WELDING OF TOOL STEEL

UDDEHOLM

Classified according to EU Directive 1999/45/EC
For further information see our "Material Safety Data Sheets".

Edition 6, – Revised 02.2014, not printed

The latest revised edition of this brochure is the English version, which is always published on our web site www.uddeholm.com

SS-EN ISO 9001
SS-EN ISO 14001

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General information on welding of tool steel

Tool steel contain up to 2.5% carbon as well as alloying elements such as manganese, chromium, molybdenum, tungsten, vanadium and nickel. The main problem in welding tool steel stems from its high hardenability. Welds cool quickly once the heat source is removed and the weld metal and part of the heat-affected zone will harden. This transformation generates stresses because the weld is normally highly constrained, with a concomitant risk for cracking unless great care is exercised.

In what follows, a description is given of the welding equipment, welding technique and weld consumables that are required in order to weld tool steel successfully. Of course, the skill and experience of the welder is also a vital ingredient in obtaining satisfactory results. With sufficient care, it is possible to achieve weld repairs or adjustments which, in terms of tooling performance, are hardly inferior to that of the base steel.

Welding of tooling may be required for anyone of the following reasons:

- refurbishment and repair of cracked or worn tooling
- renovation of chipped or worn cutting edges, e.g. on blanking tools
- adjustment of machining errors in tool making
- design changes

Welding methods for tool steel

Shielded metal-arc welding (SMAW or MMA)

PRINCIPLE

An electric arc generated by a DC or AC power source is struck between a coated, rod-like electrode and the work-piece (Fig. 1).

The electrodes consist of a central wire core, which is usually low-carbon steel, covered with a coating of pressed powder (flux). The constitution of this coating is complex and consists of iron powder, powdered ferro-alloys, slag formers and a suitable binder. The electrode is consumed under the action of the arc during welding and drops of molten metal are transferred to the work-piece. Contamination by air during the transfer of molten drops from electrode to workpiece and during solidification and cooling of the weld deposit is inhibited partly by slag formed from constituents in the electrode coating and partly by gases created during melting of the electrode.

The composition of the deposited weld metal is controlled via the constitution of the electrode coating.

POWER SOURCE

For MMA welding, it is possible to use either an AC or DC power source. However, whichever is used, the source must provide a voltage and current which is compatible with the electrode. Normal arc voltages are:

- normal recovery electrodes: 20–30 V
- high recovery electrodes: 30–50 V

Uddeholm welding consumables are of normal recovery type. A suitable power source for these is a DC unit with an open voltage of 70 V and which is capable of delivering 250A/30V at 35% intermittence.

Gas tungsten-ARC welding (GTAW or TIG)

PRINCIPLE

In MMA welding, the electrode from which the arc is struck is consumed during welding.

The electrode in TIG welding is made of tungsten or tungsten alloy which has a very high melting point (about 3300 °C/6000 °F) and is therefore not consumed during the process (Fig. 2). The arc is initially struck by subjecting the electrode-workpiece gas to a high-frequency voltage. The resulting ionization permits striking without the necessity for contact between electrode and workpiece. The tungsten electrode is always connected to the negative terminal of a DC power source because this minimizes heat generation and thereby any risk of melting the electrode. Current is conducted to the electrode via a contact inside the TIG-gun. Any consumables which are required during TIG-welding are fed obliquely into the arc in the form of rod or wire. Oxidation of the weld pool is prevented by an inert-gas shroud which streams from the TIG gun over the electrode and weld.

POWER SOURCE

TIG welding can be performed with a regular MMA power source provided this is complemented with a TIG control unit. The gun should be water cooled and be capable of handling a minimum current of 250 A at 100% intermittence. A gas lens is also a desirable feature in order that the inert gas protection is as efficient as possible. Welding is facilitated if the current can be increased steplessly from zero to the optimum level.

Laser Welding

PRINCIPLE

High power laser light is generated and focused through a lens to the welding spot. As filler material a thin wire with a diameter between 0.1–0.6 mm is primarily used. The welder guides the wire to the area to be welded. The laser beam melt the wire and the base material. The molten material solidifies leaving behind a small raised area. The welder continues spot by spot and line by line. Argon gas shields the process from oxidation (Fig.3).

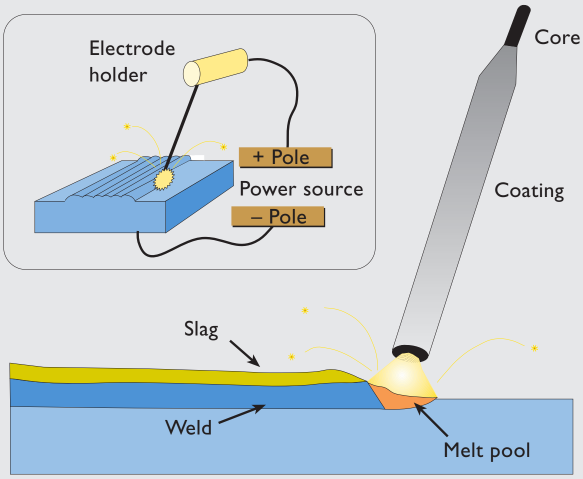


Fig. 1 Shielded Metal-Arc Welding SMAW (MMA)

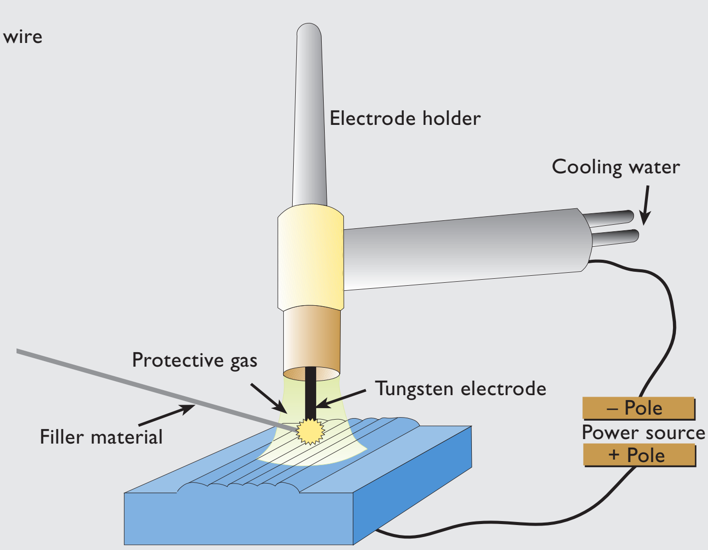


Fig. 2 Gas Tungsten Arc Welding GTAW (TIG)

