



Aluminium mold repair

Overview

- **Best repair technologies according to defect size and location**
- GTAW technologies
 - ✓ Principle
 - ✓ On aluminium products
 - ✓ Welding procedure
 - ✓ Choice of filler wires for GTAW on Alumold 500
 - ✓ Conclusions on technology and filler wire
- Mechanical repair
 - ✓ Principle
 - ✓ Example of repair and effect on injected part
- Laser, HVOF, Arc wire spray
 - ✓ Principles
 - ✓ Example of repair and effect on injected part
- Synthetic table

Best repair technologies according to defect size and situation



■ Defect location and size:

✓ Non-grained visible zone:



■ Possible repair technology:

✓ GTAW DC (with 4145 or 5xxx)

✓ GTAW AC (with 5xxx)

✓ Mechanical repair

✓ Non visible zone:



✓ GTAW AC

✓ GTAW DC

✓ Mechanical repair

✓ Visible grained zone:



✓ Mechanical repair

✓ Small (< 2mm) or surface zone:



✓ GTAW AC or DC

✓ Laser

✓ HVOF

✓ Arc wire spray

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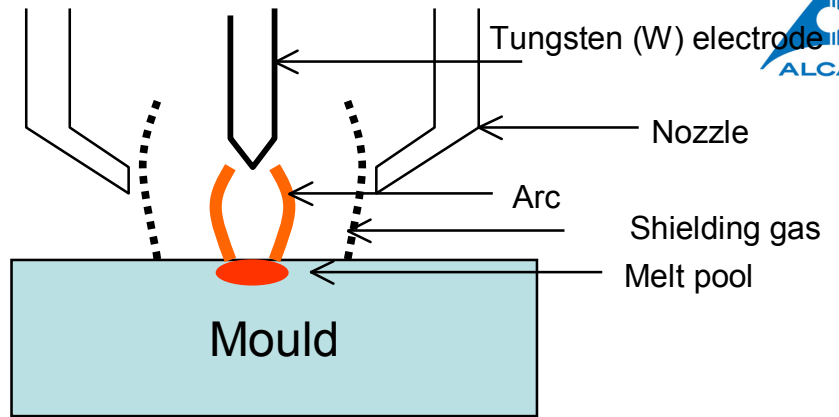
GTAW technology

Principle

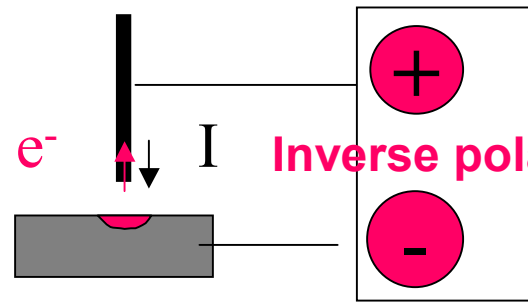
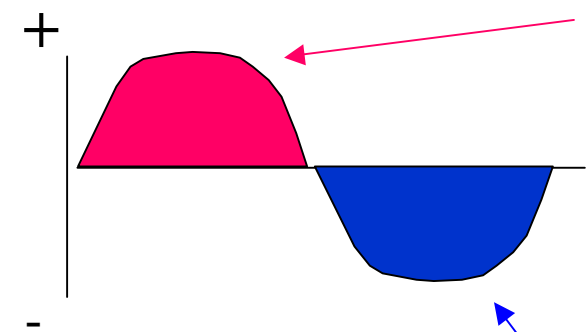
TIG = GTAW (Gas Tungsten Arc Welding)

- GTAW DC (Direct Current) usually used on steel and aluminium
- GTAW AC (Alternative Current) only on aluminium

TIG principle

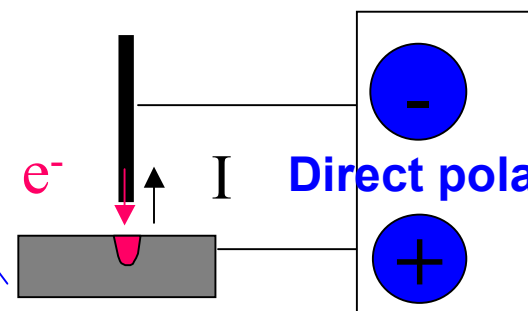


Electrode polarity



Inverse polarity

The part emits electrons.
The electrode is heated.
The melting pool is cooled.
(ex GTAW AC case)



Direct polarity

The electrode emits electrons.
The part is heated.
The penetration is increased.
(ex GTAW DC case)

GTAW technology

On aluminium products



■ Important aluminium welding recommendations:

- ✓ **Mechanical brushing** of mould surface before welding to remove oxides.
- ✓ **No CO₂** as shielding gas
- ✓ **Al welding : “hot” and “fast”** to avoid heat diffusion in the mould: current and speed maximum
- ✓ In case of tungsten deposition in the weld, the contaminated area must be milled and cleaned.

