



Introduction

This Presentation will discuss the effects of obsolescence at Stanlow oil refinery and how new technology in the form of additive manufacturing can help combat this issue.

Stanlow Oil refinery began operations in 1949 refining crude oil to produce final products to the northwest of England.

Some of the Products supplied include;

- Petrol
- Diesel
- Kerosene (Jet Fuel) direct to Liverpool and Manchester airport.

The site was operated by Shell Oil up until 2010 where it was sold to Essar Oil UK



Introduction

The Oil Refinery assets are aging, and many Original Equipment Manufacturers no longer offer effective support due to lack of spares availability or discontinued operations of the OEM's

Currently Spare parts are sourced from OEM where available and reverse engineered by a third party where spare components are not supported.

Due to the increasing costs and lead times parts are beginning to be produced on site with new CNC machinery that has been introduced in a recent project.



Introduction

During this presentation, the following topics will be discussed

- What is Additive Manufacturing?
- What types of Additive Manufacturing exist?
- What machines are available for Additive Manufacturing in industry?
- How is this applied to an Oil and Gas Application?
- What standards are used in Oil and Gas for Additive Manufacturing?
- What testing was completed to validate the printed materials?
- What are the results of the testing?
- Summary.

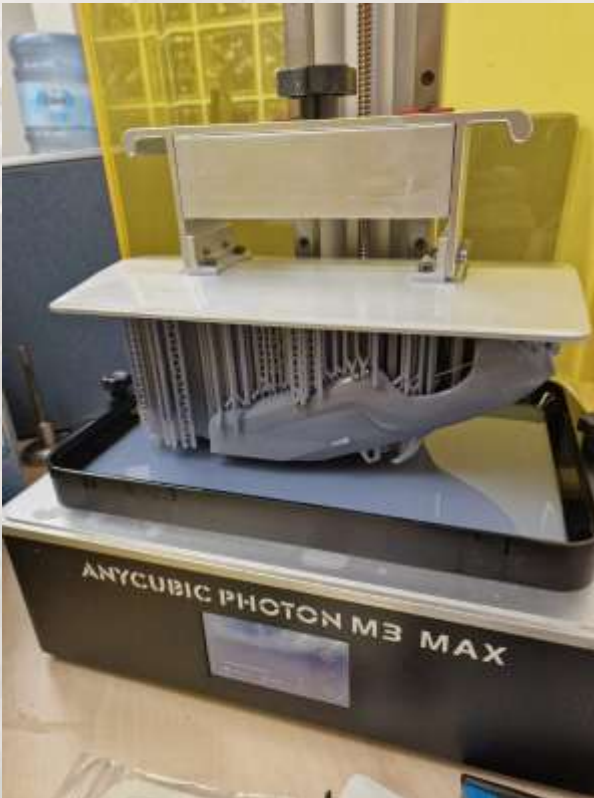
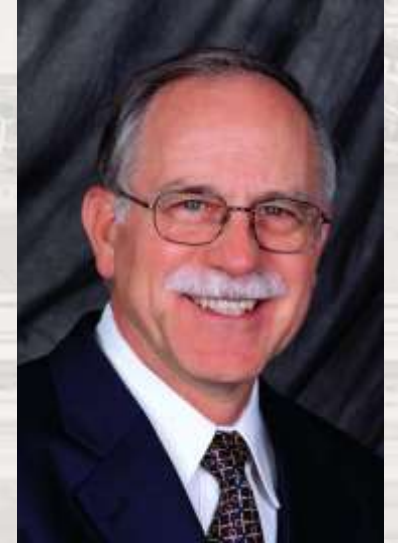


Introduction

Conceived in 1984 by Chuck Hull (right) Additive Manufacturing is a technology of producing a part layer by layer initially using UV Curing Resins known as Stereolithography (SLA) shown below in this 3D Printer as discussed

by Gibson et al, (2020)

Many options are available for utilizing this technology to navigate obsolescence within the refinery and enable on site production of parts, specifically items that cannot be produced by means other than casting such as the items below.



Additive Manufacturing

The Term Additive manufacturing Encompasses all forms of producing parts with the addition of material, in a layer-by-layer format from polymers to metals.

This comes in many forms and utilizing many materials

The main Metal Additive manufacturing being either Powder Bed or Direct Energy deposition utilizing wire or powder feed



Basic principles, materials, advantages, disadvantages, typical build volumes and tool manufacturer of seven ASTM categories of AM: binder jetting (BJ); directed energy deposition (DED); material extrusion (ME); (4) material jetting (MJ); powder bed fusion (PBF); sheet lamination (SL); and vat photopolymerization (VP). Build volumes are rounded to nearest number for convenience. Materials types have been ranked in order of suitability and common use.