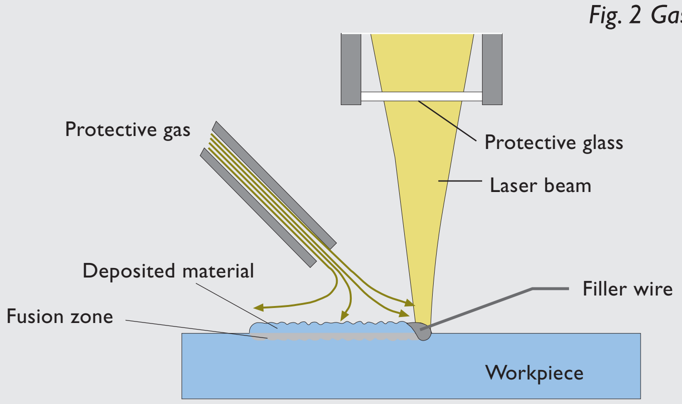


Fig. 3 Laser Welding

POWER SOURCE

For deposition welding normally a pulsed solid state laser of Nd: YAG type is used.

Typical performance:	
Nominal output	150–200 W
Max pulse output	10–12 kW
Pulse time	0.5–20 ms
Frequence	0.5–20 Hz
Spot diameter	0.5–2.0 mm (0.1–0.5 mm)

The welding bay

In order to be able to effect satisfactory welding work on tool steel, the following items of equipment are to be regarded as minimum requirements.

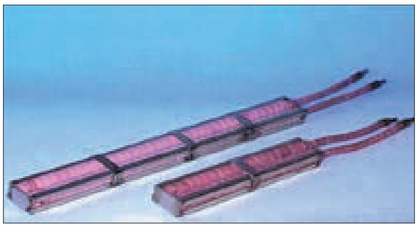
Dry cabinet

The coated electrodes used for MMA welding are strongly hygroscopic and should not be allowed to come into contact with anything other than dry air. Otherwise, the weld will be contaminated with hydrogen (see later). Hence, the welding bay should be equipped with a dry cabinet for storage of electrodes. This should be thermostatically controlled in the range 50–150 °C (120–300 °F). The electrodes should be removed from their containers and lie loose on racks.

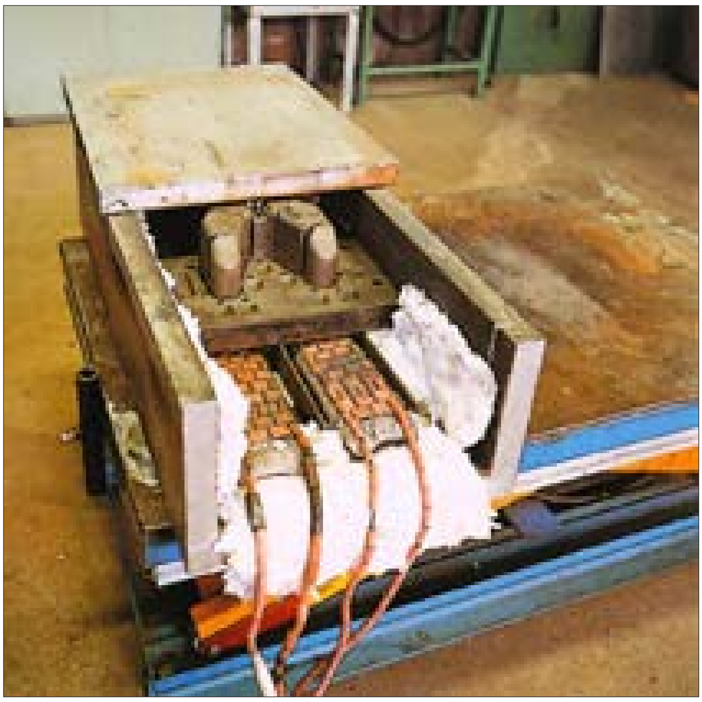
For welding of tooling outside the welding bay, it will also be found useful to have a portable heated container in which the electrodes can be carried.

Workbench

It is particularly important during critical welding operations, of the type performed with tool steel, that the welder enjoys a comfortable working position. Hence, the workbench should be stable, of the correct height a sufficiently level that the work can be positioned securely and accurately. It is advantageous if the workbench is rotatable and adjustable vertically, since both these features facilitate the welding operation.



Electrical elements for an insulated preheating box.



Preheating in an insulated box.

Preheating equipment

Tool steel cannot be welded at room temperature without considerable risk for cracking and it is generally necessary to pre-heat the mould or die before any welding can be attempted (see later). While it is certainly possible to weld tools successfully by preheating in a furnace, the chances are that the temperature will fall excessively prior to completion of the work. Hence, it is recommended that the tool be maintained at the correct temperature using an electrical heating box supplied from a current-regulated DC source. This equipment also enables the tool to be heated at a uniform and controlled rate.

To place the tool on a heated table or plate could sometimes be sufficient to maintain the temperature.

For minor repairs and adjustments, it is acceptable that the tool is preheated using a propane torch. Hence, liquid propane cylinders should be available in the welding bay.

Grinding machines

The following should be available:

- disc grinder with minimum 180 Ø x 6 mm wheel (7 Ø x 0,25”) for preparing the joint and grinding out of any defects which may occur during welding
- flat grinder capable of ≥25 000 rpm for grinding of minor defects and of the finished weld
- if a welded mould is subsequently to be polished or photo-etched, it may be necessary to have a grinder capable of giving a sufficiently fine finish
- small rotating metal files in different shapes and sizes

Filler material

The chemical composition of a weld deposit is determined by the composition of the consumable (filler metal), the base steel composition and the extent to which the base material is melted during welding. The consumable electrode or wire should mix easily with the molten base steel giving a deposit with:

- uniform composition, hardness and response to heat-treatment
- freedom from non-metallic inclusions, porosity or cracks
- suitable properties for the tooling application in question

Since tool steel welds have high hardness, they are particularly susceptible to cracking which may originate at slag particles or pores. Hence, the consumable used should be capable of producing a high-quality weld. In a similar vein, it is necessary that the consumables are produced with very tight analysis control in order that the hardness as welded and the response to heat treatment is reproducible from batch to batch. High-quality filler metals are also essential if a mould is to be polished or photo-etched after welding. Uddeholm welding consumables meet these requirements.