■ DC GTAW:

- ✓ **Difficult to use on Al products:**
arc length < 1mm,
melting pool is very deep
- ✓ **Very effective on Al thick products:** ⇒ **no preheat treatment**

■ AC GTAW:

- ✓ **Easy to use on Al products**
- ✓ **A preheat treatment about 100°C** is required to increase penetration.
T < 100°C to prevent altering the mould mechanical properties.

GTAW technology

Welding procedure (1): surface preparation

■ Surface preparation:

1. *Degreasing of the surface to be welded and the surrounding area:*

- ✓ With an appropriate solvent like Evopred or something equivalent.
Note : chloride solvents are prohibited
- ✓ By wiping the area with a clean lint free.
- ✓ the weld area must be completely dry before welding.

2. *Removing of the oxide layer on the mould :*

- ✓ By wire brushing with a stainless steel wire brush.
- ✓ This brush should only be used on aluminium.

3. *Removing of the oxide layer on the filler wire*



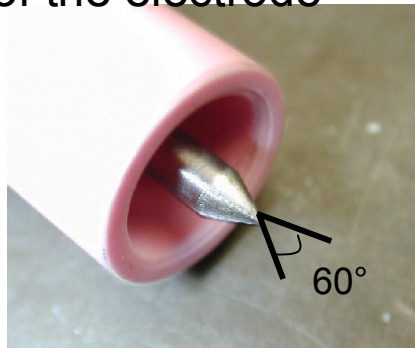
GTAW technology

Welding procedure (2): : indications of welding parameters



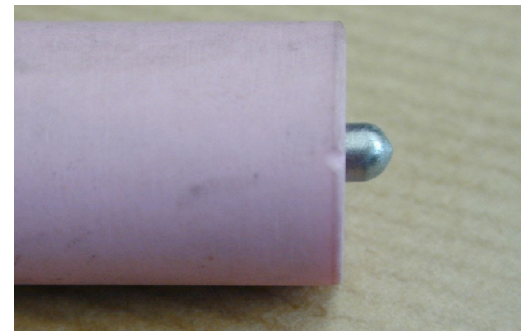
■ DC GTAW parameters:

- ✓ Generator: AC/DC
- ✓ Current: $180 \text{ A} < I < 200 \text{ A}$
- ✓ Voltage: $150 \text{ V} < U < 200 \text{ V}$
- ✓ Electrode diameter : $\geq 4 \text{ mm}$
- ✓ Nozzle internal diameter $\geq 12 \text{ mm}$
- ✓ He shielding gas
- ✓ Gas flow 20 l/min
- ✓ Filler material diameter : $\geq 3.2 \text{ mm}$
- ✓ Arc length: $\leq 1 \text{ mm}$. The melt pool is very deep.
- ✓ Electrode : W+Zr (no more W+Th according to safety rules)
- ✓ Sharpening angle of the electrode about 120°



■ AC GTAW parameters:

- ✓ Generator : AC/DC
- ✓ Current: $200 \text{ A} < I < 250 \text{ A}$
- ✓ Voltage: $180 \text{ V} < U < 240 \text{ V}$
- ✓ Electrode diameter : $\geq 4 \text{ mm}$
- ✓ Nozzle internal diameter $\geq 12 \text{ mm}$
- ✓ Ar 30% He 70% shielding gas
- ✓ Gas flow 20 l/min
- ✓ Filler material diameter : $\geq 3.2 \text{ mm}$
- ✓ Electrode in pure W No electrode sharpening
- ✓ $1 \text{ mm} < \text{Arc length} < 2 \text{ mm}$



GTAW technology

Choice of filler wires on Alumold 500



5356 : 4-5% Mg

- Classical wire
- Good internal quality
- Some surface cracks

SOLUTION: repeat welding and machining until the crack disappears

- Low hardness compared to parent metal
- No colour change / parent metal

4145 : 9-11% Si, 4-5%Cu

- Exotic wire
- **SUPPLIER:** Alcotec
- Good internal quality
- No surface crack
- Same hardness than the parent metal
- Present a colour change, visible on the injected part.

