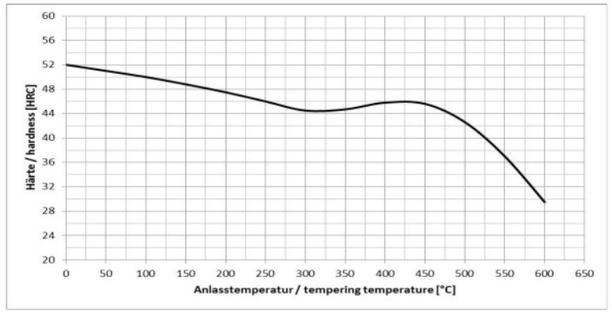
heat treatment

	T min [°C]	T max [°C]	medium / comment
annealing	780	820	furnace
hardening	1000	1040	vacuum, oil
tempering	580	700	air, protective atmosphere
stress relieving	520	550	min. 30 °C below tempering temp.
pre-heating before welding	220	250	
nitriding	450	550	min. 30 °C below tempering temp.
PVD-treating	450	550	

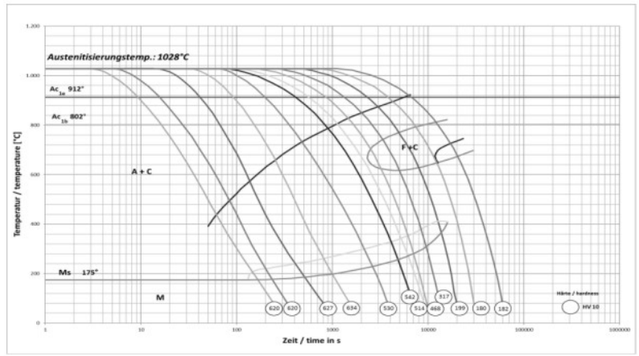
diagrams/ structure

CCT-diagram	yes
tempering diagram	yes
advice on heat treatment	soft annealing before new hardening
microstructure	martensitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 1010 °C in oil



CCT-diagram



material characteristics								
	material number / grade	**SWG 2085**						
	DIN standard	X33CrS16						
	comparable grade	AISI 420+S						
	chemical composition - reference analysis [%]	C	Si	Mn	S	Cr	Ni	
		0.33	<1.00	<1.00	0.08	16.00	<1.00	
	production technology	EAF/LF/VD, forging, Q+T						
	service hardness / strength converted acc. to DIN EN ISO 18265 table B2		HB	HRC	N/mm²			
			280 - 325	28.3 - 34.2	890 - 1032			
	delivery condition	Q+T	280 - 325	28.3 - 34.2	890 - 1032	variation upon request		
	maximum dimension	diameter			thickness			
		≤ 800 mm			≤ 600 mm			
	US-specification	EN 10228-3			SEP 1921			
		table 3 - type 1 - qual. class 2			group 3 - class C,c			
	cleanliness	DIN 50602			ASTM E45 method A			
		K4 ≤ 40 (oxides only)			B, C, D ≤ 2			

technological properties		0	1	2	3	4	5	comment
	toughness		■					in relation to service hardness
	hot strength at working temp.		■	■	■			
	wear resistance		■	■				
	corrosion resistance		■	■	■			polished surface for best corrosion resistance
	machinability		■	■	■	■		
	polishability	■						sulphur alloyed
	weldability		■					CET = 1.25 % acc. DIN EN 1011-2
	texturability	■						
	nitridability		■	■	■	■		nitriding hardness 900 - 1200 HV1
	chrome-platability	■						

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties					
	thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
		11.2	16.8	21.0	23.6
	coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
		11.0	11.1	11.2	12.0
	elastic modulus [kN/mm²]	20 °C	200 °C	300 °C	500 °C
		218	206	198	180

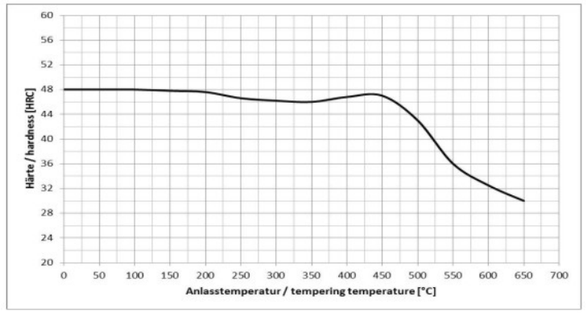
application		
	technology	mold making, injection molding, corrosion resistance
	tools	plastic molds: moldbase, cores, mold frames
	process temperature	< 300 °C
	tool size	small- and medium-sized molds
	final products	plastic injection parts
	features	pre-hardened, easy machining, corrosion-resistant

SWG processing instructions	welding

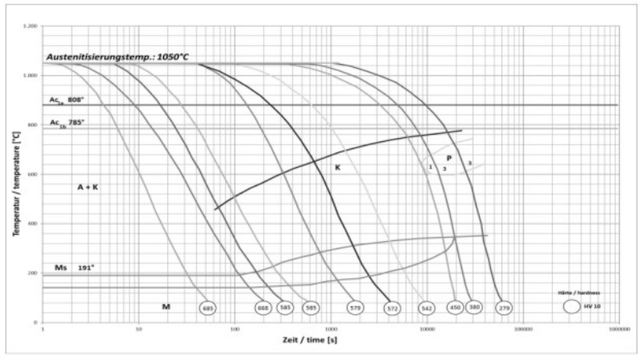
heat treatment		T min [°C]	T max [°C]	medium / comment
	annealing	720	750	air
	hardening	1020	1040	oil
	tempering	550	600	air
	stress relieving	500	530	min. 30 °C below tempering temp.
	pre-heating before welding	320	350	
	nitriding	400	530	min. 30 °C below tempering temp.
	PVD-treating	400	530	

diagrams/ structure		
	CCT-diagram	yes
	tempering diagram	yes
	advice on heat treatment	pre-hardened
	microstructure	martensitic + manganese sulfides

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 1010 °C in oil



CCT-diagram



material characteristics	material number / grade	**SWG GEST80 VICTORY ESR**						
	short designation	15NiMnCuAlMo12-6						
	comparable grade	-						
	chemical composition - reference analysis [%]	C	Mn	Cr	Mo	Ni	Cu	Al
		0.14	1.40	0.30	0.30	2.80	0.90	0.90
	production technology	EAF/LF/VD/ESR, forging, Q+T						
	service hardness / strength converted acc. to DIN EN ISO 18265 table B2		HB	HRC	N/mm²			
			359 - 400	38 - 42	1140 - 1270			
	delivery condition	Q+T	359 - 400	38 - 42	1140 - 1270	variation upon request		
	maximum dimension	diameter		thickness				
		-		≤ 400 mm				
	US-specification	EN 10228-3		SEP 1921				
		table 3 - type 1 - qual. class 4		group 3 - class E,e				
	cleanliness	DIN 50602		ASTM E45 method A				
		K1 ≤ 10		A, B, C ≤ 1; D ≤ 2				

		0	1	2	3	4	5	comment
technological properties	toughness		■	■				in relation to service hardness 38 - 42 HRC
	hot strength at working temp.		■	■	■			
	wear resistance		■	■	■	■		
	corrosion resistance	■						
	machinability		■	■	■			
	polishability		■	■	■	■		ISO/SPI: N1/A-1
	weldability		■	■	■			CET = 0.45 % acc. DIN EN 1011-2
	texturability		■	■	■	■		
	nitridability		■	■	■	■		nitriding hardness 900 - 1250 HV1
	chrome-platability		■	■	■	■		high cleanliness

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties	thermal conductivity [W · m⁻¹· K⁻¹]	20 °C	200 °C	300 °C	500 °C
		43.1	42.2	-	-
	coefficient of thermal expansion between 20 °C and ... [10⁻⁶· K⁻¹]	100 °C	200 °C	300 °C	500 °C
		11.3	12.6	13.5	-
	elastic modulus [kN/mm²]	20 °C	200 °C	300 °C	500 °C
		203	192	185	172

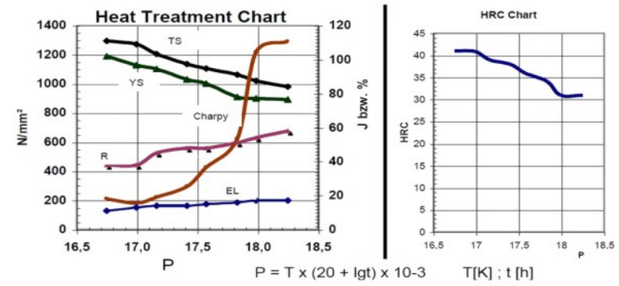
application	technology	mold making, injection molding
	tools	plastic injection molds with high surface quality
	process temperature	< 300 °C
	tool size	small- and medium-sized molds
	final products	plastic parts, textured parts, high gloss parts
	features	precipitation hardened, high cleanliness

SWG processing instructions	welding, texturing,polishing

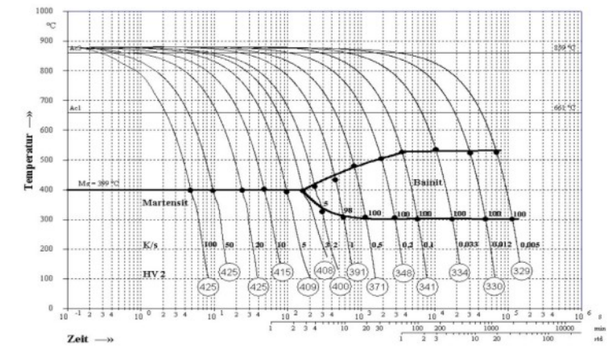
		T min [°C]	T max [°C]	medium / comment
heat treatment	annealing	640	680	air
	hardening	880	920	oil
	tempering	-	~ 550	air
	stress relieving	500	520	min. 30 °C below tempering temp.
	pre-heating before welding	320	350	
	nitriding	450	520	min. 30 °C below tempering temp.
	PVD-treating	450	520	

diagrams/ structure	CCT-diagram	yes
	tempering diagram	yes
	advice on heat treatment	precipitation hardened
	microstructure	soft-martensite + precipitations

Tempering diagram:



CCT-diagram



material characteristics	material number / grade	**SWG CPM40 VICTORY ESR**						
	short designation	15CrNiMoAlCu16-12-11						
	comparable grade	-						
	chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	Ni	others
		0.15	0.30	0.50	4.00	1.10	3.00	alloyed
	production technology	EF/LF/VD/ESR, forging, Q+T						
	service hardness / strength converted acc. to DIN EN ISO 18265 table B2		HB	HRC	N/mm²			
			359 - 400	38 - 42	1140 - 1270			
	delivery condition	Q+T	359 - 400	38 - 42	1140 - 1270	variation upon request		
	maximum dimension	diameter			thickness			
		-			≤ 400 mm			
	US-specification	EN 10228-3			SEP 1921			
		table 3 - type 1 - qual. class 4			group 3 - class E,e			
	cleanliness	DIN 50602			ASTM E45 method A			
		K1 ≤ 10			A ≤ 0,5; B, C ≤ 1,0; D ≤ 1,5			

		0	1	2	3	4	5	comment
technological properties	toughness		■					in relation to service hardness 38 - 42 HRC
	hot strength at working temp.		■	■	■			
	wear resistance		■	■	■	■		
	corrosion resistance	■						
	machinability		■	■				
	polishability		■	■	■	■		ISO/SPI: N1/A-1
	weldability		■	■				CET = 0.83 % acc. DIN EN 1011-2
	texturability		■	■	■	■		
	nitridability		■	■	■	■	■	nitriding hardness 900 - 1250 HV1
	chrome-platability		■	■	■	■		high cleanliness

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties	thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
		28.0	28.4	29.0	29.5
	coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
		11.2	11.6	12.2	12.6
	elastic modulus [kN/mm²]	20 °C	200 °C	300 °C	500 °C
		212	199	192	175