ASTM category	Basic principle	Example technology	Advantages	Disadvantages	Materials	Build volume (mm × mm × mm)	Tool manufacturer/country
BJ	Liquid binder/s jet printed onto thin layers of powder. The part is built up layer by layer by glueing the particles together.	• 3D inkjet technology.	<ul style="list-style-type: none"> Free of support/substrate Design freedom Large build volume High print speed Relatively low cost 	<ul style="list-style-type: none"> Fragile parts with limited mechanical properties May require post processing 	<ul style="list-style-type: none"> Polymers Ceramics Composites Metals Hybrid 	Versatile (small to large) X = <4000 Y = <2000 Z = <1000	ExOne, USA PolyPico, Ireland
DED	Focused thermal energy melts materials during deposition	<ul style="list-style-type: none"> Laser deposition (LD) Laser Engineered NetShaping (LENS) Electron beam Plasma arc melting 	<ul style="list-style-type: none"> High degree control of grain structure High quality parts Excellent for repair applications 	<ul style="list-style-type: none"> Surface quality and speed requires a balance Limited to metals/metal based hybrids. 	<ul style="list-style-type: none"> Metals Hybrid 	Versatile X = 600-3000 Y = 500-3500 Z = 350-5000	Optomec, USA InssTek, USA Sciaky, USA Irepa Laser, France Trumpf, Germany
ME	Material is selectively pushed out through a nozzle or orifice	<ul style="list-style-type: none"> Fused Deposition Modelling (FDM)/Fused Filament Fabrication (FFF) Fused Layer Modelling (FLM) 	<ul style="list-style-type: none"> Widespread use Inexpensive Scalable Can build fully functional parts 	<ul style="list-style-type: none"> Vertical anisotropy Step-structured surface Not amenable to fine details 	<ul style="list-style-type: none"> Polymers Composites 	Small to medium X = <900 Y = <600 Z = <900	Stratasys, USA
MJ	Droplets of build materials are deposited	<ul style="list-style-type: none"> 3D inkjet technology Direct ink writing 	<ul style="list-style-type: none"> High accuracy of droplet deposition Low waste Multiple material parts Multicolour 	<ul style="list-style-type: none"> Support material is often required Mainly photopolymers and thermoset resins can be used 	<ul style="list-style-type: none"> Polymers Ceramics Composites Hybrid Biologicals 	Small X = <300 Y = <200 Z = <200	Stratasys, USA 3D Systems, USA PolyPico, Ireland 3Dinks, USA WASP, Italy
PBF	Thermal energy fuses a small region of the powder bed of the build material	<ul style="list-style-type: none"> Electron beam melting (EBM) Direct Metal Laser Sintering (DMLS) Selective Laser Sintering/Melting (SLS/SLM) 	<ul style="list-style-type: none"> Relatively inexpensive Small footprint Powder bed acts as an integrated support structure Large range of material options 	<ul style="list-style-type: none"> Relatively slow Lack of structural integrity Size limitations High power required Finish depends on precursor powder size 	<ul style="list-style-type: none"> Metals Ceramics Polymers Composites Hybrid 	Small X = 200-300 Y = 200-300 Z = 200-350	ARCAM, Sweden; EOS, Germany; Concept Laser Cusing, Germany; MTT, Germany; Phoenix System Group, France; Renishaw, UK;Realizer, Germany; Matsushita, Japan; Voxeljet, 3Dsystems, USA
SL	Sheets/foils of materials are bonded.	<ul style="list-style-type: none"> Laminated Object Manufacturing (LOM) Ultrasound consolidation/Ultrasound Additive Manufacturing (UC/UAM) 	<ul style="list-style-type: none"> High speed, Low cost, Ease of material handling 	<ul style="list-style-type: none"> Strength and integrity of parts depend on adhesive used Finishes may require post processing Limited material use 	<ul style="list-style-type: none"> Polymers Metals Ceramics Hybrids 	Small X = 150-250 Y = 200 Z = 100-150	3D systems, USA MCor, Ireland
VP	Liquid polymer in a vat is light-cured	<ul style="list-style-type: none"> Stereo Lithography (SLA) Digital Light Processing (DLP) 	<ul style="list-style-type: none"> Large parts Excellent accuracy Excellent surface finish and details 	<ul style="list-style-type: none"> Limited to photopolymers only Low shelf life, poor mechanical properties of photopolymers Expensive precursors/Slow build process 	<ul style="list-style-type: none"> Polymers Ceramics 	Medium X < 2100 Y < 700 Z < 800	Lithoz, Austria 3D Ceram, France

Additive Manufacturing for traditionally cast components

The Cost of machine varies depending on technology, the cost of powder machines is significantly higher than wire, the feedstock is more expensive, there are fewer material options, and the production time is higher than with wire.