SOLUTION : increase the polishing in GTAW DC

5180/5280: 5%Mg 2%Zn

- Semi exotic wire
- Bad internal quality
- Some surface cracks
- **SOLUTION:** repeat welding and machining until the crack disappears
- Same hardness than the parent metal
- No colour change / parent metal

5356 (TIG DC flat side)



4145 (TIG AC flat side)

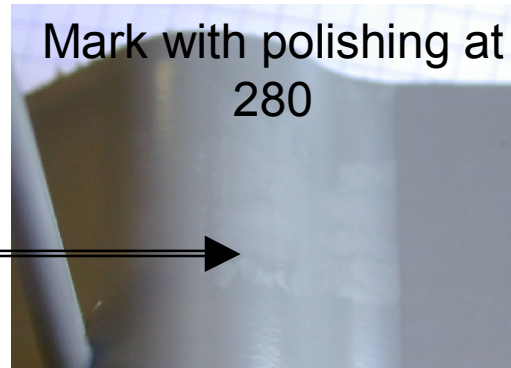
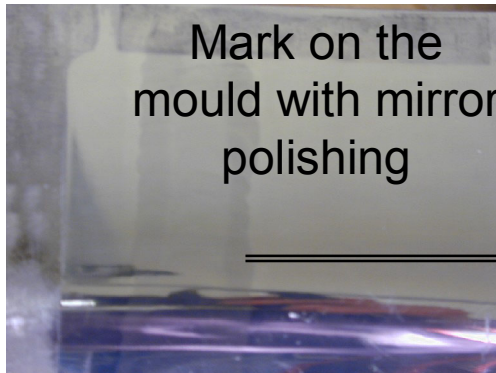


5180 (TIG DC flat side)

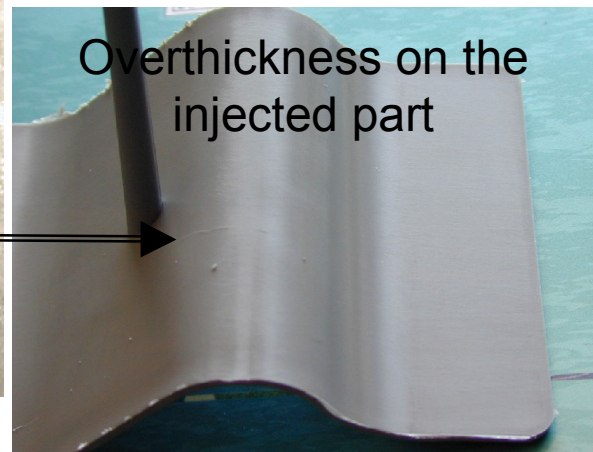
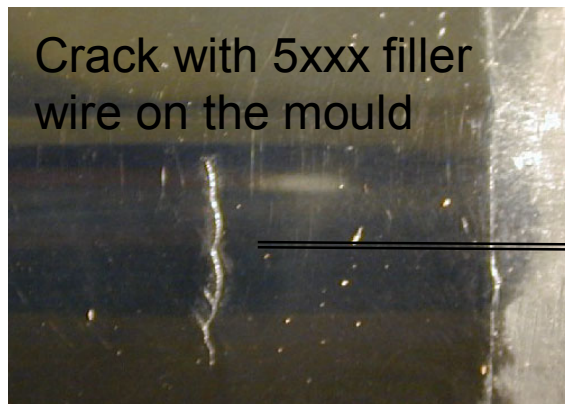


GTAW technology

Choice of filler wires on Alumold 500: solutions



4145 GTAW DC on a non grained surface: the increase of polishing decreases the colour difference on the injected part.



5356 and 5180 GTAW DC and AC on a non grained surface :
Repeat machining and welding until getting a perfect visual aspect.

GTAW technology



Choice of filler wires on ALUMOLD 500 : conclusions

	4145	5356	5180/5280
Weld mechanical properties Gap of microhardness/mould metal	OK	NOK	OK
Surface quality No surface crack = no mark on injected part	OK	Limit	Limit
Surface colour Change of surface colour	Limit	OK	OK
Internal quality Internal cracks	OK	OK	NOK
Easy availability Classical filler wire	Limit	OK	Limit

Conclusions:

- 4145 presents a good compromise of properties for Alumold 500.
- 5xxx (5356 and 5180/5280) could be the second choice.

GTAW technology

Conclusions on this technology

- **Manual and cheep technology**
- **AC GTAW** is easier to use on Aluminium products, but requires a preheat treatment (not more than 100 °C):
 - ✓ **Recommendation** : using with 5xxx filler wire in repeating welding and machining until the surface crack disappears.
- **DC GTAW** is a more complex technical process, but more effective than the previous.
 - ✓ **Recommendations** :
 - using with 5xxx filler wire in repeating welding and machining until the surface crack disappears.
 - using with 4145 filler wire with a sufficient polishing
- **Both GTAW processes must not be used in case of grained surface of the mould.**

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Mechanical repair

Principle

- An insert in the same grade than the aluminium alloy mould part is mechanically assembly on the mould.
- **Mechanical repair by hooping**
 - ✓ The insert is slightly higher than the reparation place.
 - ✓ The insert is cooled (N2 liquid), and the mould is heated.
 - ✓ The insert is machined and grained.
- **Mechanical repair by screwing**
 - ✓ The hole in the mould is threaded
 - ✓ The insert is also threaded
 - ✓ The insert is screwed inside the mould.
 - ✓ The insert is machined and grained.