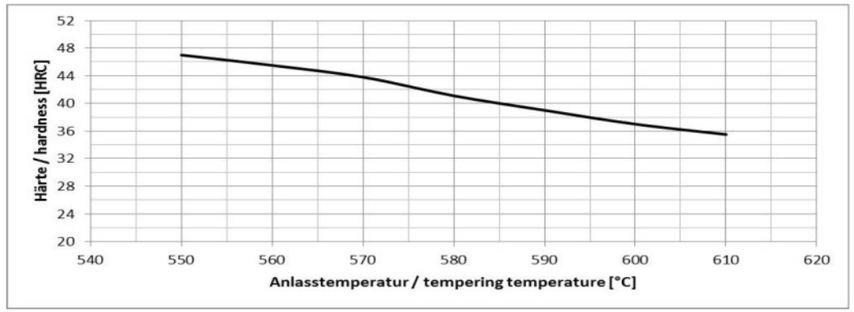
application	technology	mold making, injection molding, rapid heat cycle molding
	tools	plastic molds for "weldless molding"
	process temperature	< 300 °C
	tool size	small-, medium- and large-sized molds
	final products	plastic parts, textured, high gloss
	features	precipitation hardened, high cleanliness

SWG processing instructions	welding,texturing,polishing

		T min [°C]	T max [°C]	medium / comment
heat treatment	annealing	650	680	air
	hardening	1000	1020	oil
	tempering	540	580	air
	stress relieving	500	530	min. 30 °C below tempering temp.
	pre-heating before welding	250	350	
	nitriding	450	530	min. 30 °C below tempering temp.
	PVD-treating	450	530	

diagrams/ structure	CCT-diagram	no
	tempering diagram	yes
	advice on heat treatment	pre-hardened
	microstructure	soft-martensite + precipitations

Tempering diagram: Average values on samples dia 25 mm×length 50 mm



material characteristics								
	material number / grade	**SWG 2343 (SWG EX3)**						
	DIN standard	X37CrMoV5-1						
	comparable grade	AISI H11						
	chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	V	
		0.36	1.00	0.35	5.00	1.20	0.40	
	production technology	EAF/LF/VD, forging, EFS annealing						
	service hardness / strength		HB	HRC	N/mm²			
			-	36 - 52	-			
	delivery condition	annealed	≤ 229	-	-	variation upon request		
	maximum dimension	diameter		thickness				
		≤ 800 mm		≤ 600 mm				
	US-specification	EN 10228-3		SEP 1921				
		table 3 - type 1 - qual. class 3		group 3 - class D,d				
	cleanliness	DIN 50602		ASTM E45 method A				
		K4 ≤ 20		A ≤ 1,5; B, C, D ≤ 2				

technological properties		0	1	2	3	4	5	comment
	toughness		■	■				in relation to service hardness 42 - 48 HRC
	hot strength at working temp.		■	■	■	■		
	wear resistance		■	■	■	■		
	corrosion resistance	■						
	machinability		■	■	■	■		annealed
	polishability		■	■				ISO/SPI:N2/A-2 48 - 52 HRC; higher: 2343 ESR
	weldability		■					CET = 0.77 % acc. DIN EN 1011-2
	texturability		■	■				for texturing: 2343 ESR
	nitridability		■	■	■	■	■	nitriding hardness 900 - 1200 HV1
	chrome-platability		■	■				for chrome plating: 2343 ESR

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties					
	thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
		23.6	28.2	28.4	27.4
	coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
		11.8	12.4	12.6	12.8
	elastic modulus [kN/mm^2]	20 °C	200 °C	300 °C	500 °C
		212	199	192	175

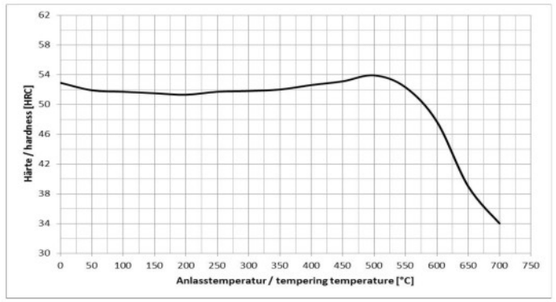
application		
	technology	mold making, injection molding, die-casting, gravity casting, drop forging
	tools	extrusion tools, forging dies, hot shear blades,mandrels, mold inserts, die-casting molds, prototyping molds
	process temperature	300 - 600 °C
	tool size	small- and medium-sized tools
	final products	light metal, steel forgings, strip steel, sheets and tubes, plastic parts (with glass fibre)
	features	-

SWG processing instructions	welding, texturing, vacuum hardening

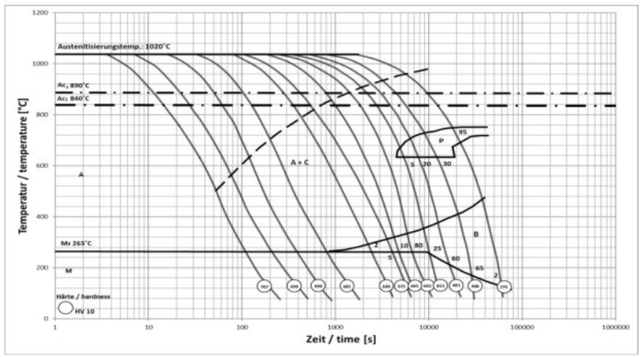
heat treatment		T min [°C]	T max [°C]	medium / comment
	annealing	820	840	furnace until 650 °C, air
	hardening	990	1010	vacuum, oil
	tempering	530	650	air, protective gas
	stress relieving	500	550	min. 30 °C below tempering temp.
	pre-heating before welding	300	320	
	nitriding	480	550	min. 30 °C below tempering temp.
	PVD-treating	480	550	

diagrams/ structure		
	CCT-diagram	yes
	tempering diagram	yes
	advice on heat treatment	vacuum hardening after pre-machining
	microstructure	martensitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 1020 °C in oil



CCT-diagram



material characteristics	material number / grade	**SWG 2343 VICTORY ESR (SWG EX3 VICTORY ESR)**						
	DIN standard	X37CrMoV5-1						
	comparable grade	AISI H11 ESR						
	chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	V	
		0.36	1.00	0.35	5.00	1.20	0.40	
	production technology	EAF/LF/VD,ESR, (3D) forging, EFS annealing						
	service hardness / strength		HB	HRC	N/mm²			
			-	36 - 52	-			
	delivery condition	annealed	≤ 229	-	-	variation upon request		
	maximum dimension	diameter		thickness				
		≤ 600 mm		≤ 450 mm				
	US-specification	EN 10228-3		SEP 1921				
		table 3 - type 1 - qual. class 4		group 3 - class E,e				
	cleanliness	DIN 50602		ASTM E45 method A				
		K1 ≤ 10		A ≤ 0,5; B, C, D ≤ 1				

		0	1	2	3	4	5	comment
technological properties	toughness		■	■	■			in relation to service hardness 42 - 48 HRC
	hot strength at working temp.		■	■	■	■		
	wear resistance		■	■	■	■	■	
	corrosion resistance	■						
	machinability		■	■	■	■		annealed
	polishability		■	■	■	■		ISO/SPI: N0/A-1, 48 - 52 HRC
	weldability		■					CET = 0.77 % acc. DIN EN 1011-2
	texturability		■	■	■	■	■	
	nitridability		■	■	■	■	■	nitriding hardness 900 - 1200 HV1
	chrome-platability		■	■	■	■	■	high cleanliness

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties	thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
		23.6	28.2	28.4	27.4
	coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
		11.8	12.4	12.6	12.8
	elastic modulus [kN/mm^2]	20 °C	200 °C	300 °C	500 °C
		212	199	192	175

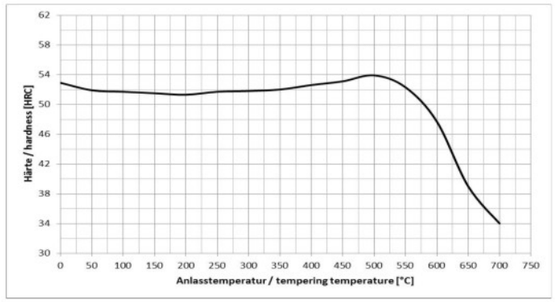
application	technology	mold making, injection molding, die-casting, gravity casting, drop forging
	tools	die-casting molds and inserts, extrusion tools,plastic injection molds and inserts with high surface requirements
	process temperature	300 - 600 °C
	tool size	small-, medium- and large-sized tools
	final products	light metal, plastic parts (high gloss and with glass fibre)
	features	-

SWG processing instructions	welding, texturing, vacuum hardening, polishing

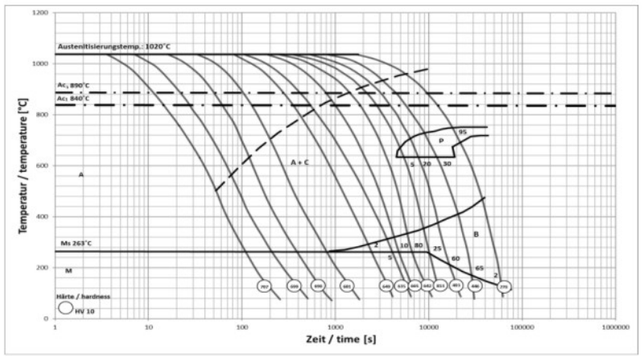
		T min [°C]	T max [°C]	medium / comment
heat treatment	annealing	820	840	furnace until 650 °C, air
	hardening	990	1010	oil, warmbath, vacuum
	tempering	530	650	air, protective gas
	stress relieving	500	550	min. 30 °C below tempering temp.
	pre-heating before welding	300	320	
	nitriding	480	550	min. 30 °C below tempering temp.
	PVD-treating	480	550	

diagrams/ structure	CCT-diagram	yes
	tempering diagram	yes
	advice on heat treatment	vacuum hardening after pre-machining
	microstructure	martensitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 1020 °C in oil



CCT-diagram



material characteristics								
	material number / grade	**SWG 2344 (SWG EX4)**						
	DIN standard	X40CrMoV5-1						
	comparable grade	AISI H13						
	chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	V	
		0.40	1.00	0.40	5.20	1.30	1.00	
	production technology	EAF/LF/VD, forging, EFS annealing						
	service hardness / strength		HB	HRC	N/mm²			
			-	36 - 52	-			
	delivery condition	annealed	≤ 229	-	-			variation upon request
	maximum dimension	diameter			thickness			
		≤ 600 mm			≤ 500 mm			
	US-specification	EN 10228-3			SEP 1921			
		table 3 - type 1 - qual. class 3			group 3 - class D,d			
	cleanliness	DIN 50602			ASTM E45 method A			
		K4 ≤ 20			A ≤ 1,5; B, C, D ≤ 2			

technological properties		0	1	2	3	4	5	comment
	toughness		■	■				in relation to service hardness 42 - 48 HRC
	hot strength at working temp.		■	■	■	■		
	wear resistance		■	■	■	■	■	
	corrosion resistance	■						
	machinability		■	■	■	■		annealed
	polishability		■	■				ISO/SPI:N2/A-2 48 - 52 HRC; higher: 2344ESR
	weldability		■					CET = 0.83 % acc. DIN EN 1011-2
	texturability		■	■	■			for texturing: 2344 ESR
	nitridability		■	■	■	■	■	nitriding hardness 900 - 1250 HV1
	chrome-platability		■	■				for chrome-plating: 2344 ESR

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties					
	thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
		24.4	26.2	26.5	26.0
	coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
		10.9	11.9	12.3	13.0
	elastic modulus [kN/mm^2]	20 °C	200 °C	300 °C	500 °C
		212	199	192	175

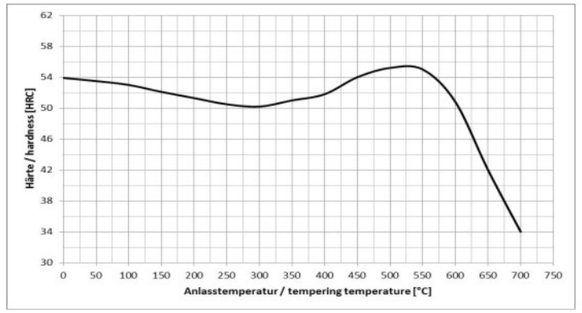
application		
	technology	mold making, injection molding, die-casting, gravity casting, hot forming
	tools	extrusion tools, press forging dies, hot shear blades, mold inserts, die-casting molds, gravity casting molds
	process temperature	< 600 °C
	tool size	small- and medium-sized tools
	final products	light metal, steel, plastic parts
	features	-

