

# INSIDE Metal Additive Manufacturing

## Wire selection for WAAM: Quality insights

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# Raw wire materials

Wire supplier: Currently welding filler wires are mostly used, specific WAAM wires will probably become more and more available

- ⌘ Specially developed WAAM DED wires
  - ⌘ Optimized to prevent wire fracture during WAAM
  - ⌘ Optimized for obtaining homogeneous deposit
  - ⌘ **Limited offer**
  
- ⌘ Standard welding wires
  - ⌘ Large offer of steels, standard catalogue is available

# AM wire standardization

- ⌘ DED additive manufacturing wire for high-value manufacturing
  - ⌘ EB & LB based DED processes (EBAM, WLAM)
  - ⌘ Arc based DED processes (WAAM i.e. GMAW, GTAW, PAW)
- ⌘ Material aspects
  - ⌘ composition
  - ⌘ dimensions and tolerances
  - ⌘ cast/helix
  - ⌘ surface condition & internal condition
- ⌘ Marking & Packaging
- ⌘ Materials handling & Storage
- ⌘ Testing methods
- *Wire suppliers/developers/manufacturers*
- *DED machine developers/manufacturers & DED (component) users*

# AM wire standardization

## ⌘ Composition

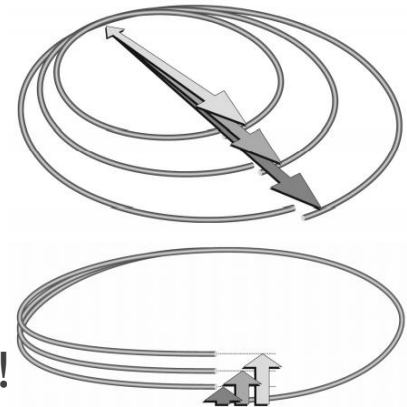
- ⌘ homogeneous throughout the length & core element distribution
- ⌘ appropriate analytical technique cfr. established/published methods
- ⌘ *permissible levels to be agreed manufacturer/supplier & customer ?*

## ⌘ Dimensions & tolerances

- ⌘ copy of welding wire (solid & cored) e.g. solid  $\varnothing 1.2\text{mm}$   $-0.04/+0.01\text{mm}$
- ⌘ dimensions/tolerances of spools, drums, ...

## ⌘ Cast & helix

- ⌘ deposition of material is not adversely affected
- ⌘ suitable for uniform uninterrupted feeding
- ⌘ welding (EN ISO 544), HQ wire suppliers do a lot better!

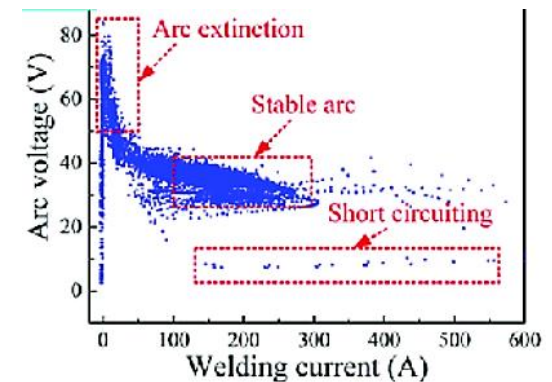
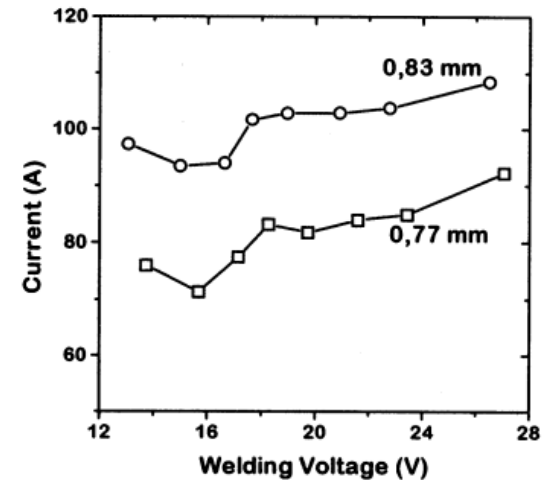


# AM wire standardization

- ⌘ Surface & internal condition
  - ⌘ free from contamination and surface defects w. potential adverse affect
  - ⌘ free of internal defects (porosity/ $\mu$ -impurities) w. potential adverse affect
  - ⌘ suitable for uniform uninterrupted feeding
- ⌘ Marking & packaging
  - ⌘ durably marked on the spool etc., on outside of each smallest package ...
  - ⌘ ID traceable to unique manufacturer/supplier/product (name, batch ...)
  - ⌘ when transported, handled, dry stored etc. assured sufficient safeguard against damage, contamination, deterioration
- ⌘ Testing methods (cfr known welding consumables & materials testing)
  - ⌘ representative samples (deposit based on agreed process parameters...)