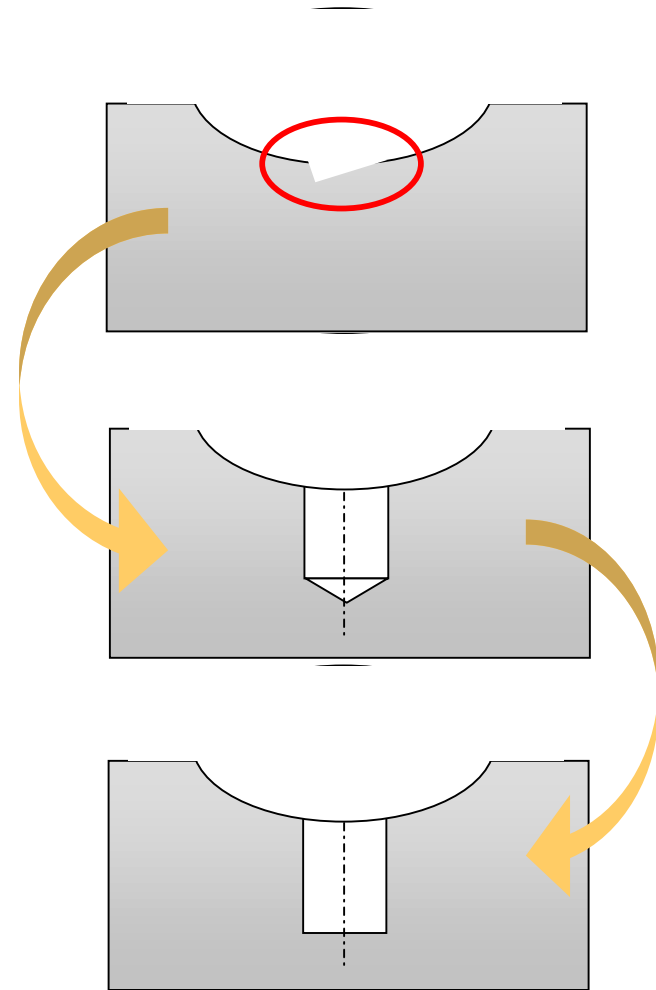
Mechanical repair

By hooping: mould preparation



1. Prepare the mould

- Drill a hole containing the defect
- Finish the hole with flat bottom and ream to obtain a good roughness
 - ✓ Diameter will be function of the size of the defect
 - ✓ Depth should be superior to $1.5 \times$ diameter



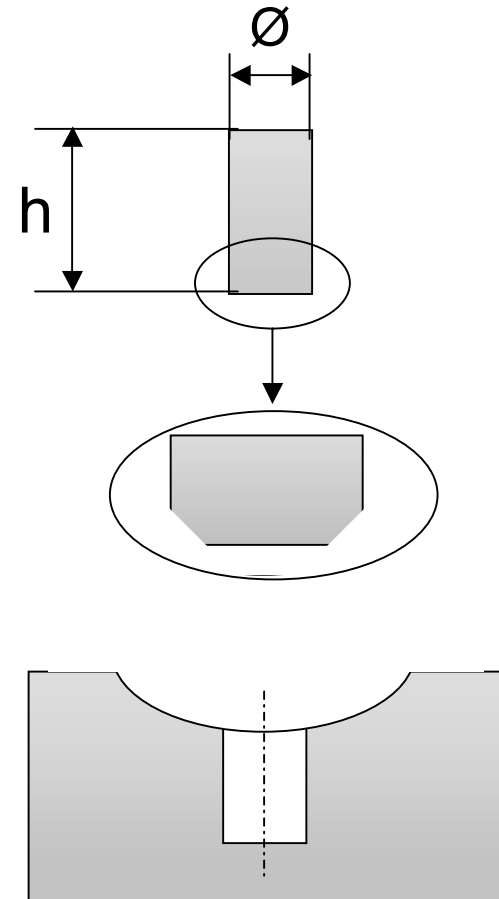
Mechanical repair

By hooping: insert preparation



2. Prepare the insert

- Machine an insert from the same alloy
 - ✓ \varnothing insert = \varnothing hole + 0.02 mm
 - ✓ h insert = h hole + 10 mm
 - ✓ Make a chamfer to facilitate entry