Filler rods are normally produced from electro-slag remelted stock. The coated electrodes are of basic type, which are far superior to rutile electrodes as regards weld cleanliness. Another advantage with basic coated electrodes over those of rutile type is that the former give a much lower hydrogen content in the weld metal.

In general, the consumable used for welding tool steel should be similar in composition to the base material. When welding in the *annealed* condition, e.g. if a mould or die has to be adjusted while in the process of manufacture, it is vital that the filler metal has the same heat treatment characteristics as the base steel, otherwise the welded area in the finished tool will have different hardness. Large compositional differences are also associated with an increased cracking risk in connection with hardening.

Uddeholm welding consumable are designed to be compatible with the corresponding tool steel grades irrespective of whether welding is carried out on annealed or hardened-and tempered base material.

Obviously, the weld metal of welded tools will require different properties for different applications.

Laser welding consumables from Uddeholm.

For the three main application segments for tool steel (cold work, hot work and plastic moulding), the important weld-metal properties are:

COLD WORK
- Hardness
- Toughness
- Wear resistance

HOT WORK
- Hardness
- Temper resistance
- Toughness
- Wear resistance
- Heat checking resistance

PLASTIC MOULDING
- Hardness
- Wear resistance
- Polishability
- Photoetchability

Uddeholm welding consumables

UDDEHOLM COATED ELECTRODES

Impax Weld
QRO 90 Weld
Calmax/Carmo Weld
Caldie Weld

UDDEHOLM TIG-RODS

Impax TIG-Weld
Stavax TIG-Weld
Corrax TIG-Weld
Nimax TIG-Weld
Mirrax TIG-Weld
Unimax TIG-Weld
QRO 90 TIG-Weld
Dievar TIG-Weld
Calmax/Carmo TIG-Weld
Caldie TIG-Weld

UDDEHOLM LASER RODS

Stavax Laser Weld
Nimax Laser Weld
Dievar Laer Weld

Hydrogen in tool steel

Welds in tool steel have high hardness and are, therefore, especially susceptible to cold cracking derived from hydrogen ingress during welding. In many cases, hydrogen is generated as a result of water vapour being adsorbed in the hygro-scopic coating of MMA electrodes.

The susceptibility of a weld to hydrogen cracking depends on:

- the microstructure of the weld metal (different microstructures have different hydrogen sensitivities)
- the hardness of the steel (the greater the hardness, the higher the susceptibility)
- the stress level
- the amount of diffusible hydrogen introduced in welding

Microstructure/hardness

The characteristic microstructures giving high hardness in the heat-affected zone and weld metal, i.e. martensite and bainite, are particularly sensitive to embrittlement by hydrogen. This susceptibility is, albeit only marginally, alleviated by tempering.

Stress level

Stresses in welds arise from three sources:

- contraction during solidification of the molten pool
- temperature differences between weld, heat-affected zone and base steel
- transformation stresses when the weld and heat-affected zone harden during cooling

In general, the stress level in the vicinity of the weld will reach the magnitude of the yield stress, which for hardened tool steel is very high indeed. It is very difficult to do anything about this but the situation can be improved somewhat via proper weld design, (bead location and sequence of runs). However, no measures to reduce stress will help if the weld is seriously contaminated by hydrogen.

Content of diffusible hydrogen

As regards the susceptibility of welds to cold cracking, this is the factor that it is easiest to do something about. By adhering to a number of simple precautions, the amount of hydrogen introduced during welding can be reduced appreciably.

- Always store coated electrodes in a heated storage cabinet or heated container once the pack has been opened (see earlier).
- Contamination on the surfaces of the joint of the surrounding tool surface, e.g. oil, rust or paint, is a source of hydrogen. Hence, the surfaces of the joint and of the tool in the vicinity of the joint should be ground to bare metal immediately prior to starting to weld.
- If preheating is performed with a propane burner, it should be remembered that this can cause moisture to form on the tool surfaces not directly impinged by the flame.

Dry cabinet for storage of electrodes.

Elevated working temperature

The basic reason for welding tool steel at elevated temperature derives from the high hardenability and therefore crack sensitivity of tool steel welds and heat-affected zones. Welding of a cold tool will cause rapid cooling of the weld metal and heat-affected zone between passes with resulting transformation to brittle martensite and risk of cracking. Cracks formed in the weld could well propagate through the entire tool. Hence, the mould or die should, during welding, be maintained at 50–100°C (90–180°F) above the M_S-temperature (martensite-start temperature) for the steel in question. The critical temperature is the M_S of the weld metal, which may not be the same as that of the base metal.

In some instances, it may be that the base steel is fully hardened and has been tempered at a temperature below the M_S-temperature. Hence, pre-heating the tool for welding will cause a drop in hardness. For example, most low-temperature tempered cold-work steel will have to be preheated to a temperature in excess of the tempering temperature, which is usually ca. 200°C (400°F). The hardness drop must be accepted in order to perform a proper preheating and mitigate the risk of cracking during welding.

During multi-run welding of a properly pre-heated tool, most of the weld will remain austenitic under the entire welding operation and will transform slowly as the tool cools down. This ensures a uniform hardness and microstructure over the whole weld in comparison with the situation where each run transforms to martensite in between passes.

It will be clear from this discussion that the entire welding operation should be completed while the tool is hot. Partially welding, letting the tool cool down and then preheating later on to finish the job, is not to be recommended because there is considerable risk that the tool will crack.

While it is feasible to pre-heat tools in a furnace, there is the possibility that the temperature is uneven (creates stresses) and that it will drop excessively before welding is completed (especially if the tool is small).

The best method, of preheating and maintaining the tool at the requested temperature during welding, is to use an insulated box with electrical elements in the walls (see page 6).