SWG processing instructions	welding, texturing, vacuum hardening

heat treatment		T min [°C]	T max [°C]	medium / comment
	annealing	820	840	furnace until 650 °C, air
	hardening	1010	1030	vacuum, oil
	tempering	530	650	air, protective gas
	stress relieving	500	550	min. 30 °C below tempering temp.
	pre-heating before welding	300	320	
	nitriding	480	550	min. 30 °C below tempering temp.
	PVD-treating	480	550	

diagrams/ structure		
	CCT-diagram	yes
	tempering diagram	yes
	advice on heat treatment	vacuum hardening after pre-machining
	microstructure	martensitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 1030 °C in oil



CCT-diagram

material characteristics

material number / grade	**SWG 2344 VICTORY ESR (SWG EX4 VICTORY ESR)**							
DIN standard	X40CrMoV5-1							
comparable grade	AISI H13 ESR							
chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	V		
	0.40	1.00	0.40	5.20	1.30	1.00		
production technology	EAF/LF/VD/ESR, (3D) forging, EFS annealing							
service hardness / strength		HB	HRC	N/mm²				
		-	36 - 52	-				
delivery condition	annealed	≤ 229	-	-				
maximum dimension	diameter		thickness					
	≤ 600 mm		≤ 450 mm					
US-specification	EN 10228-3		SEP 1921					
	table 3 - type 1 - qual. class 4		group 3 - class E,e					
cleanliness	DIN 50602		ASTM E45 method A					
	K1 ≤ 10		A ≤ 0,5; B, C, D ≤1					

variation upon request

technological properties

	0	1	2	3	4	5	comment
toughness		■	■	■			in relation to service hardness 42 - 48 HRC
hot strength at working temp.		■	■	■	■		
wear resistance		■	■	■	■	■	
corrosion resistance	■						
machinability		■	■	■	■		annealed
polishability		■	■	■	■		ISO/SPI: N0/A-1, 48 - 52 HRC
weldability		■					CET = 0.83 % acc. DIN EN 1011-2
texturability		■	■	■	■	■	
nitridability		■	■	■	■	■	nitriding hardness 900 - 1250 HV1
chrome-platability		■	■	■	■	■	high cleanliness

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties

thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
	24.4	26.2	26.5	26.0
coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
	10.9	11.9	12.3	13.0
elastic modulus [kN/mm^2]	20 °C	200 °C	300 °C	500 °C
	212	199	192	175

application

technology	mold making, injection molding, die-casting, hot forming
tools	die-casting molds and inserts, extrusion tools, plastic injection molds high polished and wear resistant
process temperature	< 600 °C
tool size	small- and medium-sized tools
final products	light metal, steel, plastic parts (reinforced, transparent, high gloss)
features	-

SWG processing instructions

welding, texturing, vacuum hardening

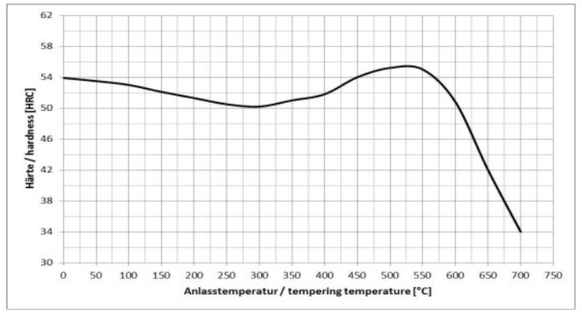
heat treatment

	T min [°C]	T max [°C]	medium / comment
annealing	820	840	furnace until 650 °C, air
hardening	1010	1030	vacuum, oil
tempering	530	650	air, protective gas
stress relieving	500	550	min. 30 °C below tempering temp.
pre-heating before welding	300	320	
nitriding	480	550	min. 30 °C below tempering temp.
PVD-treating	480	550	

diagrams/ structure

CCT-diagram	yes
tempering diagram	yes
advice on heat treatment	vacuum hardening after pre-machining or warmbath
microstructure	martensitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 1030 °C in oil



CCT-diagram

material characteristics									
material number / grade	**SWG 2347**								
DIN standard	X40CrMoVS5-1								
comparable grade	AISI H13+S								
chemical composition - reference analysis [%]	C	Si	Mn	S	Cr	Mo	V		
	0.40	1.00	0.40	0.09	5.00	1.30	0.95		
production technology	EAF/LF/VD, forging, Q+T (annealing)								
service hardness / strength converted acc. to DIN EN ISO 18265 table G.1		HB	HRC	N/mm²					
		358 - 411	37 - 42	1157 - 1337					
delivery condition	Q+T	358 - 411	37 - 42	1157 - 1337					variation upon request
	annealed	≤ 229	-	-					
maximum dimension	diameter		thickness						
	≤ 750 mm		≤ 500 mm						
US-specification	EN 10228-3		SEP 1921						
	table 3 - type 1 - qual. class 2		group 3 - class C,c						
cleanliness	DIN 50602		ASTM E45 method A						
	K4 ≤ 20 (oxides)		B, C, D ≤ 2						

technological properties	0	1	2	3	4	5	comment
toughness		■					in relation to service hardness
hot strength at working temp.		■	■	■	■	■	
wear resistance		■	■	■	■	■	
corrosion resistance	■						
machinability		■	■	■	■	■	annealed, higher than 2344
polishability	■						sulphur alloyed
weldability		■					CET = 0.83 % acc. DIN EN 1011-2
texturability	■						sulphur alloyed
nitridability		■	■	■	■	■	nitriding hardness 900 - 1250 HV1
chrome-platability	■						sulphur alloyed

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties					
thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
	24.4	26.2	26.5	26.0
coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
	10.9	11.9	12.3	13.0
elastic modulus [kN/mm^2]	20 °C	200 °C	300 °C	500 °C
	212	199	192	175

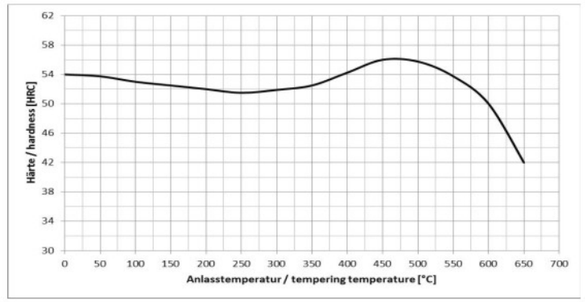
application	
technology	mold making, injection molding
tools	core parts for plastic injection molding
process temperature	< 600 °C
tool size	small- and medium-sized tools
final products	light metal, steel, plastic parts
features	not suitable for cavities with high requirements on the surface

SWG processing instructions	welding, vacuum hardening

heat treatment		T min [°C]	T max [°C]	medium / comment
	annealing	820	840	furnace until 650 °C, air
	hardening	1010	1030	vacuum, oil
	tempering	530	650	air, protective gas
	stress relieving	500	550	min. 30 °C below tempering temp.
	pre-heating before welding	300	320	
	nitriding	480	550	min. 30 °C below tempering temp.
	PVD-treating	480	550	

diagrams/ structure	
CCT-diagram	yes
tempering diagram	yes
advice on heat treatment	vacuum hardening after pre-machining
microstructure	martensitic + manganese sulfides

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 1030 °C in oil



CCT-diagram

Material data sheet
SWG 2367 VICTORY ESR (SWG EX7 VICTORY ESR)

Schmiedewerke Gröditz GMH GRUPPE

material characteristics

material number / grade	SWG 2367 VICTORY ESR (SWG EX7 VICTORY ESR)						
DIN standard	X38CrMoV5-3						
comparable grade	-						
chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	V	
	0.36	0.35	0.35	5.10	2.80	0.55	
production technology	EAF/LF/VD/ESR, (3D) forging, EFS annealing						
service hardness / strength		HB	HRC	N/mm²			
		-	35 - 52	-			
delivery condition	annealed	≤ 229	-	-			
maximum dimension	diameter		thickness				
	≤ 600 mm		≤ 400 mm				
US-specification	EN 10228-3		SEP 1921				
	table 3 - type 1 - qual. class 4		group 3 - class E,e				
cleanliness	DIN 50602		ASTM E45 method A				
	K1 ≤ 10		A ≤ 0,5; B, C, D ≤1				

variation upon request

technological properties

	0	1	2	3	4	5	comment
toughness		■	■	■			in relation to service hardness 42 - 48 HRC
hot strength at working temp.		■	■	■	■	■	
wear resistance		■	■	■	■	■	
corrosion resistance	■						
machinability		■	■	■	■		annealed
polishability		■	■	■	■		ISO/SPI: N0/A-1, 48 - 52 HRC
weldability		■					CET = 0.94 % acc. DIN EN 1011-2
texturability		■	■	■	■	■	hardened
nitridability		■	■	■	■	■	nitriding hardness 900 - 1250 HV1
chrome-platability		■	■	■	■	■	

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties

thermal conductivity [W · m⁻¹· K⁻¹]	20 °C	200 °C	300 °C	500 °C
	23.6	30.4	31.1	30.4
coefficient of thermal expansion between 20 °C and ... [10⁻⁶· K⁻¹]	100 °C	200 °C	300 °C	500 °C
	11.5	12.0	12.2	12.9
elastic modulus [kN/mm²]	20 °C	200 °C	300 °C	500 °C
	212	199	192	175

application

technology	mold making, die-casting
tools	die-casting molds and inserts with high thermal load, high life time
process temperature	< 600 °C
tool size	small-sized dies
final products	die-casting parts
features	for highest requirements on hot strength and wear resistance

SWG processing instructions	welding, vacuum hardening

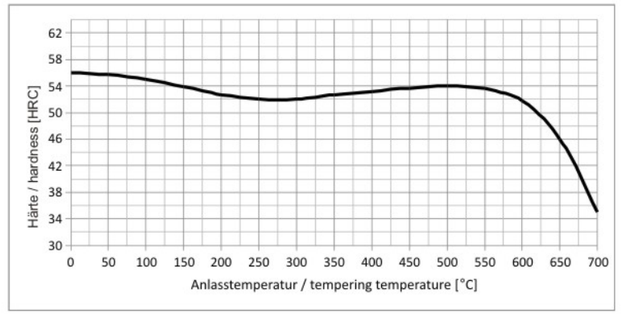
heat treatment

	T min [°C]	T max [°C]	medium / comment
annealing	820	840	furnace until 650 °C, air
hardening	1030	1060	vacuum, oil
tempering	530	650	air, protective gas
stress relieving	500	550	min. 30 °C below tempering temp.
pre-heating before welding	300	320	
nitriding	480	550	min. 30 °C below tempering temp.
PVD-treating	480	550	

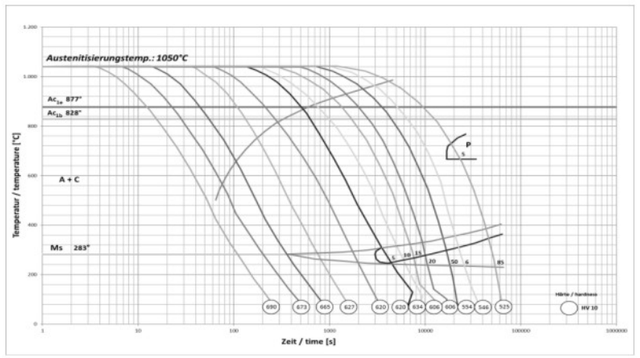
diagrams/ structure

CCT-diagram	yes
tempering diagram	yes
advice on heat treatment	vacuum hardening after pre-machining
microstructure	martensitic

Tempering diagram:



CCT-diagram



material characteristics

material number / grade	**SWG EX1 VICTORY ESR**						
short designation	X35CrMoV5-2						
comparable grade	1.2343+Mo SuperClean ESR, AISI H11+Mo ESR						
chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	V	
	0.35	≤ 0.50	≤ 0.50	5.00	2.20	0.55	
production technology	EAF/LF/VD/ESR, (3D) forging, EFS annealing						
service hardness / strength		HB	HRC	N/mm²			
		-	40 - 52	-			
delivery condition	annealed	≤ 220	-	-			variation upon request
maximum dimension	diameter			thickness			
	≤ 800 mm			≤ 550 mm			
US-specification	EN 10228-3			SEP 1921			
	table 3 - type 1 - qual. class 4			group 3 - class E,e			
cleanliness	DIN 50602			ASTM E45 method A			
	K1 ≤ 10			A ≤ 0,5; B, C, D ≤ 1			

technological properties

	0	1	2	3	4	5	comment
toughness		■	■	■	■		in relation to service hardness 42 - 48 HRC
hot strength at working temp.		■	■	■	■	■	
wear resistance		■	■	■	■	■	
corrosion resistance	■						
machinability		■	■				annealed
polishability		■	■	■	■		ISO/SPI: N0/A-1, 48 - 52 HRC
weldability		■					CET = 0.85 % acc. DIN EN 1011-2
texturability		■	■	■	■	■	hardened
nitridability		■	■	■	■	■	nitriding hardness 900 - 1250 HV1
chrome-platability		■	■	■	■	■	high cleanliness