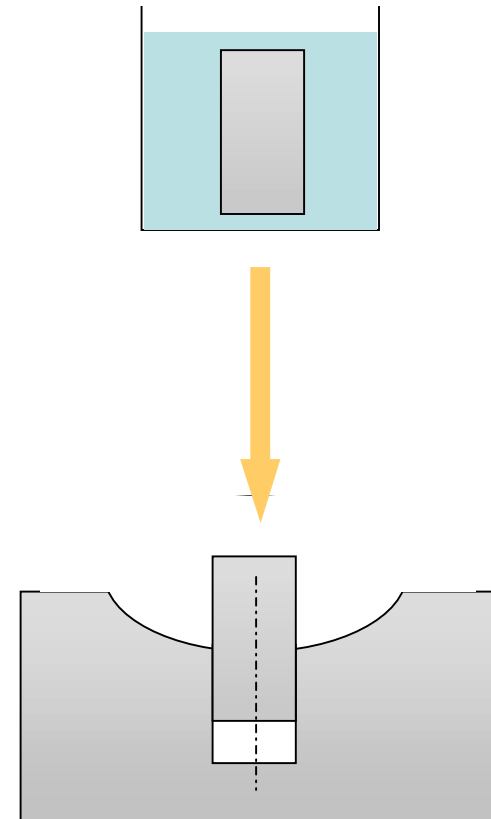
Mechanical repair

By hooping: assembly



3. Assembly

- Best solution : insert must be cooled down in liquid nitrogen (77K / -196°C)
- Alternative: put the insert in a freezer and heat up the hole area with a flame (DO NOT heat too much to prevent from degrading the metal)
- Insert the pin inside the hole and wait the return to ambient temperature



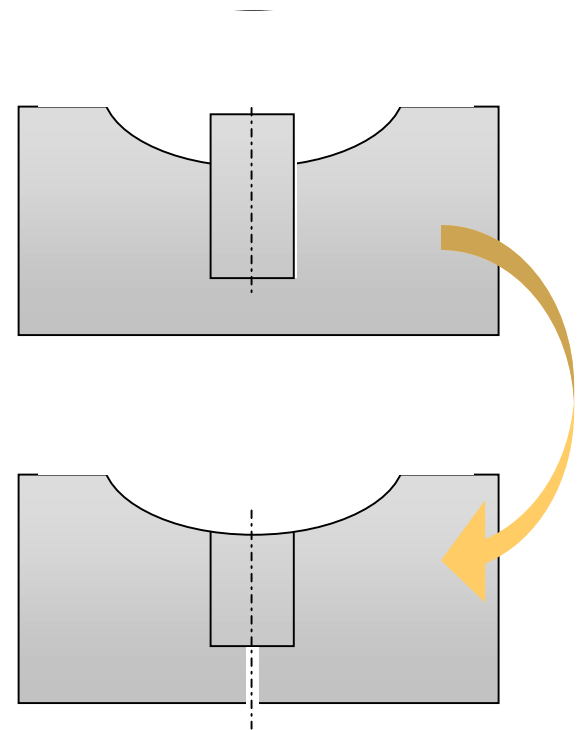
Mechanical repair

By hooping: finishing



4. Finishing

- Mill the insert
- Polish as needed
- Locally chemical etch if required
- When possible, make a venting at the back of the insert (in case of gas pocket)



Mechanical repair

By hooping: complement



More informations

- Coefficient of thermal expansion for Al : $22.3 \sim 23.8 \times 10E-6 / ^\circ C$

✓ *example : $\varnothing_o = 10 \text{ mm}$*

$$\Delta T = \text{abs}(-196 + 20) = 216 ^\circ C \text{ (with liquid nitrogen)}$$

$$\Delta \varnothing = 10 \times (23 \times 10E-6) \times 216 = 0.05 \text{ mm}$$

⇒ *it means a 10mm diameter pin will reduce by 0.05mm*

- **Compared to steel** and its low coefficient of thermal expansion ($12 \times 10E-6 / ^\circ C$), **this solution is particularly adapted to aluminium.**