Uddeholm Stavax Weld/TIG-Weld and Uddeholm Impax Weld/TIG-Weld match their corresponding tool steel grades exactly and give perfect results after polishing or texturing of a welded mould.

Welding procedure

Joint preparation

The importance of careful preparation can not be over-emphasized. Cracks should be ground out so that the groove angle will be 60° if possible. The width of the bottom should be at least 1 mm greater than the maximum electrode diameter which will be used.

Erosion or heat-checking damage on hot work tools should be ground down to sound steel.

The tool surfaces in the immediate vicinity of the intended weld and the surfaces of the groove itself must all be ground down to clean metal. Prior to starting welding, the ground areas should be checked with penetrant to make sure all defects have been removed. The tool should be welded as soon as the preparation is finished, otherwise there is risk of contamination of the surfaces with dust, dirt or moisture.

Building up the weld

To avoid undercut in the border line, between the weld and the base material, start with fine sink runs. The initial layer should be made with a small diameter MMA electrode, 2,5 mm, or via TIG welding (max. current 120 A).

The second layer is made with the same electrode diameter and current as the first in order to minimize the heat-affected zone. The remaining of the groove can be welded with a higher current and electrodes with larger diameter.

The final runs should be built up well above the surface of the tool. Even small welds should comprise a minimum of two runs. Grind off the last runs.

During MMA welding, the arc should be short and the beads deposited in distinct runs. The electrode should be angled at 90° to the joint sides so as to minimize undercut. In addition, the electrode should be held at an angle of 75–80°C to the direction of forward movement.

The arc should be struck in the joint and not on any tool surfaces which are not being welded. The sore form striking the arc is likely location for crack initiation. In order to avoid pores, the starting sore should be melted up completely at the beginning of welding. If a restart is made with a partly-used MMA electrode, the tip should be cleaned free from slag.

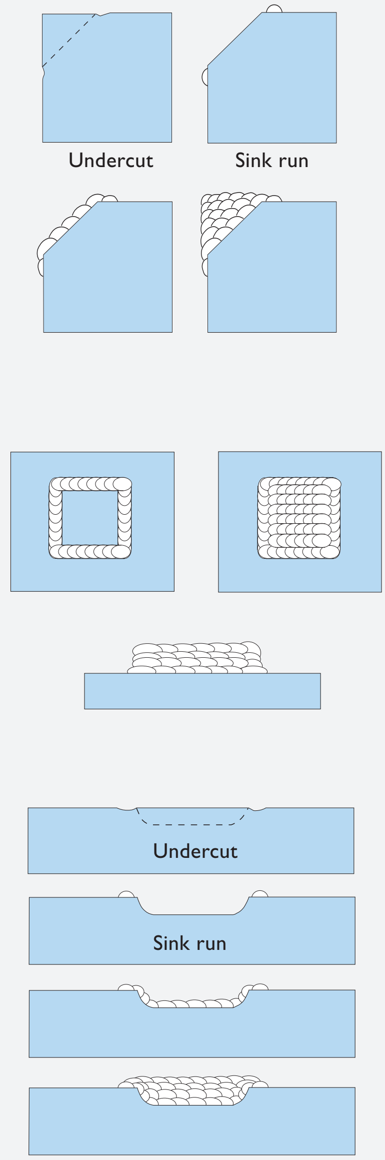
For repair or adjustment of expensive tooling, e.g. plastic mould with a polished or textured cavity, it is essential that there is good contact between the return cable and the tool. Poor contact gives problems with secondary arcing and the expensive surface can be damaged by arcing sores. Such tools should be placed on a copper plate which provides for the best possible contact. The copper plate must be preheated along with the tool.

The completed weld(s) should be carefully cleaned and inspected prior to allowing the tool to cool down. Any defect, such as arcing sores or undercut, should be dealt with immediately.

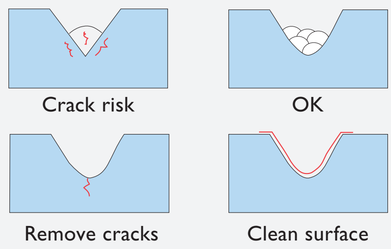
Before the tool has cooled, the surface of the weld should be ground down almost to the level of the surrounding tool before any further processing.

Moulds where welded areas have to be polished or photo-etched should have the final runs made using TIG-welding, which is less likely to give pores or inclusions in the weld metal.

BUILD UP SEQUENCE



GROOVE PREPARATION



Heat treatment after welding

Depending on the initial condition of the tool, the following heat treatments may be performed after welding:

- tempering
- soft annealing, then hardening and tempering as usual
- stress relieving

Tempering

Fully-hardened tools which are repair welded should if possible be tempered after welding.

Tempering improves the toughness of the weld metal and the heat affected zone (HAZ).

The tempering temperature should be chosen so that the hardness of the weld metal and base steel are compatible. An exception to this rule is when the weld metal exhibits appreciably improved temper resistance over the base material (e.g. Uddeholm Orvar Supreme welded with Uddeholm QRO 90 Weld); in this case, the weld should be tempered at the highest possible temperature concomitant with the base steel retaining its hardness (typically 20 °C/ 40 °F under the previous tempering temperature).

Product brochures for Uddeholm welding consumables and tool steel give tempering curves from which the tempering conditions for welded tools can be ascertained.

Very small repairs may not need to be tempered after welding; however, this should be done if at all possible.

Soft annealing

Tools which are welded to accommodate design changes or machining errors during toolmaking, and which are in soft-annealed condition, will need to be heat treated after welding. Since the weld metal and HAZ will have hardened during cooling, it is highly desirable to soft anneal the weld prior to hardening and tempering of the tool. The soft annealing cycle used is that recommended for the base steel. The welded area can then be machined and the tool may be finished and heat treated as usual. However, even if the tool can be finished by merely grinding the weld, soft annealing is first recommended in order to mitigate cracking during heat treatment.

Stress relieving

Stress relieving is sometimes carried out after welding in order to reduce residual stresses. For very large or highly-constrained welds, this is an important precaution. If the weld is to be tempered or soft annealed, then stress relieving is not normally necessary. However, pre-hardened tool steel should be stress relieved after welding since no other heat treatment is normally performed.