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties

thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
	23.6	28.2	28.4	27.4
coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
	11.9	12.4	12.6	13.0
elastic modulus [kN/mm²]	20 °C	200 °C	300 °C	500 °C
	212	199	192	175

application

technology	mold making, die-casting
tools	die-casting molds and inserts with high thermal load, high life time
process temperature	< 600 °C
tool size	medium-and large-sized dies
final products	die-casting parts
features	for highest requirements on hot strength and toughness, SuperClean technology

SWG processing instructions	welding, vacuum hardening

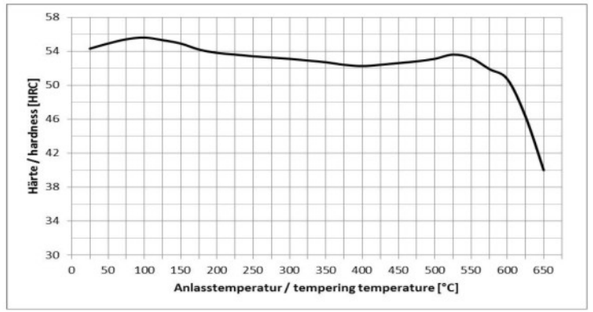
heat treatment

	T min [°C]	T max [°C]	medium / comment
annealing	820	840	furnace until 650 °C, air
hardening	1010	1030	vacuum, oil
tempering	530	650	air, protective gas
stress relieving	500	550	min. 30 °C below tempering temp.
pre-heating before welding	300	320	
nitriding	480	550	min. 30 °C below tempering temp.
PVD-treating	480	550	

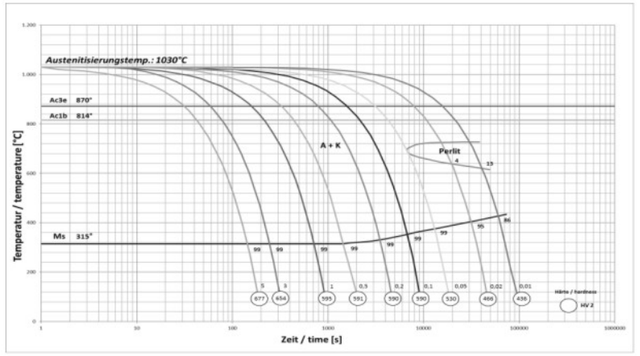
diagrams/ structure

CCT-diagram	yes
tempering diagram	yes
advice on heat treatment	vacuum hardening or warmbath after pre-machining
microstructure	martensitic

Tempering diagram:



CCT-diagram



material characteristics

material number / grade	**SWG EX2**							
short designation	X37CrMoV5-2							
comparable grade	1.2343+Mo, AISI H11+Mo							
chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	V		
	0.38	≤ 0.50	≤ 0.30	5.00	1.70	0.45		
production technology	EAF/LF/VD, forging, EFS annealing							
service hardness / strength		HB	HRC	N/mm²				
		-	40 - 52	-				
delivery condition	annealed	≤ 220	-	-				variation upon request
maximum dimension	diameter			thickness				
	≤ 800 mm			≤ 400 mm				
US-specification	EN 10228-3			SEP 1921				
	table 3 - type 1 - qual. class 3			group 3 - class D,d				
cleanliness	DIN 50602			ASTM E45 method A				
	K4 ≤ 20			A ≤ 1,5; B, C, D ≤ 2				

technological properties

	0	1	2	3	4	5	comment
toughness		■	■	■			in relation to service hardness 42 - 48 HRC
hot strength at working temp.		■	■	■	■		
wear resistance		■	■	■	■	■	
corrosion resistance	■						
machinability		■	■				annealed
polishability		■	■				ISO/SPI: N2/A-2, 48 - 52 HRC
weldability		■					CET = 0.80 % acc. DIN EN 1011-2
texturability		■	■				hardened
nitridability		■	■	■	■	■	nitriding hardness 900 - 1250 HV1
chrome-platability		■	■				

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties

thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
	23.6	28.2	28.4	27.4
coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
	11.9	12.4	12.6	13.0
elastic modulus [kN/mm^2]	20 °C	200 °C	300 °C	500 °C
	212	199	192	175

application

technology	mold making, die-casting
tools	die-casting molds and inserts with high thermal load,high life time
process temperature	< 600 °C
tool size	small- and medium-sized dies
final products	die-casting parts
features	for high requirements on hardness and toughness

SWG processing instructions	welding, vacuum hardening

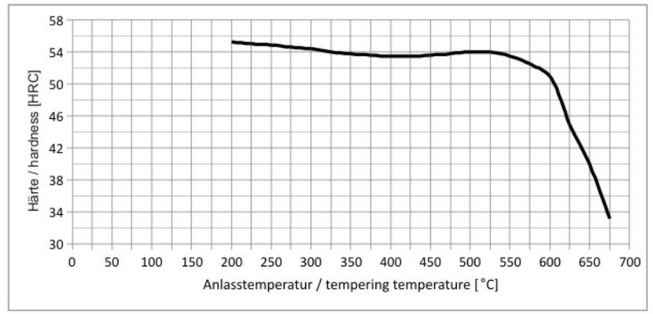
heat treatment

	T min [°C]	T max [°C]	medium / comment
annealing	820	840	furnace until 650 °C, air
hardening	1010	1030	vacuum, oil
tempering	530	650	air, protective gas
stress relieving	500	550	min. 30 °C below tempering temp.
pre-heating before welding	300	320	
nitriding	480	550	min. 30 °C below tempering temp.
PVD-treating	480	550	

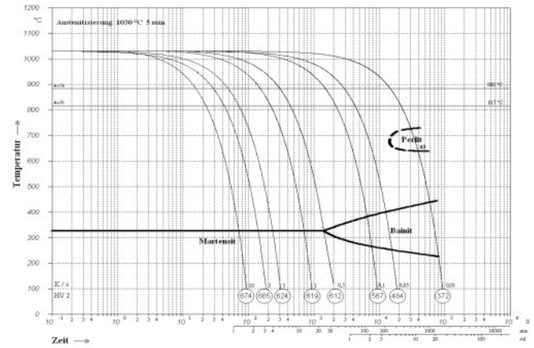
diagrams/ structure

CCT-diagram	yes
tempering diagram	yes
advice on heat treatment	vacuum hardening after pre-machining
microstructure	martensitic

Tempering diagram:



CCT-diagram



material characteristics

material number / grade	**SWG EX6 VICTORY ESR**						
short designation	-						
comparable grade	-						
chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	V	
	0.43	0.30	0.40	6.40	1.30	0.90	
production technology	EAF/LF/VD/ESR, forging, annealing						
service hardness / strength		HB	HRC	N/mm²			
		-	52 - 56	-			
delivery condition	annealed	≤ 285	-	-	variation upon request		
maximum dimension	diameter		thickness				
	≤ 500 mm		≤ 300 mm				
US-specification	EN 10228-3		SEP 1921				
	table 3 - type 1 - qual. class 4		group 3 - class E,e				
cleanliness	DIN 50602		ASTM E45 method A				
	K1 ≤ 10		A ≤ 0,5; B, C, D ≤ 1				

technological properties

	0	1	2	3	4	5	comment
toughness		■	■				in relation to service hardness
hot strength at working temp.		■	■	■	■		
wear resistance		■	■	■	■		
corrosion resistance	■						
machinability		■	■	■	■		annealed
polishability		■	■	■	■		ISO/SPI: N0/A-1
weldability		■					CET = 0.92 % acc. DIN EN 1011-2
texturability		■	■	■	■		
nitridability		■	■	■	■	■	nitriding hardness up to 1250 HV1
chrome-platability		■	■	■	■	■	high cleanliness

rating properties：0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties

thermal conductivity [W · m^{-1} · K^{-1}]	20 °C	200 °C	300 °C	500 °C
	22.3	23.8	25.4	25.5
coefficient of thermal expansion between 20 °C and ... [10^{-6} · K^{-1}]	100 °C	200 °C	300 °C	500 °C
	10.5	11.2	11.6	12.2
elastic modulus [kN/mm²]	20 °C	200 °C	300 °C	500 °C
	211	198	192	173

application

technology	cold and hot forming
tools	die forging, cutting and stamping
process temperature	< 300 °C, pre-heating of the tool to about 200°C advised
tool size	small- and medium-sized molds
final products	blanks, structural parts, pipes
features	high warm strength and wear resistance

SWG processing instructions	welding

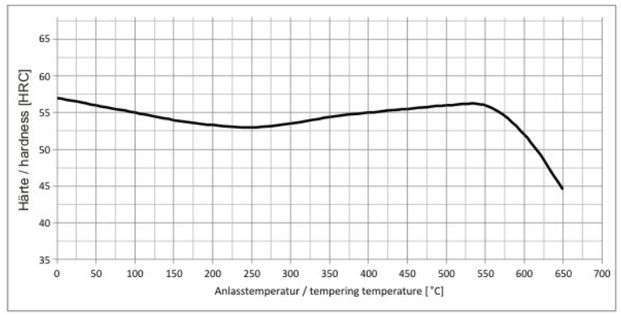
heat treatment

	T min [°C]	T max [°C]	medium / comment
annealing	810	850	furnace until min. 450°C, air
hardening	1030	1050	vacuum, oil
tempering	200	600	air
stress relieving	600	650	before hardening
pre-heating before welding	350	-	
nitriding	480	550	min. 30 °C below tempering temp.
PVD-treating	480	550	

diagrams/ structure

CCT-diagram	no
tempering diagram	yes
advice on heat treatment	vacuum heat treatment after pre-machining
microstructure	martensitic

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 1050 °C in oil



material characteristics	material number / grade	**SWG 2379**						
	DIN standard	X153CrMoV12						
	comparable grade	AISI D2						
	chemical composition - reference analysis [%]	C	Si	Mn	Cr	Mo	V	
		1.55	0.40	0.40	12.00	0.90	0.90	
	production technology	EAF/LF/VD, forging, annealing						
	service hardness / strength		HB	HRC	N/mm²			
			-	58 - 62	-			
	delivery condition	annealed	≤ 255	-	-	variation upon request		
	maximum dimension	diameter			thickness			
		≤ 800 mm			≤ 450 mm			
	US-specification	EN 10228-3			SEP 1921			
		table 3 - type 1 - qual. class 2			group 3 - class C,c			
	cleanliness	DIN 50602			ASTM E45 method A			
		-			A ≤ 1,5; B, C, D ≤ 2			

		0	1	2	3	4	5	comment
technological properties	toughness		■	■				in relation to service hardness
	hot strength at working temp.		■	■	■	■		
	wear resistance		■	■	■	■	■	
	corrosion resistance	■						
	machinability		■	■	■			annealed
	polishability	■						
	weldability	■						CET = 2.28 % acc. DIN EN 1011-2
	texturability	■						
	nitridability		■	■	■	■	■	nitriding hardness 900 - 1250 HV1
	chrome-platability	■						

rating properties: 0 = not suitable; 1 = low; 2 = middle; 3 = good; 4 = very good; 5 = perfectly suitable

physical properties	thermal conductivity [W · m^{-1}· K^{-1}]	20 °C	200 °C	300 °C	500 °C
		16.7	18.0	20.5	23.0
	coefficient of thermal expansion between 20 °C and ... [10^{-6}· K^{-1}]	100 °C	200 °C	300 °C	500 °C
		10.5	11.0	11.2	12.0
	elastic modulus [kN/mm^2]	20 °C	200 °C	300 °C	500 °C
		215	211	204	198