Wire Laser Metal Deposition (Wire DED)

Meltio Robot Cell - £315,000

Wire Cost Kg - £10 (Inconel 600)



Selective Laser Melting (Powder Bed SLM)

Base price - £4m+

Powder Cost Kg - £80 (Inconel £600)



Powder Laser Metal Deposition (Powder DED)

Base Price - £2m+

Powder Cost Kg - £80 (Inconel 600)



Additive Manufacturing for traditionally cast components

Wire Laser Metal Deposition (Wire DED)

Pros	Cons
Wire Material Cheap – 8x cheaper than Powder	Print Quality not as good as SLM
Build Size Not Restricted	
No Airbourne Particles	
Quicker material Change Time (Can Print 2 at once)	
Material readily available	
Fastest Print time	
Able to repair parts and re-clad	



Selective Laser Melting (Powder Bed SLM)

Pros	Cons
Best Print Quality	Material More expensive than Wire
Large but limited build Size	Airbourne Particles
	Slow Material Change Time up to 1 Day
	Additional Material Handling facility required
	Slowest Print time (4 times slower than Wire)
	Limited Build Size
	Not able to repair Parts



Powder Laser Metal Deposition (Powder DED)

Pros	Cons
Good Print Quality	Material More expensive than Wire
Able to repair Parts	Airbourne Particles
Includes 5 Axis Milling Machine	Slow Material Change Time 2-4 hours
Large but Limited Part Size	Additional Material Handling facility required
	Slow Print time (2 times slower than wire)
	Limited Build Size




Method and Methodology

Following a review of the available technologies Laser Wire Direct energy Deposition will be further explored for the solution of manufacturing components to combat obsolescence.

The Majority of equipment at Stanlow is constructed using Cast Iron and Cast Steel (A216 WCB). To produce parts that will supersede these materials the best available wire filament is ER70S-6

Samples of the Material will be printed in two directions

- Z Axis – to test the Laye- to-Layer bonding
- 90° to the Z axis



Meltio Material Datasheet

Meltio Mild Steel ER70-S

ER70S-6 / S 42 4 M21 3Si1 / AWS A5.18

ER70-S, also known as low alloy carbon steel or mild steel, is a highly versatile material due to its strength, ductility, and low cost. It is used in many applications, including construction, automotive and manufacturing. Its excellent weldability and machinability make it easy to work with, while its high ductility and toughness make it suitable for structural applications.

General Properties

Wire Diameter	Weight on Spool	Spool Type	Wire Coating	Melting Point	Wire Density	Recom. Build plate	Drive Wheels	Insertion ³
1.0 mm	15 kg	B5300	Uncoated	1425 -1485 °C	7.8 g/cm ³	304 Steel	1.0 V-Groove	Local

Chemical Composition

Fe	C	Mn	Si	S	P
Bal.	0.07	1.48	0.85	0.02	0.01

Tested Print Profiles

Laser	Profile name	Laser Power [W]	Energy Density [J/mm ²]	Deposition Rate [g/h]	Volume rate [cc/h]	Relative Density [%]	Max Pore/Defect [µm]
976 nm	Verified Density	1100	146.6	196	16.72	99.19	-
450 nm	Rev 38 2025-02-21	1000	99.2	283	26.28	99.63	137 / 250

* Printing profiles available in our official Slicers: **Meltio Horizon** for standalone Printers and **Meltio Space** for Laser Integration K&S.