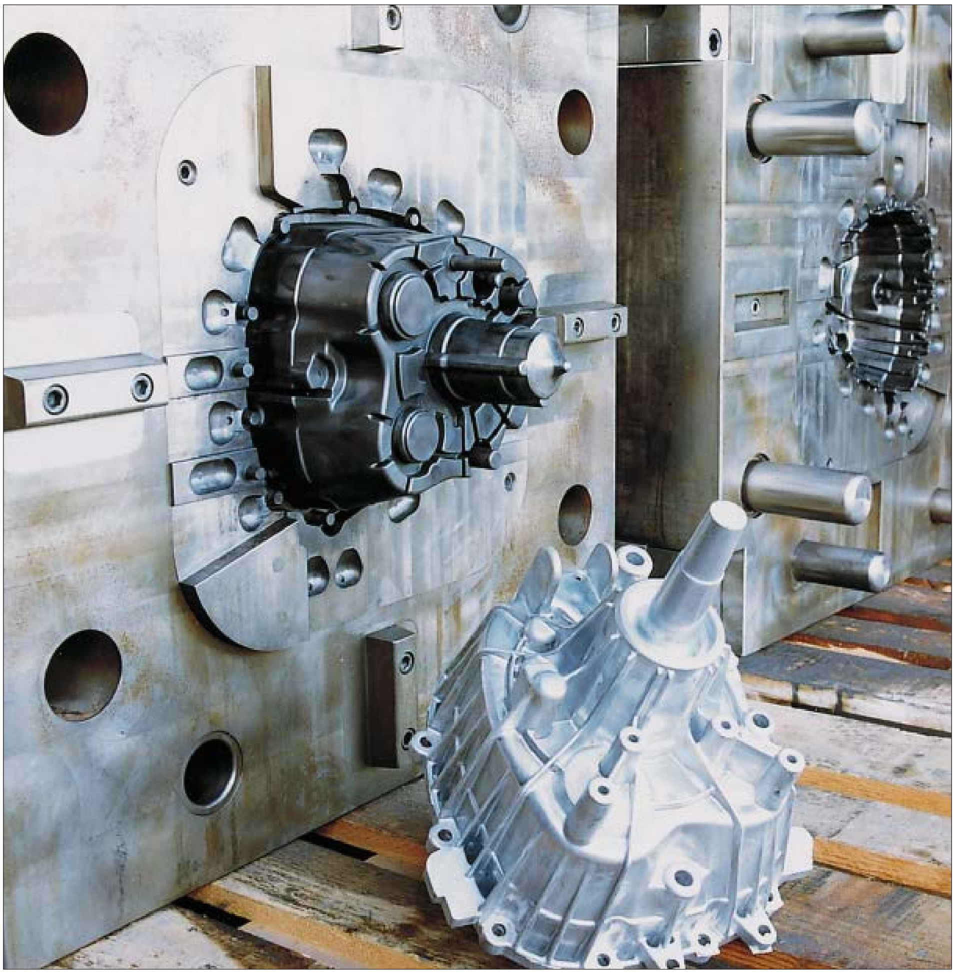
The stress relieving temperature must be chosen such that neither the base steel nor the welded area soften extensively during the operation.

Very small weld repairs or adjustments will normally not require a stress relieving treatment.

Heat treatment of a die-casting die after welding.

Further information

Information concerning heat treatment of the tool subsequent to welding can be obtained from the brochures for the welding consumable and/or the tool steel in question.



Guidelines for welding in Uddeholm tool steel

The tables, on following pages, give details concerning weld repair or adjustment of tooling made from Uddeholm steel grades for hot work, cold work and plastic moulding applications.

WELDING IN HOT WORK TOOL STEEL – MMA (SMAW)

UDDEHOLM STEEL GRADE	CONDITION	WELDING METHOD	CONSUMABLES	PREHEATING TEMPERATURE	HARDNESS AS WELDED	POST TREATMENT	REMARKS
VIDAR SUPERIOR VIDAR 1 VIDAR 1 ESR	Soft annealed Hardened	MMA (SMAW)	QRO 90 WELD UTP 673	Min. 325 °C (620 °F)	48–53 HRC 55–58 HRC	Soft annealing Tempering	
ORVAR SUPREME ORVAR SUPERIOR ORVAR 2 MICRODIZED	Soft annealed Hardened	MMA (SMAW)	QRO 90 WELD UTP 673	Min. 325 °C (620 °F)	48–53 HRC 55–58 HRC	Soft annealing Tempering	
DIEVAR	Soft annealed Hardened	MMA (SMAW)	QRO 90 WELD	Min. 325 °C (620 °F)	48–53 HRC	Soft annealing Tempering	Soft annealing, see product brochure Temper hardened material 10–20 °C (20–40 °F) below last tempering temperature
QRO 90 SUPREME HOTVAR	Soft annealed Hardened	MMA (SMAW)	QRO 90 WELD	325 °C (620 °F)	48–53 HRC	Soft annealing Tempering	
ALVAR ALVAR 14	Prehardened	MMA (SMAW)	UTP 73 G4 ESAB OK 83.28	225–275 °C (430–520 °F)	340–390 HB	None	Stress relieve large repairs

WELDING IN HOT WORK TOOL STEEL – TIG (GTAW)