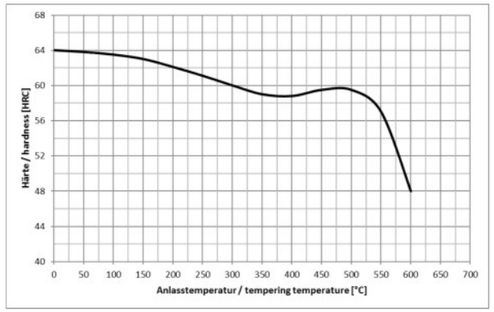
application	technology	cold forming, mold making
	tools	stamping tools, press tools, mold inserts,guiding plates, cutting tools, wear plates
	process temperature	< 200 °C
	tool size	small-sized tools
	final products	steel sheets, reinforced plastics
	features	highest hardness, proper toughness, easily nitridable

SWG processing instructions	vacuum hardening

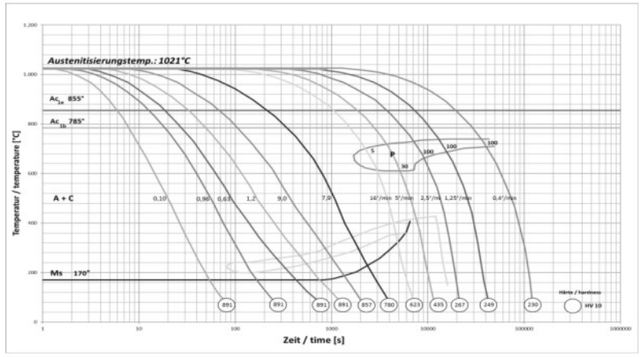
		T min [°C]	T max [°C]	medium / comment
heat treatment	annealing	800	850	furnace until 450 °C, then air
	hardening	1020	1040	warmbath, vacuum
	tempering	200	550	furnace, protective gas
	stress relieving	200	550	min. 30 °C below tempering temp.
	pre-heating before welding			not weldable
	nitriding	450	530	min. 30 °C below tempering temp.
	PVD-treating	450	530	

diagrams/ structure	CCT-diagram	yes
	tempering diagram	yes
	advice on heat treatment	vacuum hardening after pre-machining
	microstructure	martensit + primary carbides (ledeburit)

Tempering diagram: Average values on samples dia 25 mm×length 50 mm; hardened at 1020 °C in air



CCT-diagram



POLISHING RECOMMENDATION FOR SWG PLASTIC MOLD STEELS

Step one: Oil stone rough grinding

1. See below listed the oil stone number from rough to fine:

120# - 180# - 240# - 280# - 320#;
avoid deep traces on the molds surface;

2. Practical hints for rough grinding:

(1) Don't put too much pressure on the work-piece in order to avoid friction heat, because this will cause microstructure transformation and also avoid deep trace on the mold surface;
(2) Avoid the mold cavity surface to form thick areas of plastic deformation;
(3) Change the grinding direction in a 45° angle to the previous grinding direction, when changing to the next oil stone.
(4) Clean the mold and oil stone frequently during grinding;
(5) The work-piece and hands should be cleaned carefully between each change of oil stone in order to prevent coarse abrasive particles and dust.

Step two: Abrasive paper fine grinding

1. See below listed the abrasive paper number from rough to fine:

320# - 400# - 500# - 600# - 800# - 1000# - 1200# - 1500# - 2000# (if mirror polishing add - 2500# - 3000#);

2. Practical hints for rough grinding:

(1) Use a bamboo stick to press the abrasive paper on the work-piece to grind, single direction grinding with suitable pressure until the surface only shows scratches from the present grinding step (observe with a loupe).
(2) Change the grinding direction in a 45° angle when changing another abrasive paper.
(3) Reduce the polishing pressure after changing the abrasive paper number.
(4) Change to a new abrasive paper in time.

Step three: Polishing

1. See below listed the number of diamond polishing paste:

(7#) - 5# - 3# - 1#;

2. Practical hints for polishing:

(1) Clean the mold surface completely;
(2) Stop polishing immediately after the grinding trace has completely disappeared and then clean the polished surface with water or coal oil.

Remarks:

(1) If possible, make a clear request to the roughness of the mold surface after fine machining or EDM in order to shorten the total grinding & polishing time and assure the polishing quality;

(2) If polishing defects (such as pin holes, spots, orange skin etc.) appear during the grinding steps (rough- or fine grinding), grinding must be stopped immediately as continuous grinding can not remove defects. It is necessary to change to the previous used rough oil stone or abrasive paper. After completely removing the defects, the normal grinding steps must follow.

(3) If some deep nicks appear during grinding, not only that this nick area must be grinded, but the whole mold surface has to be grinded to remove nicks,
otherwise area grinding will lead to part recess of the mold surface.

(4) Both, the easy and difficult grinding parts of the mold must be carried out evenly.

(5) To grind a thin part or slit or small hole, it would be better to use electric-grinding tools.

(6) The final grinding direction must be according to the mold releasing direction.

WELDING RECOMMENDATION FOR SWG PLASTIC MOLD STEELS

Table of contents

1 Introduction

As it is generally known, steels with a carbon content of up to 0.2 % are easy to weld. Tool steels contain 0.3 % to 2.5 % of carbon plus alloying elements such as manganese, chromium, molybdenum, tungsten, vanadium or nickel. They are thus among those steels that are difficult to weld. Hence, many tool steel producers advise not to weld steels that are difficult to weld wherever possible. However, the user of the steel may obtain considerable economic benefits through repair welding. Thus, options have been developed in recent years to enable the user to avail himself of this approach. Improved qualities of welding filler materials, enhanced welding systems, enhancements of welding technologies, and last but not least improvements in tool steels properties have resulted in turning the welding of costly tools such as die molds, large forging dies, body tools or molds, cutting, punching or forming tools into reality. It is especially with these items that repairs or corrections through welding are a very attractive and economic alternative compared to the manufacturing of a new tool.

Please note expressly that the information provided below in relation to the repair welding of tool steels are mere recommendations and are not to be understood as binding processing instructions.

2 General information regarding the welding of tool steels

When it comes to the welding of tool steels, the major issue is the higher hardenability of these steels. As soon as the source of energy is removed, the welded spot will quickly cool, the weld metal and the heat-affected zone (HAZ) will excessively harden due to structural transformation. This transformation will result in stress as the welded zone is wedged in by the surrounding cold texture. Stress cracking may occur and the components may get distorted. To largely reduce this risk the tools will have to be preheated prior to welding as a function of the material. Welding of tools may be necessary in the following instances:

- to fettle or repair cracked or worn tools;
- to recondition worn or broken cutting edges such as of cutting tools;
- to carry out correction work after manufacturing defects or flaws; and
- design alterations.

The welding procedure, welding filler materials, welding parameters, preheating temperature and post weld heat treatment will have to be customized as a function of the size and properties of the tool to be welded as well as the size of the welded joint.

3 Welding processes for tool steels

3.1 Process description for TIG welding

Inert gas shielded arc welding processes in which the arc between a non-fusing tungsten electrode and the workpiece burns in argon inert gas. Here, the welding filler material is fed manually through a filler rod or automatically as a wire. The arc and the molten pool are protected by the inert gas.

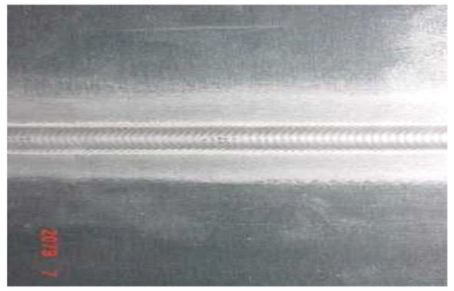


Figure 1:TIG butt weld

Figure 2:MIG fillet weld

3.2 Process description for MIG / MAG welding

Are welding processes where the arc burns in an inert gas atmosphere (inert gas or active gas) between the continuously fed wire electrode and the workpiece. The name of this process is derived from the type of gas used: MIG (for metal inert gas welding) or MAG （for metal active gas welding, respectively). The generic name of these processes is inert gas metal arc welding. The water-cooled burner is hand-operated, or moved by a mechanically controlled device. The main benefits of MIG / MAG welding processes include their high productivity, relatively low heat input and corresponding high quality of the weld seam (Figure 2). This process can be used on any structural material such as steel, aluminum or its alloys and some other non-ferrous metals.

3.3 Process description for arc welding

The melt flow is created through exposure to the arc. This open arc burns visibly between the electrode, which also fuses as a welding filler material, and the workpiece (Figure 3). In most instances, the core wire of the electrodes is of identical or similar chemical composition as that of the components to be welded. The type of covering has an effect on the welding behaviour of the electrode and the properties of the finished weld. The economic scope of application includes joint welding in any working position. This process is also suited for deposition welding, of the components to be welded. This process is also suited for deposition welding and easy to use through selection of a proper welding filler material. Materials that can be welded with this process include carbon steels, low-alloyed steels or high-alloyed steels as well as cast iron or even non-ferrous metals. However, non-ferrous metals have been largely ousted by other processes and are suited to a very limited extent only. This process is widely used, sturdy and can be used at construction job-sites under practically any conditions.

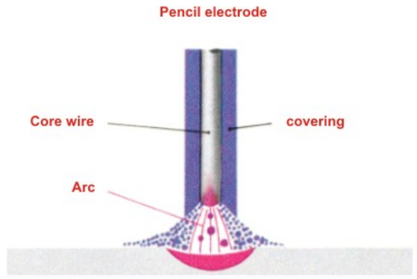


Figure 3: Principle of manual arc welding

4 Properties of the filler material and the welded joint

The chemical composition of the weld metal is determined by the composition of the welding filler material and the dilution with the base material occurring during the welding process. The welding electrode of the welding wire or welding rod respectively should easily alloy with the base material such as to form a welded joint of uniform composition, hardness and hardenability. Moreover, the welded joint should be free from non- metallic inclusions, pores or cracks, and should have the properties suited for the potential tool or mold applications.
The welding filler material used must facilitate a clean, non-porous weld metal. The filler materials must be produced with very tight analytical tolerances such that the hardness after welding and the hardness behaviour will be reproducible for each batch. Generally, the welding filler material should have a composition similar to that of the base metal. Welding filler materials intended for use in relatively soft and tough intermediate layers or buffer layers on base metals particularly prone to cracking are exempted from this requirement. The selection of the welding filler material will be determined by the required properties of the welding to be made. The most important properties of the weldments for the three main uses, viz. cold forming, hot forming and plastic molding, include:

Cold forming

- hardness
- retention of hardness,
- resistance to abrasion and wear,
- design alterations.

Hot forming

- hardness,
- retention of hardness,
- toughness,
- resistance to abrasion and wear, and
- resistance to chill cracking;

Plastic molding

- hardness,
- resistance to abrasion and wear,
- polishability and
- suitability for photo etching.

5 Hydrogen-induced defects

Depending on the microstructure, the hardness of the material, the amount of hydrogen absorbed and the mechanical stress present in the component, hydrogen introduced into the welded joint via the welding process may result in what is called hydrogen-induced defects. Hydrogen sources are, amongst others:

Humidity
(prevailing in the atmosphere, the electrode covering and the wire surface),
Crystal water
(bound to minerals in the welding filler materials), and
Organic compounds
(cellulosic electrodes, oil, paint and varnish).

Typical hydrogen-induced defects occur in the form of "flakes or fish eyes" microcracks, delayed fractures (cold cracking) or brittleness of the lattice.
The structures typical of tool steels that will result in high hardness in the heat-affected zone (HAZ) and in the weld metal, viz. martensite and bainite, are especially prone to hydrogen embrittlement and cracking. Embrittlement through hydrogen may be slightly reduced through tempering.
Hydrogen absorption during welding may be significantly reduced through a number of precautions.
A first precaution would be to use hydrogen-controlled electrodes. Welding filler materials offered as being "hydrogen-controlled" must not contain more than 15 ml of diffusible hydrogen in 100g of weld metal (after re-drying; see farther below) (determined according to DIN 8572).
For especially high requirements, hydrogen-controlled electrodes with introduction of 5 ml in 100 g of weld metal ("H5" in EN 499) are specified, and are also available. Hydrogen-controlled electrodes packed vacuum-tight and airtight are more resistant to moisture absorption. After opening the package, they can be used for welding within a specified period of time (such as within eight 8 hours) without any re-drying while a hydrogen content in the weld metal of < 5 ml will be guaranteed. To reduce the hydrogen content alkaline pencil electrodes must be re-dried before welding. The drying temperature and time are usually between 250°C and 350°C and two (2) hours respectively, or are recommended by the manufacturer on a case-by-case basis.
To eliminate any further hydrogen source, any contaminations or impurities (such as oil, rust, paint or varnish or similar) on the spot to be welded and on the surrounding surface of the tool or mold must be thoroughly removed through grinding.
Finally a comment regarding the preheating by means of a propane gas burner. When using such a burner, be mindful of the fact that such use may result in the formation of moisture on the surfaces that are not directly touched by the flame.