Structural Properties *

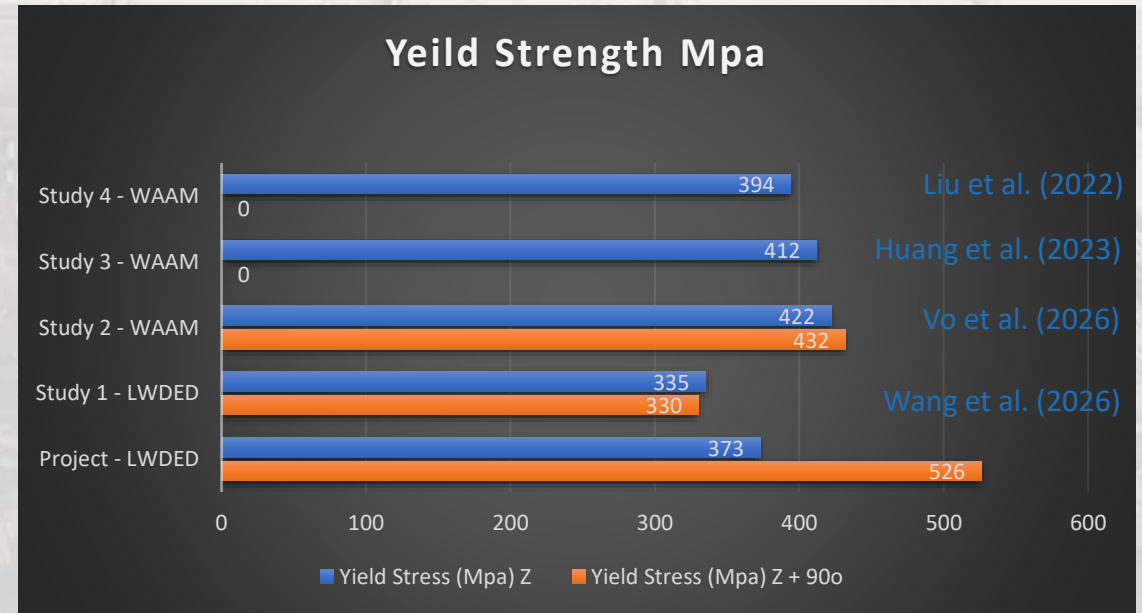
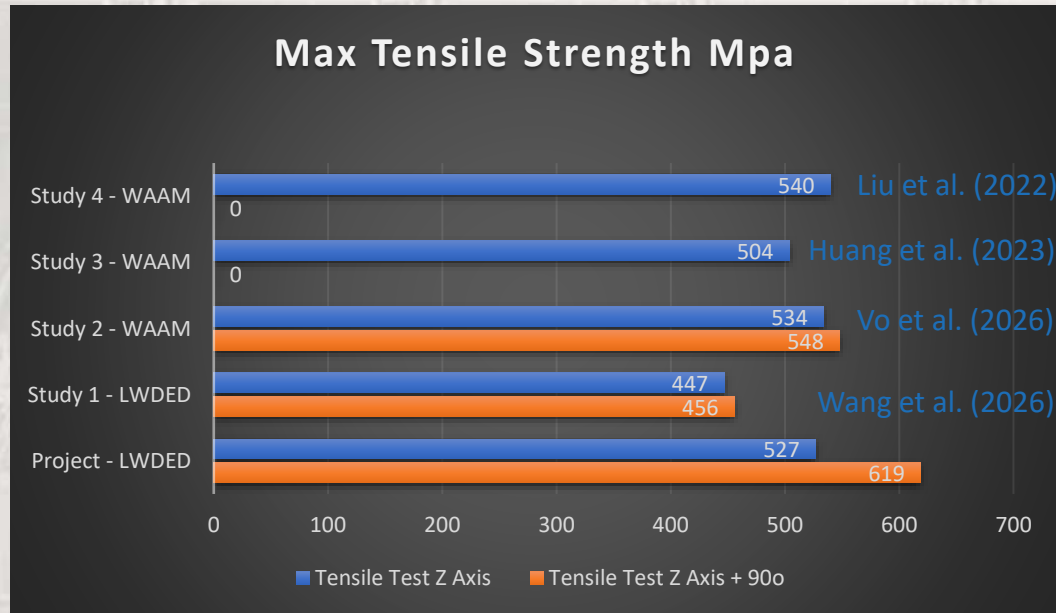
ASTM E883M (UNE EN ISO 6893-1 UNE EN ISO 6507-1)	Wire	Infrared Laser				Blue Laser			
		Heat Treatment		As Printed		Heat Treatment		As Printed	
		XY	XZ	XY	XZ	XY	XZ	XY	XZ
Ultimate Tensile strength [MPa]	565	-	-	590 ± 5	525 ± 12	W/P	W/P	W/P	W/P
Yield strength [MPa]	490	-	-	484 ± 8	462 ± 37	W/P	W/P	W/P	W/P
Elongation [%]	25	-	-	71 ± 1	15 ± 9	W/P	W/P	W/P	W/P
Hardness [HV-30]	-	-	-	-	175	-	-	-	136

Reference Standards

	Chemig (ASTM A584)	Wright (ASTM A.8)
Ultimate Tensile strength [MPa]	565	550
Yield strength [MPa]	205	250
Elongation [%]	24	23
Hardness [HV-30]	160	127

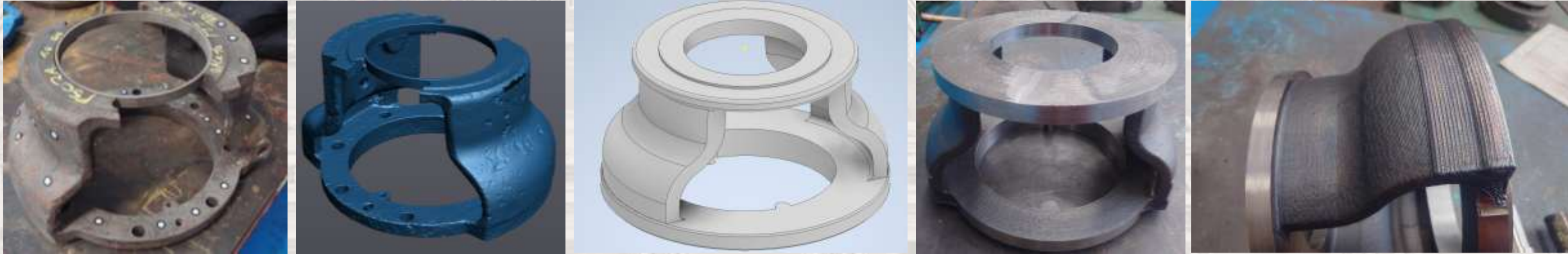
Literature review

Few Studies exist showing the performance of the ER70S-6 Mild Steel Wire Filament, none compare their performance to existing material processing. Below are 4 of the closest matching studies and their performance to this project.