UDDEHOLM STEEL GRADE	CONDITION	WELDING METHOD	CONSUMABLES	PREHEATING TEMPERATURE	HARDNESS AS WELDED	POST TREATMENT	REMARKS
VIDAR SUPERIOR VIDAR 1 VIDAR 1 ESR	Soft annealed Hardened	TIG (GTAW)	QRO 90 TIG WELD DIEVAR TIG WELD	Min. 325 °C (620 °F)	48–53 HRC	Soft annealing Tempering	
ORVAR SUPREME ORVAR SUPERIOR ORVAR 2 MICRODIZED	Soft annealed Hardned	TIG (GTAW)	QRO 90 TIG WELD DIEVAR TIG WELD	Min. 325 °C (620 °F)	48–53 HRC	Soft annealing Tempering	
		LASER	DIEVAR LASER WELD	None	48–53 HRC	Temper 250 °C (480 °F) 2 h	
DIEVAR	Soft annealed Hardened	TIG (GTAW)	DIEVAR TIG WELD QRO 90 TIG WELD	Min. 325 °C (620 °F)	48–53 HRC	Soft annealing Tempering	Soft annealing, see product brochure Temper hardened material 10–20 °C (20–40 °F) below lasttempering temperature
		LASER	DIEVAR LASER WELD	None	48–53 HRC	Temper 250 °C (480 °F) 2 h	
QRO 90 SUPREME HOTVAR	Soft annealed Hardened	TIG (GTAW)	QRO 90 TIG WELD	325 °C (620 °F)	48–53 HRC	Soft annealing Tempering	
ALVAR ALVAR 14	Prehardened	TIG (GTAW)	UTP A 73 G4 ESAB OK TIG ROD 13.22	225–275 °C (430–520 °F)	340–390 HB	None	Stress relieve large repairs

GUIDELINES FOR WELDING IN COLD WORK TOOL STEEL – MMA (SMAW)

UDDEHOLM STEEL GRADE	CONDITION	WELDING METHOD	CONSUMABLES	PREHEATING TEMPERATURE	HARDNESS AS WELDED	POST TREATMENT	REMARKS
ARNE RIGOR VIKING FERMO*	Hardened Prehardened	MMA (SMAW)	Type AWS E312 ESAB OK 84.52 UTP 67S UTP 73 G2	200–250 °C (390–480 °F)	300 HB 53–54 HRC 55–58 HRC 55–58 HRC	Tempering 10–20 °C (20–40 °F) below last tempering temp.	Initial layers with soft weld metal
CALDIE*	Hardened	MMA (SMAW)	CALDIE WELD	200–250 °C (390–480 °F)	58–62 HRC	Tempering 510 °C (950 °F)	
SLEIPNER	Hardened	MMA (SMAW)	CALDIE WELD UTP 690	250 °C (480 °F)	58–62 HRC 60–64 HRC	Tempering 10–20 °C (20–40 °F) below last tempering temp.	
SVERKER 21 SVERKER 3	Hardened	MMA (SMAW)	Type Inconel 625 UTP 73 G2 UTP 67S UTP 690	250 °C (480 °F)	280 HB 55–58 HRC 55–58 HRC 60–64 HRC	Tempering 10–20 °C (20–40 °F) below last tempering temp.	Initial layers with soft weld metal
CARMO*	Prehardened	MMA (SMAW)	CALMAX/CARMO WELD	200–250 °C (390–480 °F)	58–62 HRC	Tempering	
CALMAX		MMA (SMAW)	See “Welding guidelines for plastic mould steel”				
VANADIS 4 EXTRA**	Hardened	MMA (SMAW)	Type Inconel 625 UTP 73 G2 UTP 690	200 °C (390 °F)	280 HB 55–58 HRC 60–64 HRC	Tempering 200 °C (390 °F) or 505 °C (940 °F) depend-ing on the last used temp. temp.	Initial layers with soft weld metal

* Minor welding operations in Uddeholm Fermo, Uddeholm Caldie and Uddeholm Carmo can be done at ambient temperature.
** Welding in Uddeholm Vanadis 4 Extra SuperClean should generally be avoided due to the risk of cracking.

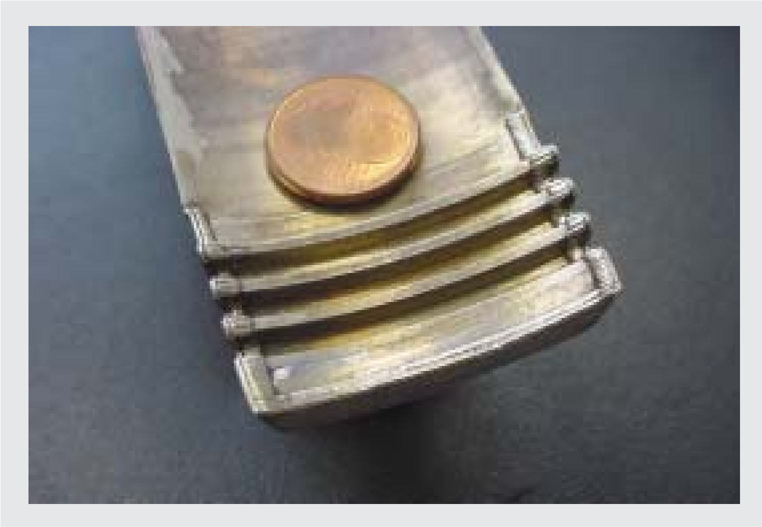
GUIDELINES FOR WELDING IN COLD WORK TOOL STEEL – TIG (GTAW)