6 Preheating

Tool steels should be welded in a preheated condition only. A brief justification for this requirement has already been given in Section 2. That is why the mold or the tool should always be kept at a temperature of 50 to 100°C above the Ms temperature (the beginning of the austenite-to-martensite transformation) of the steel to be welded. Strictly, the critical temperature is the Ms temperature of the weld metal, which is not necessarily the same as that of the base metal. Sometimes it will happen that the base metal has been tempered at a temperature below the Ms temperature. In such an instance, preheating will result in loss of strength. This will be true, for example, for most cold-forming tool steels that are tempered at low temperatures (approx. 200°C). This loss of strength, however, must be tolerated for the benefit of preheating and the reduction of the risk of cracking. Where appropriate, a full new heat treatment of the weldments of tools or molds will be required.

7 Welding

7.1 Preliminary remarks

Even when using the best equipment available and the appropriate welding filler materials, tool steels cannot be successfully welded without thorough weld preparation, welding and post weld heat treatment. At any rate, it is recommended to draft a detailed welding procedure before proceeding to the repair work on hand. This will especially apply if larger repairs or design changes are to be carried out or implemented respectively. In addition to all the details usually specified in a welding procedure, this repair welding procedure must specifically contain the following additional information:

- the location of the spot to be repaired or corrected within the component,
- details on repair (eliminate cracks),
- details on the weld preparation, welding, calking, grinding, milling,
- in-process inspection or testing, type and method,
- the weld shape, weld pool backing-up,
- shims, abutting pieces,

- preheating and required equipment,
- control of preheating temperatures,
- welding filler materials including certificates,
- auxiliary materials, gases, powders, pastes,
- welding parameters,
- the welding sequence,
- the number of weld passes and seam design,
- flank weld cladding, supervision of the distortion, treatment after welding of the weld metal, such as stretching through swaging,
- heat treatment, specification of annealing temperatures or times,
- definition of in-process annealing, if appropriate, and
- the type, time and scope of non-destructive testing.

7.2 Preparation of the weld

Thorough preparation of the weld is indispensable. Cracks, if any, must be thoroughly reground such that the weld bottom is rounded of and that the side edges form an angle of no less than 30 degrees to the perpendicular. The root gap in the weld bottom should be larger than the diameter of the largest electrode to be used by at least one (1) millimetre. Any spots damaged on hot-working tools or molds damaged through erosion or chill cracks must be ground or sanded off down to the intact base metal. The same is true for the tool or mold surface near the welding point or the seam surfaces. At any rate, the ground or sanded surfaces should be inspected for damage by means of magnetic particle inspection (fluorescent testing). To avoid contamination of the seam surfaces, welding work should commence immediately after the magnetic particle inspection. The testing medium must be fully removed beforehand.

7.3 Welding

For manual arc welding, the first pass should be welded with an electrode of small diameter (max. diameter of 3.25 mm). For TIG welding, a maximum current of 120A should not be exceeded. For details regarding the recommended current ranges for TIG welding as a function of the diameter of the tungsten electrodes used refer to Table 1 in the DIN EN 26848 standard

The second pass is applied with an electrode of the same diameter and at the same current as for the first pass. The following fillers may then be welded with electrodes of a larger diameter and at higher currents.

The final passes must be welded with a weld reinforcement. To guarantee tempering of the heat-affected zone in the base metal, even smallest welds must be done in no less than two passes.

Welding should be done with an electrode as steep as possible and with a short arc according to the single-bead technique. The arc should always be ignited in the welding groove, but not anywhere on the component as cracking may occur at the point of ignition. These basic requirements may also be applied correspondingly to inert gas metal arc welding (MIG / MAG welding).

For repair or corrective welding of costly tools such as plastic molds with photo-etched surfaces, good current connection between the tool or mold and the welding cable is indispensable. If this is not a given, the high-quality surface may be damaged through arcing. For work like this, the tools or molds should be placed on a copper plate to guarantee optimal current connection. The copper plate must be preheated with the tool.

After completion of the welding work, the seam must be thoroughly cleaned and inspected before the tool is cooled. Defects such as weld toes or cavitations must be removed even before the cooling. After cooling, the weld seam can be machined off to the level of the surrounding tool or mold surface.

Whenever welded spots on molds require polishing or photo-etching, the last few passes should be performed as TIG welding as this will reduce the risk of formation of pores or of inclusions in the weld metal.

8 Post weld heat treatment

8.1 Options of heat treatment

Depending on the initial state of the tool, the following heat treatment options may be used after welding:

- tempering,
- hardening and tempering,
- soft annealing and
- stress-relieving.

8.2 Tempering

Quenched and tempered tools that have been subjected to repair or corrective welding should be annealed after welding whenever possible.

Tempering will improve the toughness of the weld metal, and will be especially critical if the welded spot will be subjected to high levels of stress in operation. Such operating conditions will be imposed on hot-working or cold-working molds, for example.

The tempering temperature should be selected such that the hardness of the weld metal and of the base metal are as similar as possible. If the weld metal has much better tempering properties as compared to the base metal, this rule will be disregarded. In this case, the welding point should be tempered at the highest possible temperature without, however, allowing the hardness of the base metal to drop (a typical tempering temperature will then be 20 to 30°c below the tempering temperature last used on the base metal). Really minor repair or corrective welds do not necessarily have to be tempered. However, tempering is recommended whenever practical.

8.3 Hardening and tempering

Quenched and tempered tools that have been tempered at a temperature below the Ms temperature (such as at approx. 200°C for cold-working steels) must be hardened and tempered again after welding if the loss of strength caused through preheating cannot be tolerated. Also, refer to the information provided in Section 6 hereof. Hardening and tempering must be performed in compliance with the requirements made on the tool (in terms of hardness or toughness) and using the heat treatment parameters (in terms of the heating rate, temperatures, holding times, quenching medium or similar) for the base metal.

8.4 Soft annealing

Tools in an annealed condition that require welding due to design changes or defects in workmanship must be soft annealed after welding (so as to be able to machine the weld metal hardened during cooling). Here, soft annealing will be similar to that for the base metal. Even if merely grinding should be required to finish the tool, soft annealing should not be neglected in order to largely avoid the risk of cracking during the final heat treatment.

8.5 Stress relieving

Stress relieving is not used or not required in instances where the welded tool is subjected to another heat treatment (tempering, soft annealing, hardening with subsequent tempering) after welding. But stress-relieving will make sense in instances where a hardened and tempered tool is welded with a welding filler material, whose weld metal hardness is on the same level with the service hardness of the tool. In this case, stress relieving after welding is absolutely adequate.

The temperature for the stressrelieving should be selected such that neither the base metal nor the welding point will get too soft during stress-relieving. Really minor repair or corrective welds will usually not require any stress-relief heat treatment.

8.6 Heat treatment and surface protection

During heat treatment at high temperatures such as during hardening, the surfaces of tools should be protected as much as possible against oxidation at high temperatures or scaling. For that reason, such treatment should occur under vacuum or inert gas.

9 References

Thieme/ Jahre: Instandsetzungsschweißen, Anleitung für den Betrieb (Repair welding, instructions for operation) DVS, volume 89

10 Attached tables

The following tables provide details for repair or corrective welding on tools made of hot-working steels, plastic mold steels, and cold-working steels. Moreover, some corrosion-resistant chromium or chromiumnickel steels also used in tool or mold making have additionally been included.

Repair Welding Of Tool Steels

SWG grade	Short Designation	Heat treatment condition	Preheating tempera -ture	Welding process	Possible filler metal*)	Hardness of the purely weld	Post weld heat treatment	Remarks
2311	40CrMnMo7	prehardened	300-400°C	111 111 131+135 141	UTP 73 G 3 Fontargen E 710 UTP A 73 G 3 UTP A 73 G 3	45 - 50 HRC ca. 43 HRC 42 - 46 HRC 42 - 46 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature; min. 500°C
2312	40CrMnMoS8-6	prehardened	300-400°C	111 111 131+135 141	UTP 73 G 3 Fontargen E 710 UTP A 73 G 3 UTP A 73 G 3	45 - 50 HRC ca. 43 HRC 42 - 46 HRC 42 - 46 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature; min. 500°C
2738 2738H 2738HH	40CrMnNiMo8-6-4	prehardened	300-400°C	111 111 111 131+135 141	UTP 73 G 3 Fontargen E 710 CRONITEX 130 UTP A 73 G 3 UTP A 73 G 3	45 - 50 HRC ca. 43 HRC ca. 35 HRC 42 - 46 HRC 42 - 46 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature; min. 500°C
738HH	25MnCrNiMoV6-6-4	prehardened	300-350°C	111 111 111 131+135 131+135 141 141	UTP 73 G 3 Fontargen E 710 CRONITEX 130 UTP A 73 G 3 CRONITEX 130 ST UTP A 73 G 3 CRONITEX 130 ST	45 - 50 HRC ca. 43 HRC ca. 35 HRC 42 - 46 HRC ca. 35 HRC 42 - 46 HRC ca. 35 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature; min. 500°C
XPM	25MnCrNiMoV6-6-4	prehardened	300-350°C	111 111 111 131+135 131+135 141 141	UTP 73 G 3 Fontargen E 710 CRONITEX 130 UTP A 73 G 3 CRONITEX 130 ST UTP A 73 G 3 CRONITEX 130 ST	45 - 50 HRC ca. 43 HRC ca. 35 HRC 42 - 46 HRC ca. 35 HRC 42 - 46 HRC ca. 35 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature; min. 500°C
XPM V ESR	25MnCrNiMoV6-6-4	prehardened	300-350°C	111 111 131+135 141	UTP 73 G 4 E3-UM-40-PT UTP A 73 G 4 UTP A 73 G 4	38 - 42 HRC 38 - 42 HRC 38 - 42 HRC 38 - 42 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature; min. 500°C
2711	54NiCrMoV6	prehardened	300-350°C	111 111 131+135 141	UTP 73 G 4 UTP 73 G 3 UTP A 73 G 4 UTP A 73 G 3	38 - 42 HRC 45 - 50 HRC 38 - 42 HRC 42 - 46 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature; min. 500°C
2711 mod	54NiCrMoV6mod	prehardened	300-350°C	111 111 131+135 141	UTP 73 G 3 ESAB OK 83-28 UTP A 73 G 4 UTP A 73 G 3	45 - 50 HRC 38 - 42 HRC 38 - 42 HRC 42 - 46 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature; min. 500°C
2714	56NiCrMoV7	prehardened	300-350°C	111 111 131+135 141	UTP 73 G 3 ESAB OK 83-28 UTP A 73 G 4 UTP A 73 G 3	45 - 50 HRC 38 - 42 HRC 38 - 42 HRC 42 - 46 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature; min. 500°C
2767	45NiCrMo4	hardened and tempered	300-400°C	111 111 131+135 141	UTP 73 G 2 UTP 73 G 3 UTP A 73 G 2 UTP A 73 G 3	ca. 55 HRC 45 - 50 HRC 55 - 58 HRC 42 - 46 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature;
2767	45NiCrMo4	annealed	250-300°C	111 111 131+135 141	UTP 73 G 2 UTP 73 G 3 UTP A 73 G 2 UTP A 73 G 3	ca. 55 HRC 45 - 50 HRC 55 - 58 HRC 42 - 46 HRC	annealing	
2357	50CrMoV13-14	hardened and tempered	300-400°C	111 111 131+135 131+135 141 141	UTP 73 G 3 UTP 73 G 4 UTP A 73 G 3 UTP A 73 G 4 UTP A 73 G 3 UTP A 73 G 4	42 - 46 HRC 38 - 42 HRC 42 - 46 HRC 38 - 42 HRC 42 - 46 HRC 38 - 42 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature;

Welding processes (ISO 4063): 111 – Manual metal arc welding 131 – MIG welding (MIG) 135 – MAG welding (MAG) 141 – TIG welding (TIG)
*) The information on the welding consumables have a purely advisory role, does not purport to be complete and are only a first orientation of the user to proceed.