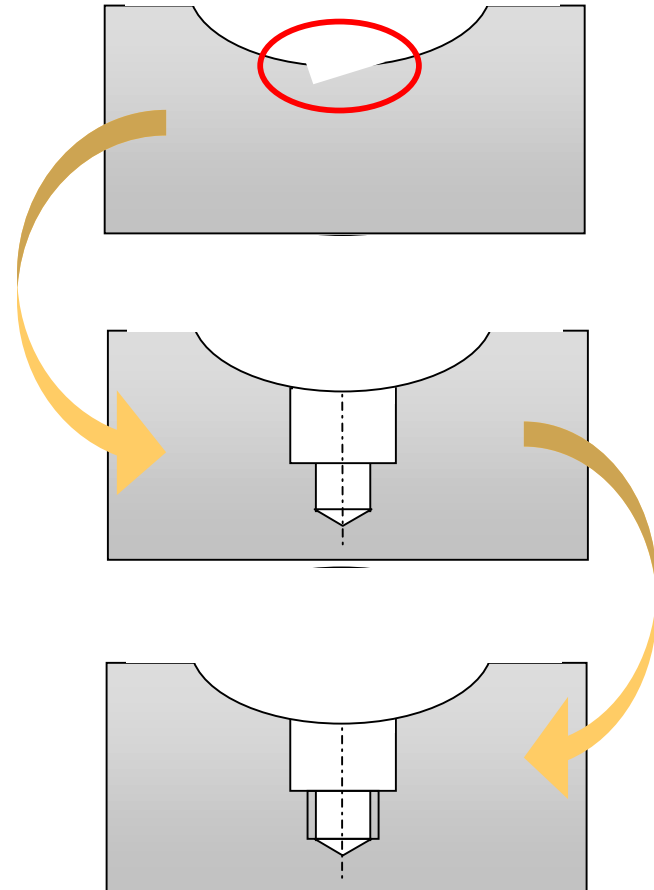
Mechanical repair

By screwing: mould preparation



1. Prepare the mould

- Drill a hole containing the defect
- Ream the hole to obtain a good roughness, and make a thread in the bottom (3-4 threads)
 - ✓ Diameter will be function of the size of the defect
 - ✓ Depth should be superior to $1.5 \times$ diameter



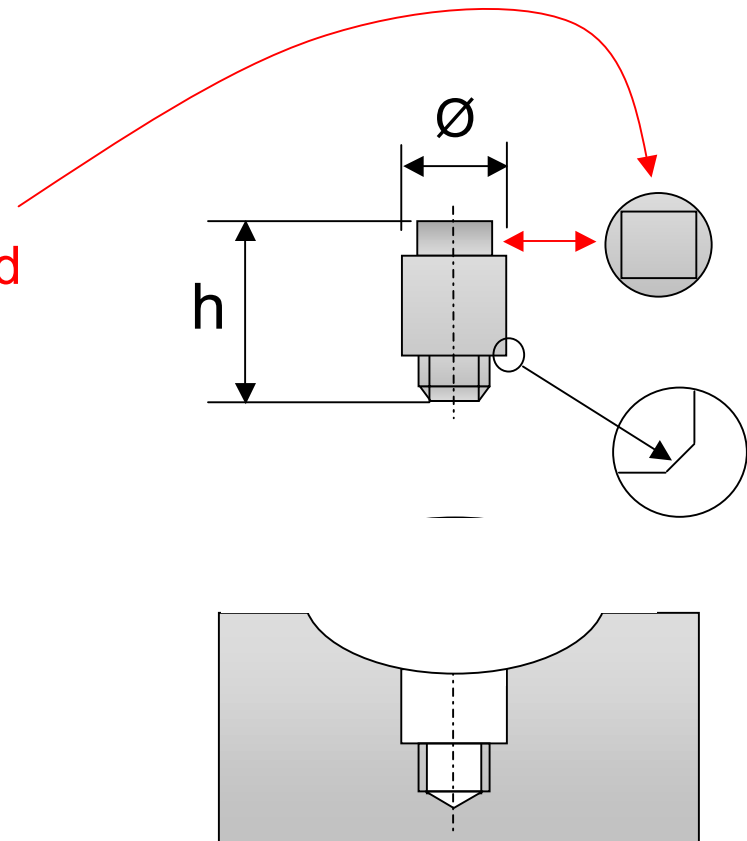
Mechanical repair

By screwing: insert preparation



2. Prepare the insert

- Machine an insert from the same alloy with a **squared head** to screw
 - ✓ \emptyset of the insert **tightened near the surface (slight cone)**
 - ✓ h insert = h hole + 10 mm
 - ✓ **Make a chamfer** to facilitate entry