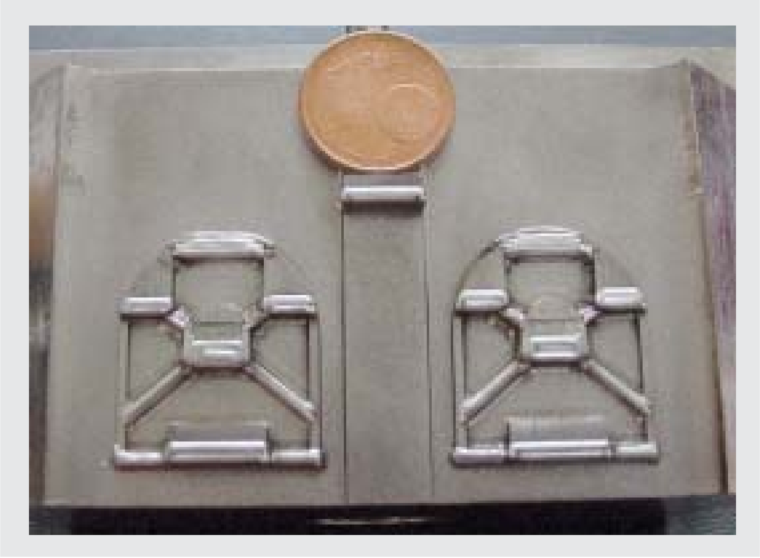
UDDEHOLM STEEL GRADE	CONDITION	WELDING METHOD	CONSUMABLES	PREHEATING TEMPERATURE	HARDNESS AS WELDED	POST TREATMENT	REMARKS
ARNE RIGOR VIKING FERMO*	Hardened Prehardened	TIG (GTAW)	Type AWS ER312 UTP ADUR 600 UTP A 73 G2	200–250 °C (390–480 °F)	300 HB 55–58 HRC 53–56 HRC	Tempering 10–20 °C below last tempering temp.	Initial layers with soft weld metal
CALDIE*	Hardened	TIG (GTAW)	CALDIE TIG-WELD	200–250 °C (390–480 °F)	58–62 HRC	Tempering 510 °C (950 °F)	
SLEIPNER	Hardened	TIG (GTAW)	CALDIE TIG-WELD UTP A 696	250 °C (480 °F)	58–62 HRC 60–64 HRC	Tempering 10–20 °C (20–40 °F) below last tempering temp.	
SVERKER 21 SVERKER 3	Hardened	TIG (GTAW)	Type Inconel 625 UTP A 73 G2 UTP ADUR 600 UTP A 696	250 °C (480 °F)	280 HB 53–56 HRC 55–58 HRC 60–64 HRC	Tempering 10–20 °C (20–40 °F) below last tempering temp.	Initial layers with soft weld metal
CARMO*	Prehardened	TIG (GTAW)	CALMAX/CARMO TIG WELD	200–250 °C (390–480 °F)	58–62 HRC	Tempering	
CALMAX		TIG (GTAW)	See "Welding guidelines for plastic mould steel"				
VANADIS 4 EXTRA**	Hardened	TIG (GTAW)	Type Inconel 625 UTP A 73 G2 UTP 696	200 °C (390 °F)	280 HB 53–56 HRC 60–64 HRC	Tempering 200 °C (390 °F) or 505 °C (940 °F) depend- ing on the last used temp. temp.	Initial layers with soft weld metal

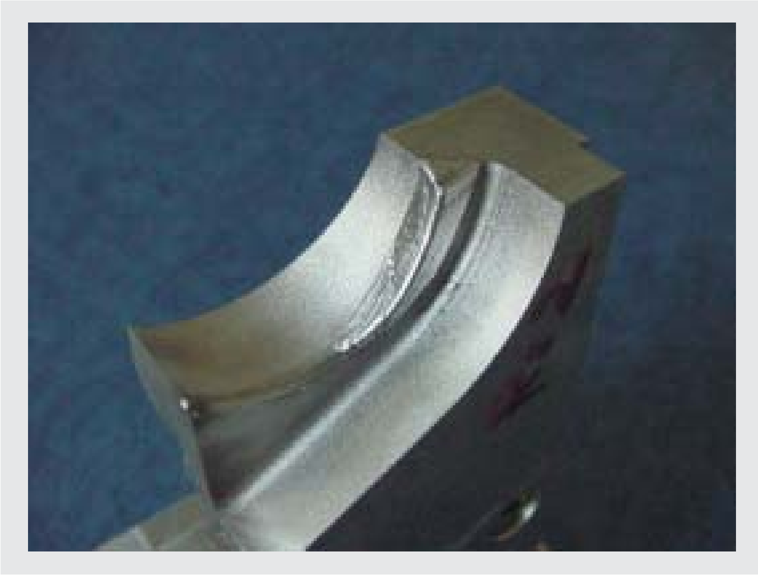
* Minor welding operations in Uddeholm Fermo, Uddeholm Caldie and Uddeholm Carmo can be done at ambient temperature.

** Welding in Uddeholm Vanadis 4 Extra SuperClean should generally be avoided due to the risk of cracking.

EXAMPLE OF LASER WELDS







GUIDELINES FOR WELDING IN PLASTIC MOULD STEEL – TIG (GTAW) AND LASER

UDDEHOLM STEEL GRADE	CONDITION	WELDING METHOD	CONSUMABLES	PREHEATING TEMPERATURE	HARDNESS AS WELDED	POST TREATMENT	REMARKS
STAVAX ESR POLMAX	Soft annealed	TIG (GTAW)	STAVAX TIG-WELD	200–250 °C (390–480 °F)	54–56 HRC	Soft annealing	Heat treatment see product brochure
STAVAX ESR POLMAX	Soft annealed	LASER	STAVAX LASER WELD	None	48–50 HRC	None	Heat treatment see product brochure
STAVAX ESR POLMAX	Hardened	TIG (GTAW)	STAVAX TIG-WELD	200–250 °C (390–480 °F)	54–56 HRC	Tempering 200–250 °C (390–480 °F)	
STAVAX ESR POLMAX	Hardened	LASER	STAVAX LASER WELD	None	48–50 HRC	None	
MIRRAX ESR	Sot annealed	TIG (GTAW)	MIRRAX TIG-WELD STAVAX TIG-WELD	200–250 °C (390–480 °F)	54–56 HRC	Annealing 700-750 °C (1290-1380 °F) 5h	
MIRRAX ESR	Hardened	TIG (GTAW)	MIRRAX TIG-WELD STAVAX TIG-WELD	200–250 °C (390–480 °F)	54–56 HRC	Tempering 10–20 °C (20–40 °F) below last tempering temp.	
MIRRAX 40*	Prehardened	TIG (GTAW)	MIRRAX TIG-WELD	200–250 °C (390–480 °F)	54–56 HRC	Temper 560 °C (1040 °F) 2 h	Weld metal hardness after temp. 38–42 HRC
IMPAX SUPREME*	Prehardened	TIG (GTAW)	IMPAX TIG-WELD	200–250 °C (390–480 °F)	320–350 HB	large repairs 550 °C (1020 °F)	Stress relieve See data sheet for IMPAX TIG-WELD
NIMAX	Prehardened	TIG (GTAW)	NIMAX TIG-WELD	None	360–400 HB	Stress relieve large repairs 550 °C (1020 °F)	
NIMAX	Prehardened	LASER	NIMAX LASER WELD	None	360–400 HB	None	
UNIMAX	Soft annealed	TIG (GTAW)	UNIMAX TIG-WELD UTP A 73 G2 UTP ADUR 600	200–250 °C (390–480 °F)	54–58 HRC	Soft annealing	Heat treatment see product brochure
UNIMAX	Hardened	TIG (GTAW)	UNIMAX TIG-WELD UTP A 73 G2 UTP ADUR 600	200–250 °C (390–480 °F)	54–60 HRC	Tempering 510 °C (950 °F)	
RAMAX HH*	Prehardened	TIG (GTAW)	Austenitic stainless steel. Type AWS ER312 STAVAX TIG-WELD	200–250 °C (390–480 °F)	28–30 HRC 54–56 HRC	Tempering	Heat treatment see product brochure
CORRAX	Solution treated Aged	TIG (GTAW)	CORRAX TIG-WELD	None	30–35 HRC	Ageing	See data sheet for Corrax TIG-Weld
CALMAX	Soft annealed	TIG (GTAW)	CALMAX/CARMO TIG-WELD	200–250 °C (390–480 °F)	58–61 HRC	Soft annealing	Heat treatment see product brochure
CALMAX	Hardened	TIG (GTAW)	CALMAX/CARMO TIG-WELD	180–250 °C (360–480 °F)	58–61 HRC	Tempering	Heat treatment see product brochure
HOLDAX*	Prehardened	TIG (GTAW)	IMPAX TIG-WELD	150–200 °C (300–390 °F)	320–350 HB	Stress relieve large repairs 550 °C (1020 °F)	
ORVAR SUPREME VIDAR 1 ESR	Soft annealed	TIG (GTAW)	DIEVAR TIG WELD UTP A673	Min. 325 °C (620 °F)	48–53 HRC	Soft annealing	Soft annealing, see product brochure
ORVAR SUPREME VIDAR 1 ESR	Hardned	TIG (GTAW)	DIEVAR TIG WELD UTP A673	Min. 325 °C (620 °F)	57–60 HRC	Tempering	Temper hardened material 10–20 °C (20–40 °F) below last tempering temperature
ORVAR SUPREME VIDAR 1 ESR	Hardned	LASER	DIEVAR LASER WELD	None	48–53 HRC	Temper 250 °C (480 °F) 2 h	Temper hardened material 10–20 °C (20–40 °F) below last tempering temperature
ELMAX**	Hardened	TIG (GTAW)	UTP A 701	250–300 °C (480–570 °F)	54–57 HRC	Tempering 200 °C (390 °F)	