SWG grade	Short Designation	Heat treatment condition	Preheating tempera -ture	Welding process	Possible filler metal*)	Hardness of the purely weld	Post weld heat treatment	Remarks
2357	50CrMoV13-14	annealed	250-300°C	111 111 131+135 131+135 141 141	UTP 73 G 3 UTP 73 G 4 UTP A 73 G 3 UTP A 73 G 4 UTP A 73 G 3 UTP A 73 G 4	42 - 46 HRC 38 - 42 HRC 42 - 46 HRC 38 - 42 HRC 42 - 46 HRC 38 - 42 HRC	annealing	
GPM58 V ESR	X50CrMoV5-2	hardened and tempered	400-450°C	111 111 131+135 141	QRO 90 WELD UTP 73 G 2 UTP A 73 G 2 QRO 90 TIG-WELD	50 - 55 HRC ca. 55 HRC 53 - 58 HRC 50 - 55 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature;
GPM58 V ESR	X50CrMoV5-2	annealed	350-400°C	111 111 131+135 141	QRO 90 WELD UTP 73 G 2 UTP A 73 G 2 QRO 90 TIG-WELD	50 - 55 HRC ca. 55 HRC 53 - 58 HRC 50 - 55 HRC	annealed	
2083	X42Cr13	hardened and tempered	200-250°C	111 111 111 141 131+135 141	STAVAX WELD UTP 73 G 2 *) UTP 665 **) STAVAX TIG-WELD UTP A 73 G 2 *) UTP A 73 G 2 *)	54 - 56 HRC ca. 55 HRC 35 - 40 HRC 54 - 56 HRC 53 - 58 HRC 53 - 58 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature *) not corrosion resistant **) 55-57 HRC on Chrome-cutting steel
2083	X42Cr13	annealed	200-250°C	111 111 111 141 131+135 141	STAVAX WELD UTP 73 G 2 *) UTP 665 **) STAVAX TIG-WELD UTP A 73 G 2 *) UTP A 73 G 2 *)	54 - 56 HRC ca. 55 HRC 35 - 40 HRC 54 - 56 HRC 53 - 58 HRC 53 - 58 HRC	annealed	*) not corrosion resistant **) 55-57 HRC on Chrome-cutting steel
2083 mod V ESR	X40Cr14	hardened and tempered	200-250°C	111 111 111 141 131+135 141	STAVAX WELD UTP 73 G 2 *) UTP 665 **) STAVAX TIG-WELD UTP A 73 G 2 *)	54 - 56 HRC ca. 55 HRC 35 - 40 HRC 54 - 56 HRC 53 - 58 HRC 53 - 58 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature *) not corrosion resistant **) 55-57 HRC on Chrome-cutting steel
2083 mod V ESR	X40Cr14	annealed	200-250°C	111 111 111 141 131+135 141	STAVAX WELD UTP 73 G 2 *) UTP 665 **) STAVAX TIG-WELD UTP A 73 G 2 *) UTP A 73 G 2 *)	54 - 56 HRC ca. 55 HRC 35 - 40 HRC 54 - 56 HRC 53 - 58 HRC 53 - 58 HRC	annealed	*) not corrosion resistant **) 55-57 HRC on Chrome-cutting steel
CRMHP V ESR	X28CrNi13	hardened and tempered	200-250°C	111 111 131+135 141	UTP 73 G 2 *) UTP 665 **) UTP A 73 G 2 *) UTP A 73 G 2 *)	ca. 55 HRC 35 - 40 HRC 53 - 58 HRC 53 - 58 HRC	tempering or new hardening + tempering	Welding not recommended for optical applications; min. 30°C below tempering temperature *) not corrosion resistant **) 55-57 HRC on Chrome-cutting steel
CRMHP V ESR	X28CrNi13	annealed	200-250°C	111 111 131+135 141	UTP 73 G 2 *) UTP 665 **) UTP A 73 G 2 *) UTP A 73 G 2 *)	ca. 55 HRC 35 - 40 HRC 53 - 58 HRC 53 - 58 HRC	annealed	Welding not recommended for optical applications; *) not corrosion resistant **) 55-57 HRC on Chrome-cutting steel
CPM50 V ESR	X28CrNiMo13	prehardened	200-250°C	111 111 131+135 141	UTP 73 G 2 *) UTP 665 **) UTP A 73 G 2 *) UTP A 73 G 2 *)	ca. 55 HRC 35 - 40 HRC 53 - 58 HRC 53 - 58 HRC	tempering or new hardening + tempering	Welding not recommended for optical applications; min. 30°C below tempering temperature *) not corrosion resistant **) 55-57 HRC on Chrome-cutting steel; min. 500°C
OPTI N+	X15CrNi13	hardened and tempered	200-250°C	111 111 131+135 141	UTP 73 G 2 *) UTP 665 **) UTP A 73 G 2 *) UTP A 73 G 2 *)	ca. 55 HRC 35 - 40 HRC 53 - 58 HRC 53 - 58 HRC	tempering or new hardening + tempering	Welding not recommended for optical applications; min. 30°C below tempering temperature *) not corrosion resistant **) 55-57 HRC on Chrome-cutting steel

Welding processes (ISO 4063): 111 – Manual metal arc welding 131 – MIG welding (MIG) 135 – MAG welding (MAG) 141 – TIG welding (TIG)
*) The information on the welding consumables have a purely advisory role, does not purport to be complete and are only a first orientation of the user to proceed.

Repair Welding Of Tool Steels

SWG grade	Short Designation	Heat treatment condition	Preheating tempera -ture	Welding process	Possible filler metal*)	Hardness of the purely weld	Post weld heat treatment	Remarks
OPTI N+	X15CrNi13	annealed	200-250°C	111 111 131+135 141	UTP 73 G 2 *) UTP 665 **) UTP A 73 G 2 *) UTP A 73 G 2 *)	ca. 55 HRC 35 - 40 HRC 53 - 58 HRC 53 - 58 HRC	annealed	Welding not recommended for optical applications; *) not corrosion resistant **) 55-57 HRC on Chrome-cutting steel
CRM13S	~X10CrMnS13	prehardened	200-250°C	111 111 141	UTP 665 **) Welding rod of similar chemical composition as grade recommended	35 - 40 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature; min. 500°C **) 55-57 HRC on Chrome-cutting steel
2316	X38CrMo16	prehardened	300-400°C	111 111 131+135 141	UTP 73 G 3 *) UTP 665 **) UTP A 73 G 3 *) UTP A 73 G 3 *)	45 - 50 HRC 35 - 40 HRC 42 - 46 HRC 42 - 46 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature *) not corrosion resistant **) 55-57 HRC on Chrome-cutting steel; min. 500°C
2085	X33CrS16	prehardened	200-250°C	111 111 131+135 141	UTP 73 G 2 *) UTP 665 **) UTP A 73 G 2 *) UTP A 73 G 2 *)	ca. 55 HRC 35 - 40 HRC 53 - 58 HRC 53 - 58 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature *) not corrosion resistant **) 55-57 HRC on Chrome-cutting steel; min. 500°C
GEST80 V ESR	15NiMnCuAlMo12-6	prehardened	200-350°C	111 111 131+135 131+135 141 141	NAK-W UTP 73 G 4 NAK-W UTP A 73 G 4 NAK-W UTP A 73 G 4	38 - 42 HRC 38 - 42 HRC 38 - 42 HRC 38 - 42 HRC 38 - 42 HRC 38 - 42 HRC	aging (post-heat treatment) or new hardening + aging	min. 30°C below tempering temperature; min. 500°C
CPM40 V ESR	15CrNiMoAlCu16-12-11	prehardened	200-350°C	111 131+135 141	UTP 73 G 4 UTP A 73 G 4 UTP A 73 G 4 Welding rod of similar chemical composition as grade recommended	38 - 42 HRC 38 - 42 HRC 38 - 42 HRC	aging (post-heat treatment) or new hardening + aging	min. 30°C below tempering temperature; min. 500°C
2343 (EX3)	X38CrMoV5-1	hardened and tempered	400-450°C	111 111 131+135 141	QRO 90 WELD UTP 73 G 2 UTP A 73 G 2 QRO 90 TIG-WELD	50 - 55 HRC ca. 55 HRC 53 - 58 HRC 50 - 55 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature
2343 (EX3)	X38CrMoV5-1	annealed	350-400°C	111 111 131+135 141	QRO 90 WELD UTP 73 G 2 UTP A 73 G 2 QRO 90 TIG-WELD	50 - 55 HRC ca. 55 HRC 53 - 58 HRC 50 - 55 HRC	annealed	
2344 (EX4)	X40CrMoV5-1	hardened and tempered	400-450°C	111 111 131+135 141	QRO 90 WELD UTP 73 G 2 UTP A 73 G 2 QRO 90 TIG-WELD	50 - 55 HRC ca. 55 HRC 53 - 58 HRC 50 - 55 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature
2344 (EX4)	X40CrMoV5-1	annealed	350-400°C	111 111 131+135 141	QRO 90 WELD UTP 73 G 2 UTP A 73 G 2 QRO 90 TIG-WELD	50 - 55 HRC ca. 55 HRC 53 - 58 HRC 50 - 55 HRC	annealed	
2347	X40CrMoVS5-1	prehardened	min. 350°C	111 111 131+135 141	QRO 90 WELD UTP 73 G 2 UTP A 73 G 2 QRO 90 TIG-WELD	50 - 55 HRC ca. 55 HRC 53 - 58 HRC 50 - 55 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature; min. 500°C
2367 (EX7)	X38CrMoV5-3	hardened and tempered	400-450°C	111 111 131+135 141	QRO 90 WELD UTP 73 G 2 UTP A 73 G 2 QRO 90 TIG-WELD	50 - 55 HRC ca. 55 HRC 53 - 58 HRC 50 - 55 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature
2367 (EX7)	X38CrMoV5-3	annealed	350-400°C	111 111 131+135 141	QRO 90 WELD UTP 73 G 2 UTP A 73 G 2 QRO 90 TIG-WELD	50 - 55 HRC ca. 55 HRC 53 - 58 HRC 50 - 55 HRC	annealed	

Welding processes (ISO 4063): 111 – Manual metal arc welding 131 – MIG welding (MIG) 135 – MAG welding (MAG) 141 – TIG welding (TIG)
*) The information on the welding consumables have a purely advisory role, does not purport to be complete and are only a first orientation of the user to proceed.

SWG grade	Short Designation	Heat treatment condition	Preheating tempera -ture	Welding process	Possible filler metal*)	Hardness of the purely weld	Post weld heat treatment	Remarks
EX1	X35CrMoV5-2	hardened and tempered	400-450°C	111 111 131+135 141	QRO 90 WELD UTP 73 G 2 UTP A 73 G 2 QRO 90 TIG-WELD	50 - 55 HRC ca. 55 HRC 53 - 58 HRC 50 - 55 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature
EX1	X35CrMoV5-2	annealed	350-400°C	111 111 131+135 141	QRO 90 WELD UTP 73 G 2 UTP A 73 G 2 QRO 90 TIG-WELD	50 - 55 HRC ca. 55 HRC 53 - 58 HRC 50 - 55 HRC	annealing	
EX2	X37CrMoV5-2	hardened and tempered	400-450°C	111 111 131+135 141	QRO 90 WELD UTP 73 G 2 UTP A 73 G 2 QRO 90 TIG-WELD	50 - 55 HRC ca. 55 HRC 53 - 58 HRC 50 - 55 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature;
EX2	X37CrMoV5-2	annealed	350-400°C	111 111 131+135 141	QRO 90 WELD UTP 73 G 2 UTP A 73 G 2 QRO 90 TIG-WELD	50 - 55 HRC ca. 55 HRC 53 - 58 HRC 50 - 55 HRC	annealed	
EX6	-	hardened and tempered	400-450°C	111 111 131+135 141	UTP 73 G 2 Fontargen E 709 UTP A 73 G 2 UTP A 73 G 2	ca. 55 HRC 57 - 62 HRC 53 - 58 HRC 53 - 58 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature;
EX6	-	annealed	350-400°C	111 111 131+135 141	UTP 73 G 2 Fontargen E 709 UTP A 73 G 2 UTP A 73 G 2	ca. 55 HRC 57 - 62 HRC 53 - 58 HRC 53 - 58 HRC	tempering or new hardening + tempering	min. 30°C below tempering temperature;
2379	X153CrVMo12	hardened and tempered	450-500°C	111 111 131+135 131+135	UTP 67 S UTP 65 D *) UTP A DUR 600 UTP A 651 *)	56 - 58 HRC ca. 240 HB 54 - 60 HRC ca. 240 HB	tempering or new hardening + tempering	min. 30°C below tempering temperature;
2379	X153CrVMo12	annealed	400-450°C	111 111 131+135 131+135	UTP 67 S UTP 65 D *) UTP A DUR 600 UTP A 651 *)	56 - 58 HRC ca. 240 HB 54 - 60 HRC ca. 240 HB	annealed	*) for buffer layers

Welding processes (ISO 4063): 111 – Manual metal arc welding 131 – MIG welding (MIG) 135 – MAG welding (MAG) 141 – TIG welding (TIG)
*) The information on the welding consumables have a purely advisory role, does not purport to be complete and are only a first orientation of the user to proceed.