Additive Manufacturing for traditionally cast components

Trial part from P502 using the Wire DED Meltio Robot Cell



The Original Cast Part that requires Reverse Engineering → 3D Laser Scan of Part to enable CAD Model to be made → CAD Model with allowance for machining to be printed → 3D Printed part Ready to final Machine Cost of Print - £100.92 → Part Final Machined ready to fit to pump

Cost Scenario 1: Gas Installation considering a 50l bottle (GBP £2.94/m³)

Consumable	Quantity	Price	Cost
Material	4.95 kg	5.61 £/kg	£27.75
Shield Gas	18 m ³	2.94 £/m ³	£52.98
Inertization	0 m ³	2.94 £/m ³	£0.00
Electricity	100.00 kWh	0.2 £/kWh	£20.18
Print cost			£100.92

ITT overhauled the Sister Pump and Replaced the same part at a cost of £4784 (8 weeks lead)

We have saved - £4395.08 (including machining and CAD Work)

Additive Manufacturing for traditionally cast components

Samples Have been Printed to destructively test the material to validate the printed material in accordance to the American Petroleum Institute Standard API20S



Charpy Impact Illustration OM Metalab (2026)

Samples Printed to be Machined into test subjects



Sample Tensile, Yield and elongation testing



Charpy Impact testing



Material Microstructure

The results from these test will be compared to forged steel, cast steel and the original cast iron material.



American Petroleum Institute Standard API20S

API20S Is the standard created for Oil and Gas industry to manage the Additive manufacturing process for material validation

Due to the nature of Additive manufacturing the Z axis (Build Direction) is the weakest plane for the 3D Printing Due to the layer to layer bond.

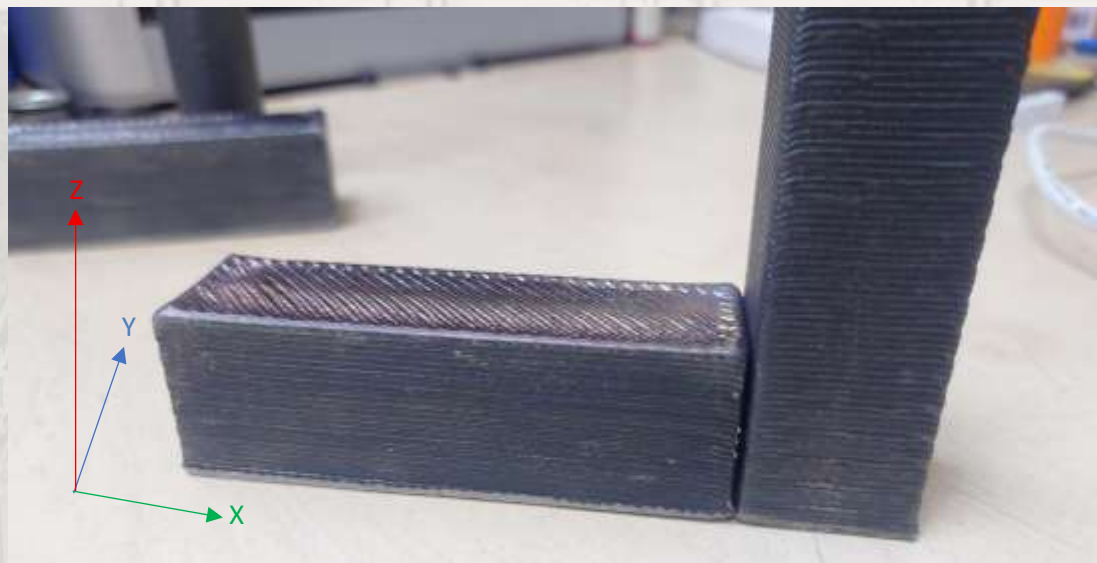


Table 4—Quality Control Requirements—Directed Energy Deposition (Wire)—First Article Inspection

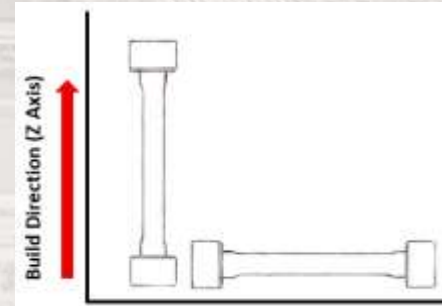
	Parameter	AMSL 1 ^a	AMSL 2 ^b	AMSL 3 ^c
Test specimens	Chemical analysis (see 4.6.4.2)	Feedstock certificate only	Feedstock certificate only	Required
	Tensile testing (see 4.6.4.3)	1 specimen in Z-direction (1 total)	1 specimen in Z-direction (1 total)	3 specimens, orientations by agreement
	Impact testing (see 4.6.4.4)	—	—	1 set in Z-orientation, 1 set 90° degrees from Z
	Hardness testing (see 4.6.4.5)	—	—	Required
	Microstructure analysis (see 4.6.4.6)	—	—	Samples to be taken from the two planes that contain Z-axis and are perpendicular to each other