# AM wire standardization

- ⌘ “WAAM” processing not taken into account
  - ⌘ are welding conditions representative enough
  - ⌘ influence of wire diameter tolerance on A/V e.g. GMAW source
    - ⌘ what about different contact tubes (e.g. standard vs clamshells e.g. Fronius “Contec”) & wear/tear
    - ⌘ optimized composition for multi-pass welding (less silicates cfr. arc start & inclusion ...)
- ⌘ A/V cyclogram approach (result driven testing)
  - ⌘ define acceptable variation for ≠ arc processes
  - ⌘ define acceptable variation for ≠ wires/materials



# Some available steel wire materials

## Traditional welding wire

- Diameters : 0.6-1.6 mm
- Cost : 5-25 €/kg

Name	DIN	Type	C	Si	Mn	Cr	Ni	Mo	N	V	Nb+Ta	Other
S355	1.1108	Low alloyed	0.1	0.3	1.05							
S460	1.5513	Low alloyed										
S500			0.1	0.65	1.4		1.35					
s620			0.1	0.65	1.55		1.10	0.40				
S700			0.08	0.60	1.7	0.2	1.5	0.5				
S800												
304L	1.4306	Aust stainless	0.02	0.2-0.75	1.6	18.20	10					Cu 10
316L	1.4404	Aust stainless	0.015	0.45	1.6	16.5	12	2.6	0.04			
P22			0.08	0.5	1	2.5		1	0.04			
17-4PH (GP1)	1.4542	Martensitic Stainless	0,02	0.35	0.45	16.3	4.5	0.4	0.25			Cu 3.3
15-5PH (PH1)	1.4540	Martensitic Stainless	0,04	0.65	0.7	15,2	4.5	0.4				Cu 3.2
410		Ferritic stainless	0.01	0.65	0.7	12.2	4.6	0.5				
430		Ferritic stainless	0.07	0.8	0.7	17.5						

Info Böhler

# Some available steel wire materials

Suppliers specific WAAM wire - e.g. Voestalpine Böhler Welding

Product Name	C	Si	Mn	Cr	Mo	Ni	Rp0,2	Rm	A5	
<b>Böhler 3Dprint AM50</b>	0,10	0,65	1,40	<0,05	<0,05	1,35	>500 MPa	560 - 720 MPa	>18%	low alloyed steel
<b>Böhler 3Dprint AM62</b>	0,10	0,55	1,60	0,25	0,50	0,95	>620 MPa	700 - 890 MPa	>18%	medium alloyed steel
<b>Böhler 3Dprint AM70</b>	0,08	0,60	1,70	0,20	0,50	1,50	>690 MPa	770 - 940 MPa	>17%	medium alloyed steel

Product Name	C	Si	Mn	Cr	Mo	Ni	N	
<b>Böhler 3Dprint AM2209</b>	0,025	0,5	1,6	23	3	9	0,14	duplex steel (no heat treatment)
<b>Böhler 3Dprint AM2205</b>	0,025	0,5	1,5	22	3	5	0,15	duplex steel (with solution annealing heat treatment)

Product Name	C	Si	Mn	Cr	Mo	Ni	Cu	
<b>Böhler 3Dprint AM304L</b>	0,02	0,5	1,7	20		10		standard low carbon austenitic stainless steel
<b>Böhler 3Dprint AM316L</b>	0,02	0,5	1,7	18,5	2,6	12,3		standard low carbon austenitic stainless steel with Molybdenum
<b>Böhler 3Dprint AM174PH</b>	0,03	0,4	0,5	16,5		4,5	3,3	martensitic precipitation-hardening stainless steel
<b>Böhler 3Dprint AM155PH</b>	0,02	0,5	0,5	14,8		4,5	3,3	martensitic precipitation-hardening stainless steel - free of ferrite (aerospace grade)
<b>Böhler 3Dprint AM410NiMo</b>	0,03	0,8	0,7	13	0,5	4,7		martensitic stainless steel
<b>Böhler 3Dprint AM430</b>	0,02	0,5	0,5	18				ferritic stainless steel