* Minor welding operations can be done at ambient temperature.

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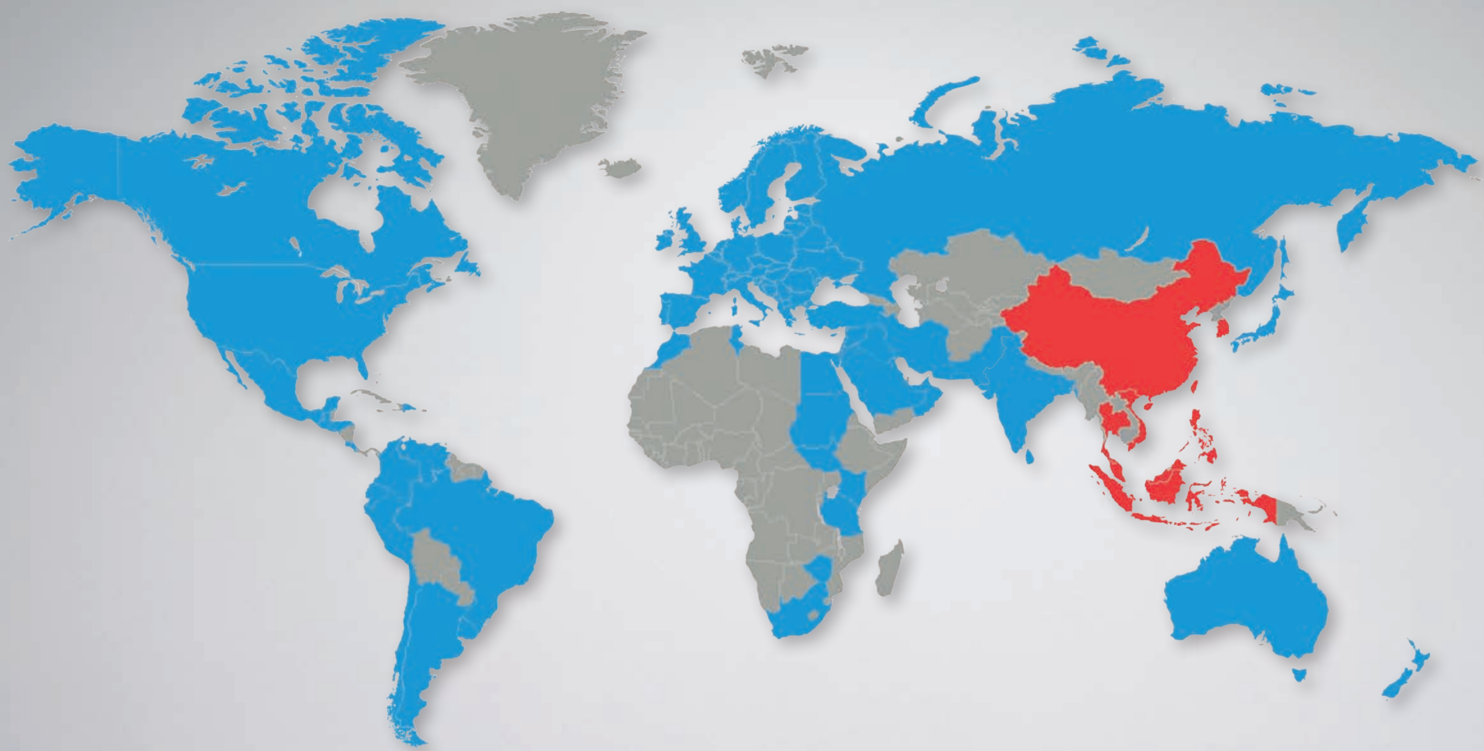

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UDDEHOLM is the world's leading supplier of tooling materials. This is a position we have reached by improving our customers' everyday business. Long tradition combined with research and product development equips Uddeholm to solve any tooling problem that may arise. It is a challenging process, but the goal is clear – to be your number one partner and tool steel provider.

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