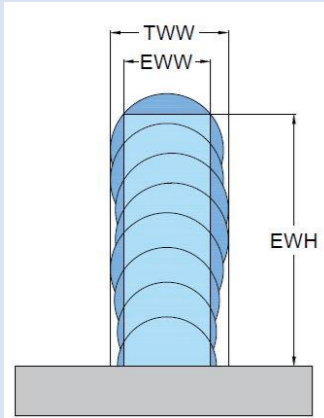


1. Allowance for machining

Effective Wall Width (EWW)



- Depends on WAAM parameters
- Shape errors are much higher than roughness

Roughing step:

- Allowance to remove per side (EWW): 0.7-1.8 mm
- Allowance for faces (EWH): 3-5 mm

Impact of deformations

• Thin-walled

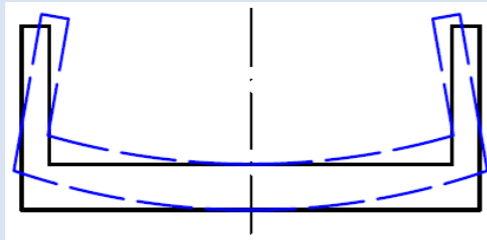
Extra allowance to compensate deformations:

- 1.3 ... 2 mm per side for outer surfaces
- 0.2 ... 0.5 mm per side for inner surfaces

• Solid components

WAAM parameters during deposition matter:

- Low TS -> EWW is not effected
- High TS -> EWW reduces on $\approx 7-8\%$



Rule of thumb

- Allowance for machining: 0.7-1.8 mm per side + extra allowance to compensate deformations of the substrate plate
- Implement roughing step in 2-3 passes
- Allowance for finishing can be calculated by taking surface quality after roughing step $Ra\ 0.8-1.5\ \mu m$

2. PWHT (Post Welded Heat Treatment)

- **Stress relief to avoid:**
 - Deformation
 - corrosion (i.e. stress corrosion cracking stainless steel)
 - brittle fracture (i.e. steel at low temperature)
 - Fatigue cracking (i.e. for welds in compression)
- **Annealing** for material homogenization (i.e. duplex)

Rule of thumb "stress relief carbon steel"

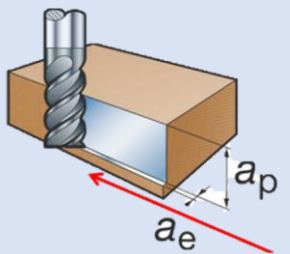
- Temperature: $\pm 580-620^\circ C$
- Heating rate: maximum $280^\circ C/hour$
- Holding time: $\pm 1\ hour/inch$ ($\approx 2,4\ min/mm$) with a minimum of 30 minutes and a maximum of 2 hours
- Cooling rate: maximum $220^\circ C/hour$

3. Clamping & alignment

- **Be aware of:** positioning and alignment accuracy is low due to:
 - Deformations
 - Significant waviness**NO reference surfaces**
- 1st step – prepare reference surfaces:
 - Pre-machining
 - 3D scanning of the clamped part
 - Soft jaws
- Alignment:
 - Using 3D scanned component. Use pre-machined surfaces or jig for alignment
 - Manual using wavy WAAM surfaces \rightarrow bigger allowance is required to compensate the positioning and alignment errors

4. Cutting parameters

- **Roughing:**
 - Limit a_p up to 3mm for thin walled parts
 - Reduce the amount of roughing passes to the minimal \rightarrow remove the inconsistent surface area as fast as possible
 - Cutting velocity: Middle of the manufacturer recommendation
 - Federate: highest value recommended by the tool manufacturer \rightarrow big chips
- **Finishing:**
 - Cutting velocity: Middle of the manufacturer recommendation
 - Feed rate: chose the value in the lower range of recommendation by the tool manufacturer \rightarrow surface quality improves
 - Provide sufficient a_e value $\geq 0.3mm$ \rightarrow stable chips formation



Take into account

- Hardness and tensile properties of the WAAM material are higher than of the usual steel. Take it into account during selection of cutting parameters
- Cutting velocity should be high enough to avoid built up edge (BUE) formation
- Dry cutting is preferable during roughing of low-carbon steel with carbide tools \rightarrow increases tool life