Mechanical repair

By screwing: assembly and finishing

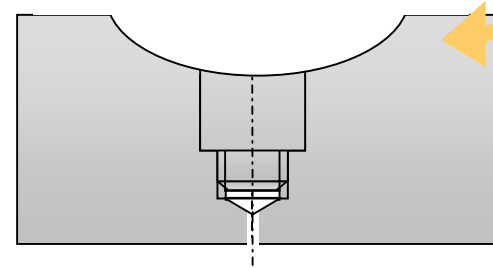
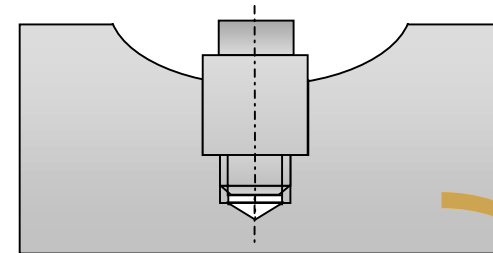
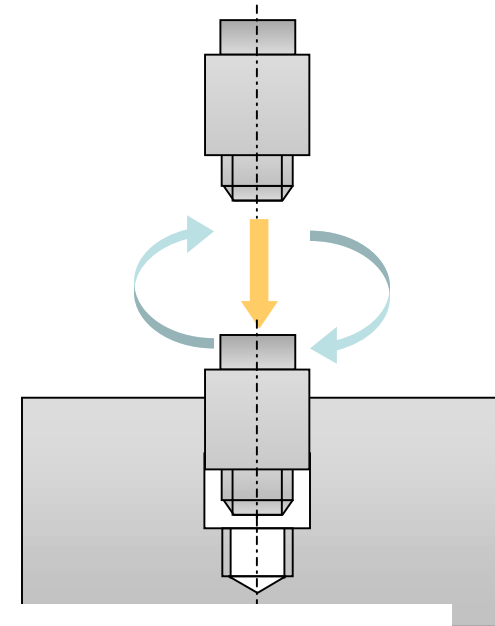


3. Assembly

- Screw the insert inside the hole and tighten

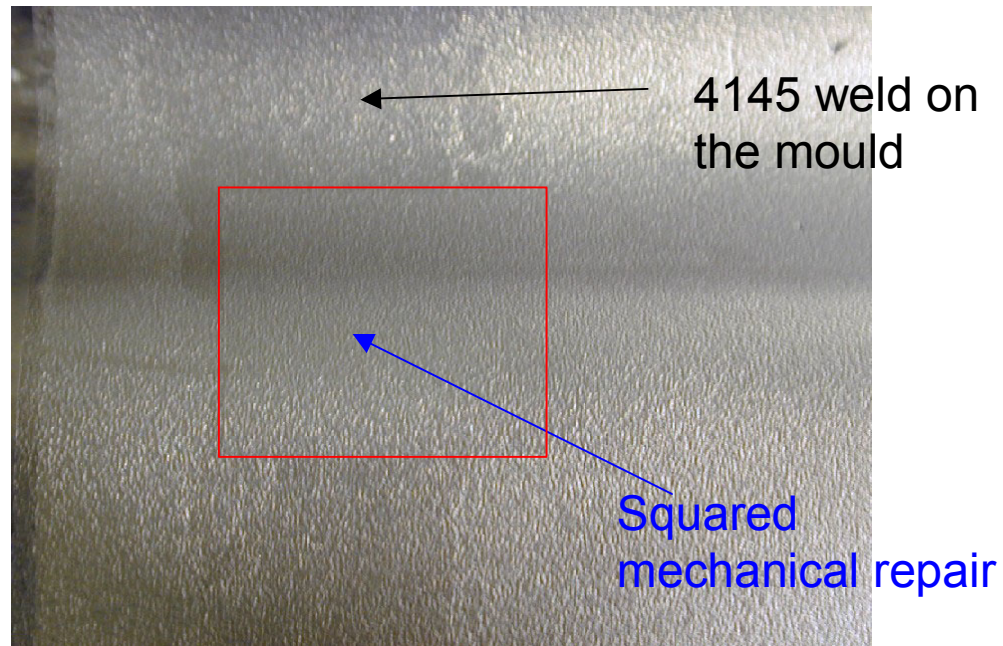
4. Finishing

- Mill the insert
- Polish as needed
- Locally chemical etch if required
- When possible, make a venting at the back of the insert (in case of gas pocket)



Mechanical repair

Example on a grained mould



- The insert is only visible in the weld
- No mark is visible on the injected part

Overview

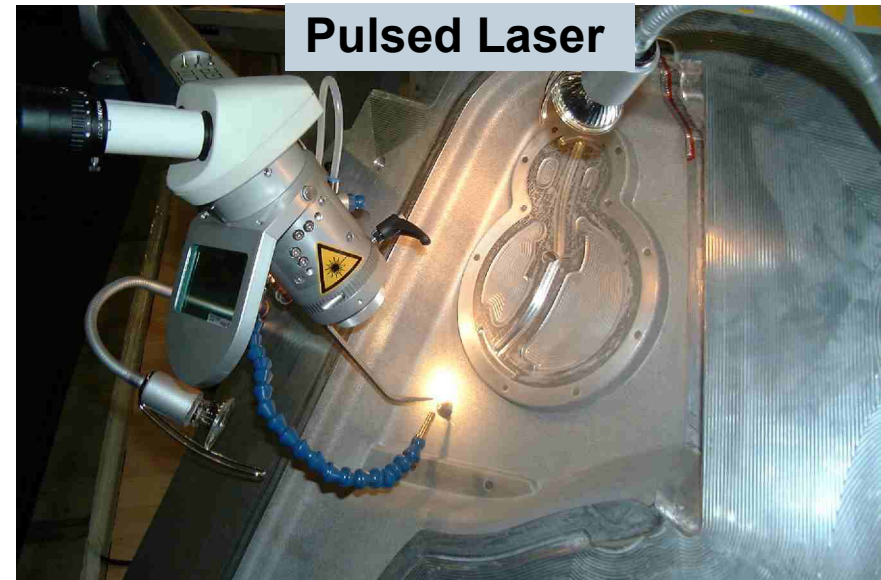
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Laser, HVOF, arc wire spray