Tensile Testing Methodology

The tensile testing is completed using the below BS EN specimen drawing

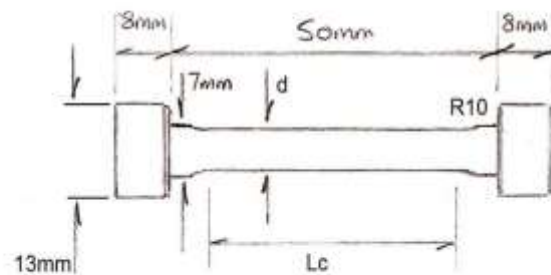
The samples are mounted on each end of the bottle grips and placed into the testing apparatus

The apparatus slowly increase force using the green measuring device to detect yield limits.

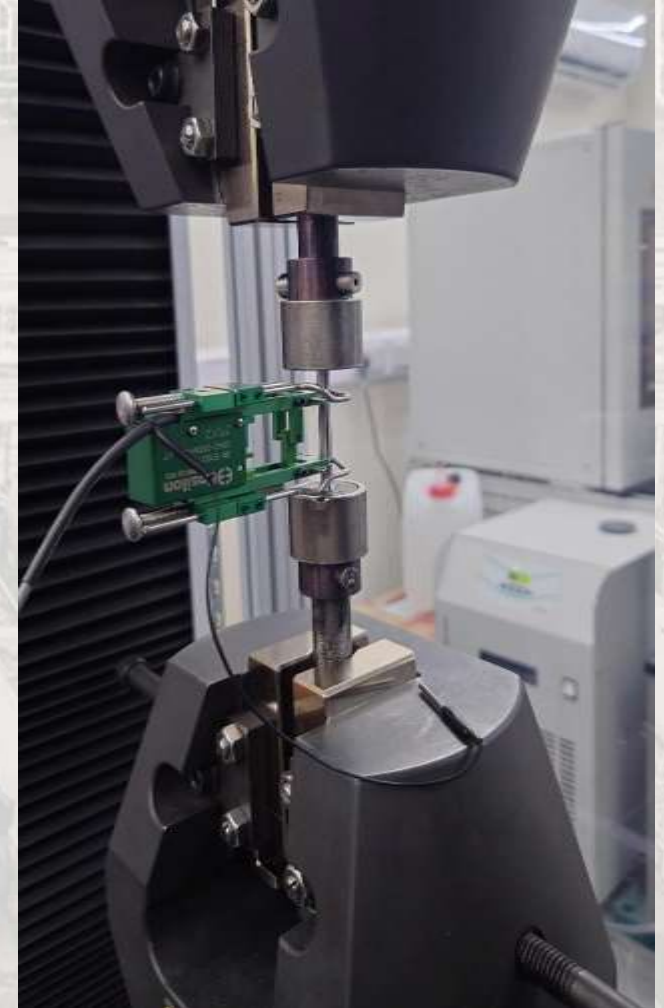


Specification:	BS EN ISO 6892-1:2019	Ref:	Annex D
Details:	Machined test pieces of round cross-section (Small Specimen)		