PHOTO-ETCHING RECOMMENDATION FOR SWG PLASTIC MOLD STEELS

Photo-etching, graining or etch graining on the surface of finished molding tools is a chemical method of surface treatment in order to provide a textured surface on highlighted parts of the tool. Such textured tools give the plastic products a more attractive surface decor with a better grip, surface protection and visual appeal. A wide scale of natural and artificial surface patterns can be created by the photo etching technology.

Leather structure grain on the cavity side of a plastic injection mould

The photo-etching process

In order to admit a structure in negative relief into the steel surface the most common method is the established etching technique. The required pattern is created by photographic and computer processing and after that the film negative is transferred step by step to the clean mold surface and the seams are corrected manually. In the next step the film layer is exposed under ultraviolet light and washed in a developer bath afterwards. The pattern is then etched into the developed zones of the layer to the required depth by the application of an acid under closely controlled condition. The etching process is carried out with appropriate acids such as nitric acid or ferric chloride prepared specifically for this purpose by placing tools or tool components to an acid bath or alternatively spraying

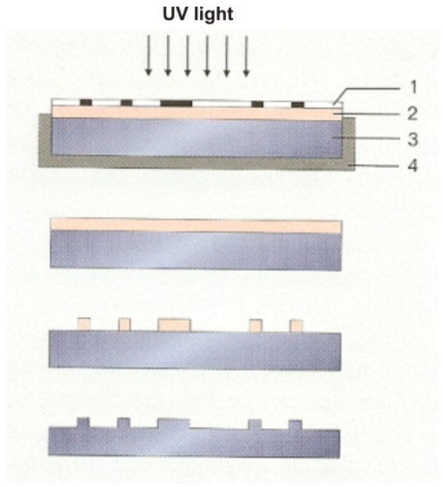
Creating a negative relief by photographic and computer processing

Preparing the relevant mould surface with a film negative before etchingA

tool components to an acid bath or alternatively spraying acid directly onto the tool contour. The length of the reaction time determines the etching depth and reveals the characteristics of the etched relief. The depth of the etched zone varies between 0.05 and 0.5 mm. Many structures are created by more than just one etching or film on the surface. Only through a combination of various etching steps and films special textures can be realized.

Summary of the essential process steps of photo-etching:

- creating the surface structure by means of photographs and computer corrections,
- producing a film with the desired structure
- sticking the film on to the surface of the mold and a layer of a photosensitive resist



Principle of photo-etching
1 film, 2 photosensitive resist, 3 mould steel, 4 cover

- working out all the seams and corrections
- UV exposing and developing of the photosensitive resist under the film
- removing of the exposed zones of the surface
- etching the steel surface in the areas of the developed zones by means of a proper acid in a defined time to reach a certain depth of the relief
- stop the etching phase by washing the surface
- if necessary repeating the process with the next film.

Preparing of the mold surface before photo-etching

Complete the machining operation by stress-relieving, followed by finish-machining and grinding the surface. There is generally no advantage in using finer abrasives than 220 grain on a surface that is to be photo-etched. Polishing is to avoid. Surface finishes achieved by grinding with a 240 – 320 grit are adequate. Following the rule:

- Fine structures with flat etch depth use 320 grit.
- Rough structures with deep etch depth use 240 grit.

The depth of the photo-etched structure is dependent on steel composition and the hardness at the surface.
Spark eroded surfaces should always be ground or polished, otherwise re-hardened surface layers from the spark erosion will cause a poor etching result.
Flame-hardening or nitriding should be avoided prior to photo-etching. If surface hardening is needed it has to be done always after the photo-etching.
Generally welded zones results in a poor surface quality after photo-etching.
In some cases a welded tool can be photo-etched provided that the same material is used in the weld as in the tool itself and welding operation is carried out exactly to the welding instruction of the steel supplier. Of great importance is beside of the right filler material the pre-heating and tempering of the welding. In such cases the welded area should be indicated to the photo-etcher.
To avoid problems with photo-etching an etching test has to be done before with the following steps:

- degreasing of the mold surface (e.g. with braking cleaner, spirit or similar)
- apply the test liquid (test acid like 3% alcoholic nitric acid on the mold surface with a brush - avoid that the acid contacts areas outside of the test field
- operation time max. 1 min (surface is getting dark)
- rinse off the test liquid with clear water
- dry bubbles with compressed air (not drying by textile or paper)
- Check the mold surface for:
- EDM residuals (gloss spots from white zones)
- unsatisfactory weldings e.g. bright areas revealing the welding pattern
- stripes and grooves with orientations from machining or grinding
- hard spot areas (e.g. due to high surface hardness)
- abnormal microstructures (e.g. resulting from hard zones or welding)
- carry out the manual corrections and repair of problem zones (contact mold maker or welder)

Steel factors on the quality of photo-etching result

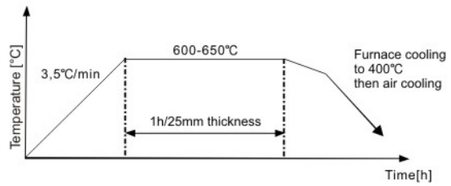
The majority of photo-etched molds are made out of plastic mold steel. Etching process and optical appearance of the grain is dependent on the steel grade and its hardness. Other influencing factors of the material on the grain result are the homogeneity, the cleanliness and the grain flow of the steel. One rule is to use all the inserts in case of a complex tool always from one steel grade and if possible from the same steel bar. The grain flow of the used steel shall always be in the same direction. In general, all mold steels with a chromium content up to 15% and nickel up to 5 % are suitable for the photo-etching process. For etching chromium-alloyed corrosion resistant mold steels such as 2083 or 2316 special etchants and longer etching times are needed. Steel with higher hardness takes longer etching times for same grain result as a steel with lower hardness. So, local differences in chemical composition (segregation) and hardness deviations within one steel bar can lead to an inhomogeneous and insufficient appearance of the grain. Etching of steel with a poor cleanliness or with a high sulphur content usually results in a grain structure with unacceptable stripes and holes. For this reason, the sulphur-alloyed mold steels 2085 and 2312 shall never be used for mold cavities with a grained or polished surface. Standard grades for photo-etching are the pre-hardened plastic mold grades 2311, 2711, 2738, SWG 738HH and SWG XPM or the through hardening steels 2767 and 2343 (ESR grade). Poor grain results can be expected when etching the grades 1730 (C45) and the high carbide content steel 2379 (D2). In any case an etching test has to be done in order to identify critical zones on the steel surface so that the photo etcher has the chance to react with a proper etching technique. The standard etchant is still based on nitric acid which is a grain boundary active acid. Although this etchant is easy to handle and leads normally to constant results it reacts very sensitive to steel segregation as can be expected with larger block sizes. Steel grade SWG XPM and SWG 738HH are less sensitive to segregation and grain problems with larger molds than standard grade 2738. To avoid problems resulting from big steel blocks the proper etching technique can be the use of an etchant based on ferric chloride acid.

HEAT TREATMENT RECOMMENDATION FOR SWG HOT WORKING STEELS

Attention:

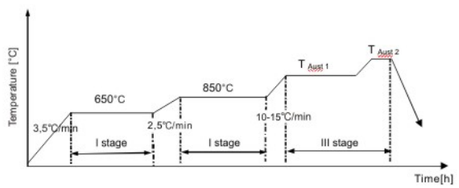
We want to point out very clearly that this heat-treatment processing recommendation is only a recommendation.
The responsibility for the whole heat treatment process is fully at the heat treatment shop and not by us.

1. Stress-relieving treatment before quenching



According to each 25mm effective thickness of the workpiece hold one hour to account the temperature holding time.

2. Vacuum high pressure gas quenching



High pressure N_2 quenching
≥ 9 bar(min 28°C/min)
cooling to 500°C,
reduce pressure appropriate

SWG grade	T Aust 1 [°C]	T Aust 2 [°C]
EX1	1000	1010-1015
EX2	1000	1010-1015
2343 (EX3)	990	1010
2344 (EX4)	1010	1030
2367 (EX7)	1010	1030

Table 1: hardening temperature

(Following we use Ta to represent the furnace cavity temperature, Tc to represent the mold core temperature and Ts to represent the temperature of 16mm depth under the mold surface)

Note:

(1) Pre-heat

With the mold of different complexity and thickness, we can choose to pre-heat 2~3 times. The pre-heat holding time is to be chosen according to when the core temperature of the mold reaches or approaches the furnace cavity temperature.

(a) I stage pre-heat
The heating-up speed can be 150~210°C/h, when Ta = 650°C start to hold the temperature, when Ta – Tc ⩽ 30°C turn to the next stage.

(b) II stage pre-heat
The heating-up speed can be 120~150°C/h, when Ta = 850°C start to hold the temperature, when Ta-Tc ⩽ 10°C turn to the next stage.

(2) Heating stage

The heating-up speed can be 10~15°C/min, when Ta reaches T_{Aust1}, start to hold the temperature. When $T_{Aust1} - T_{core} = 10°C$ start to account the hold time, 80% of soaking time at T_{Aust1} further 20% of soaking time at T_{Aust2}. (s. table 1: hardening temperature)(In the risk of coarse grain development, the hardening temperature should not exceed T_{Aust2}!)

In China people usually hold the temperature for one minute for each 2 mm effective thickness. But as batch and furnace condition are different, so we better use the K shape thermojunction to test the mold core temperature and temperature of 16mm depth to the mold surface, then to determine the holding time.

(3) Quenching stage

We can choose the quenching N_2 gas pressure according to different mold thicknesses and complexity, generally it should be higher than 9 bar (means the cooling rate of Ts⩾28°C/min) up to 500°C then reduce the pressure appropriately. To ensure that the workpiece does not deform and no cracking occurs adapt the high pressure as far as possible to improve the workpiece cooling ability. So a fine grained microstructure can be gained.

We can choose continuous cooling or isothermal cooling, when cooling to 150°C then use air cooling, when the mold temperature is lower than 70°C we should immediately turn to the tempering stage.

3. Tempering

(1) Tempering temperature: Table 2
(2) Holding time: According to each 25mm effective thickness of the workpiece hold one hour to account the temperature holding time, but total holding time no less than 4 hours.
(3) Tempering times: ⩾3 times.
  [1] The first time tempering at table 2
  [2] The second time tempering according to the hardness measuring
  [3] The third time tempering = hardness fine tuning
  - if hardness is ok, the third time tempering temperature -30°C below highest tempering temperature of first or second tempering.

To reach the hardness range 44 - 46 HRC:

SWG grade	1. tempering [°C]	2. tempering	3. tempering
EX1	580	According hardness measuring	2. tempering – 30°C
EX2	580		
2343 (EX3)	570		
2344 (EX4)	580		
2367 (EX7)	580		

Table2: hardening temperature

Add.

(1) Al-alloy die casting mold recommend tempering hardness:
  Large-sized mold 42 ~ 44 HRC
  Medium-sized mold 44 ~ 46 HRC
  Minitype mold 46 ~ 48 HRC

(2) Zn-alloy die casting mold recommend tempering hardness:
  50 ~ 54 HRC.