Surface repair technologies



- **Pulsed laser:**
 - ✓ Small heat affected zone
 - ✓ Accurated repair
- **HVOF (High Velocity Oxy Fuel):**
 - ✓ Molten metal droplets generated by combustion of O₂, ethen, acetylen, hydrogen, propan.
 - ✓ Throwing down on the mould
- **Arc wire Spray**
 - ✓ Molten metal droplets generated by an electric arc
 - ✓ Throwing down on the mould
- **Do not work for 5 mm defect:**
too high size of defect



HVOF				Arc wire spray			
Gase:	Flammen-temperatur:	Material:	Partikel-geschwindigkeit:	Energie:	Lichtbogen-temperatur:	Material:	Partikel-geschwindigkeit:
Acetylen Ethen Sauerstoff Wasserstoff Propan	max. 3160 °C	alle	bis 550 m/sek.	elektrischer Strom	ca. 4000 °C	nur elektr. leitend.	ca. 150 m/sek.
		Spritzzusatz- werkstoff: Pulver	Auftragsleistung: 4 – 8 kg/h Keramik: 2 – 4 kg/h			Spritzzusatz- werkstoff: Draht	Auftragsleistung: 8 – 20 kg/h

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Conclusions: How can we repair a mould?



- **If it is located in a chemical grained zone:**
 - ✓ Better solution: mechanical repair
- **If it is located in a visible non-grained zone:**
 - ✓ Different solutions:
 - GTAW DC 4145
 - GTAW AC or GTAW DC 5356 in repeating the operation welding/machining until satisfying visual surface aspect
 - Mechanical repair
- **If it is a very small zone:**
 - ✓ GTAW processes
 - ✓ Arc wire spray and HVOF can be convenient
- **If it is a non visible zone:**
 - ✓ The more robust and the easiest solution is GTAW AC 4145 (or 5XXX).

Repair technologies	+	-	Aspect of the injected part without graining	Aspect of the injected part with graining	Conclusions for non grained part	Conclusions for grained part
Arc Wire spray	No effect on base metal properties	Impossible to machine for 10 mm defect size (no metallurgical bonding between weld metal and base metal)	Not tested	Not tested	- Non valid technology for defect of few mm - Interesting process for very small defect? Must be confirmed	- Non valid technology for defect of few mm - Interesting process for very small defect? Must be confirmed
HVOF	No effect on base metal properties	Impossible to machine or 10 mm defect size (no metallurgical bonding between weld metal and base metal)	Not tested	Not tested	- Non valid technology for defect of few mm - Interesting process for very small defect? Must be confirmed	- Non valid technology for defect of few mm - Interesting process for very small defect? Must be confirmed
TIG AC	- Easy to perform - Can be a long operation if we repeat welding + machining	- Requires preheating at roughly 100°C - Loss of base metal mechanical properties due to preheating	- 5XXX: few overthicknesses on the part due to small cracks on the mould - 4145: visible under thickness along the weld on the part	Marks on the injected part	- 5XXX can be used with repeat welding+machining to delete cracks - With 4145 can appear a difference of colour on the injected part	Non valid technology for grained part: all the filler materials present marks on the part
TIG DC	- Requires trained welder (very short distance between weld pool and electrode 1mm) - Lower deposition rate, which can improve the surface quality	- Loss of base metal mechanical properties due to high heat input	- 4145 induces no visible mark with polishing more than 320. - 5XXX: few overthicknesses on the part due to small cracks on the mould	Marks on the injected part	- 5XXX can be used with repeat welding+machining to delete cracks - 4145 can be used with sufficient polishing (>320)	Non valid technology for grained part: all the filler materials present marks on the part
Mechanical repair	- Good bonding between insert and mould	- Loss of base metal mechanical properties due to heating of the mould - Requires new metal	Not tested	No marks on the injected part	Can be used	Can be used

Non OK
Limit
OK