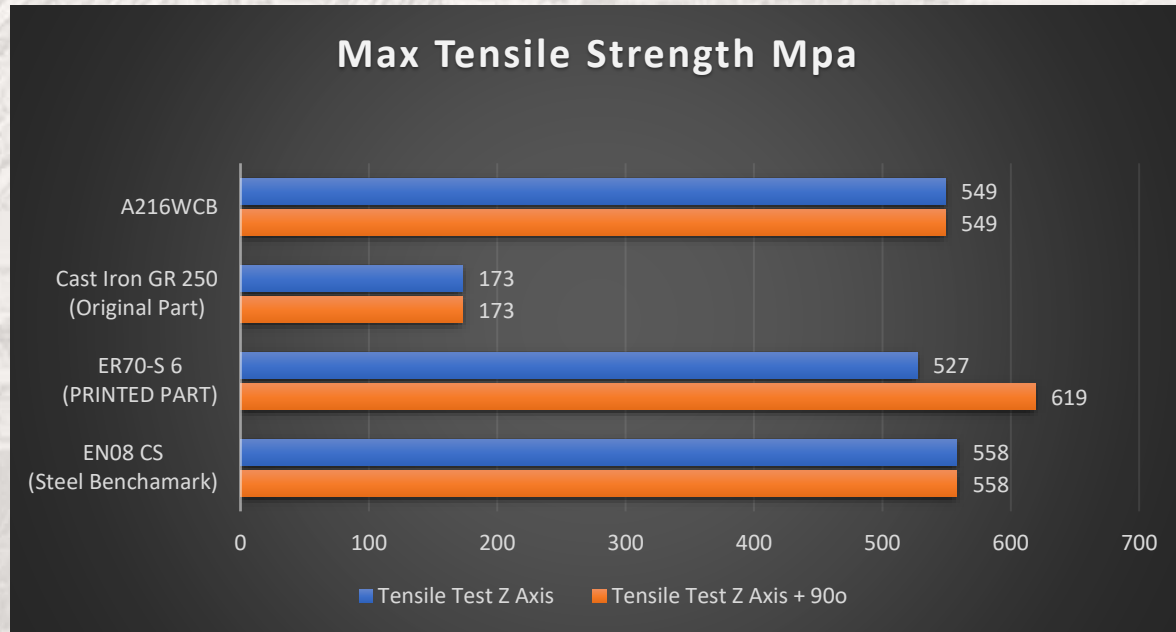
Example sketch



Mini 'Bottle Grips'



Tensile Testing Results

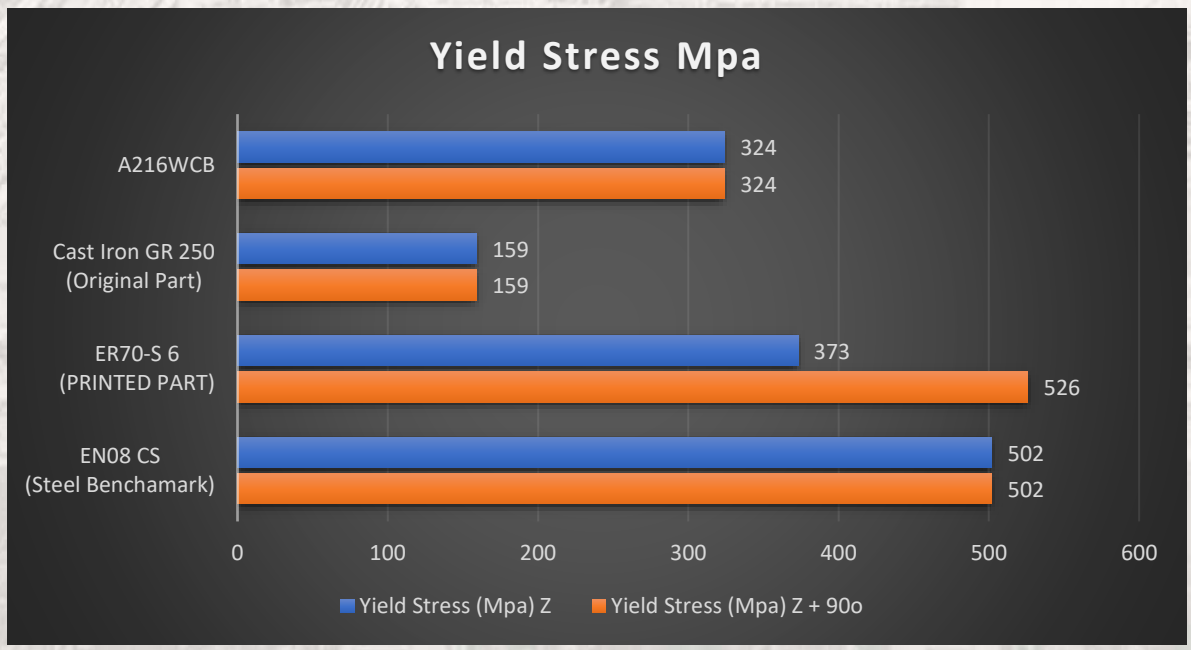


The Performance of the Printed Material is comparable to Forged Steel and Cast Steel depending on Print orientation

The Minimum Tensile Strength Specification for A216 WCB is 485 Mpa



Yield Stress Testing Results



The Performance of the Printed Material is comparable to Forged Steel and Cast Steel depending on Print orientation

The Minimum Yield Strength Specification for A216 WCB is 250 Mpa

ASTM A216 Specifications
TABLE 2 Tensile Requirements

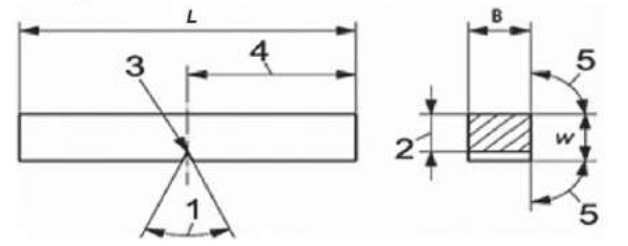
	Grade WCA	Grade WCB	Grade WCC
Tensile strength, ksi [MPa]	60 to 85 [415 to 585]	70 to 95 [485 to 655]	70 to 95 [485 to 655]
Yield strength, ^A min, ksi [MPa]	30 [205]	36 [250]	40 [275]

Impact Testing Methodology

Utilizing Charpy impact testing apparatus each sample is placed in the anvil of the machine, and the pendulum rotates down and records the work done to break the test sample, each sample is produced to the drawing and information below

Designation	Symbol and no.	V-notch test piece		
		Nominal dimension	Machining tolerance	Tolerance class
Length	L	55 mm	± 0.60 mm	± 15
Width	W	10 mm	± 0.075 mm	± 12
Thickness ^a	B	10 mm	± 0.11 mm	± 13
— standard test piece		10 mm	± 0.11 mm	± 13
— subsize test piece		7.5 mm	± 0.11 mm	± 13
— subsize test piece		5 mm	± 0.06 mm	± 12
— subsize test piece		2.5 mm	± 0.05 mm	± 12
Angle of notch	1	45°	$\pm 2°$	—
Ligament	2	8 mm	± 0.075 mm	± 12
Notch radius	3	0.25 mm	± 0.025 mm	—
Notch position (centering)	4	27.5 mm	± 0.42 mm ^d	± 15
Angle between plane of symmetry of notch and longitudinal axis of test piece		90°	$\pm 2°$	—
Angle between adjacent longitudinal faces of test piece	5	90°	$\pm 2°$	—
Surface roughness ^b	NA	<5 μ m		

Example sketch

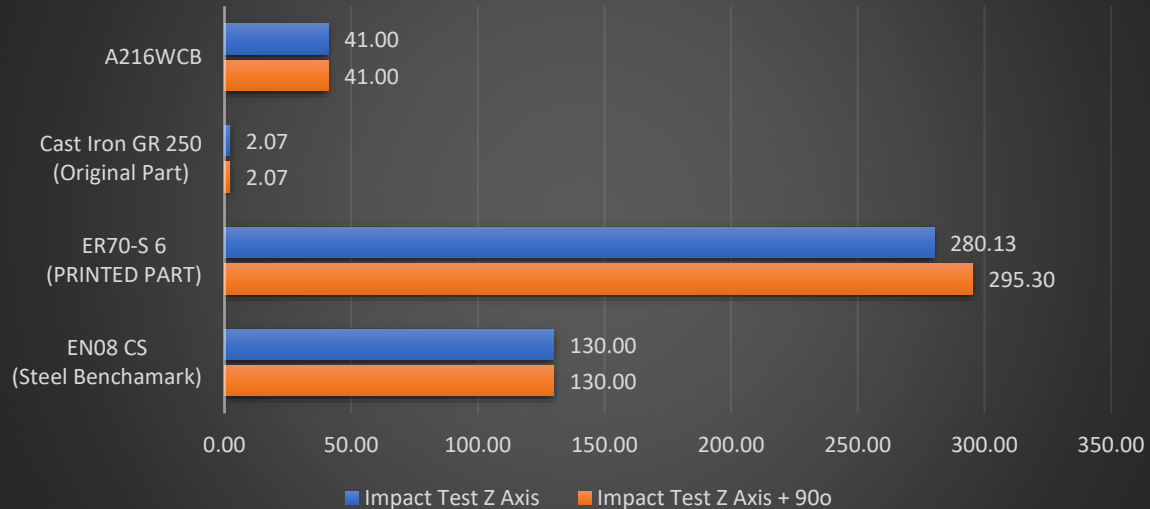


a) V-notch geometry



Impact Testing Results

Impact Testing Joules



The Performance of the
Printed Material is Improved
over Cast Steel and Forged
Steel

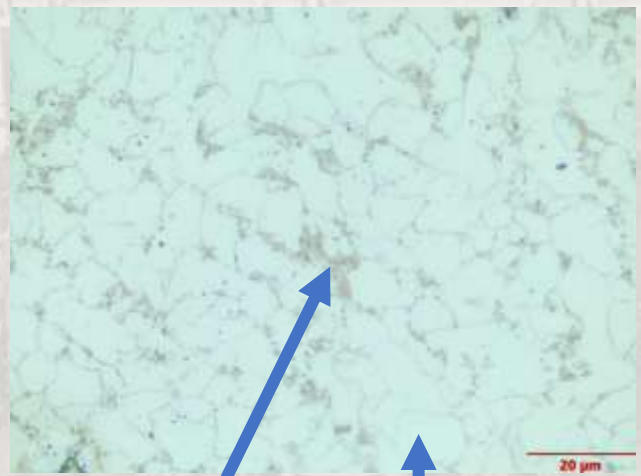


Microstructure analysis

Printed ER70S-6 Microstructure

Small Crystals High strength and ductility low quantities of pearlite structures

Shown by a higher elongation in the tensile test and increase toughness in the Impact Tests

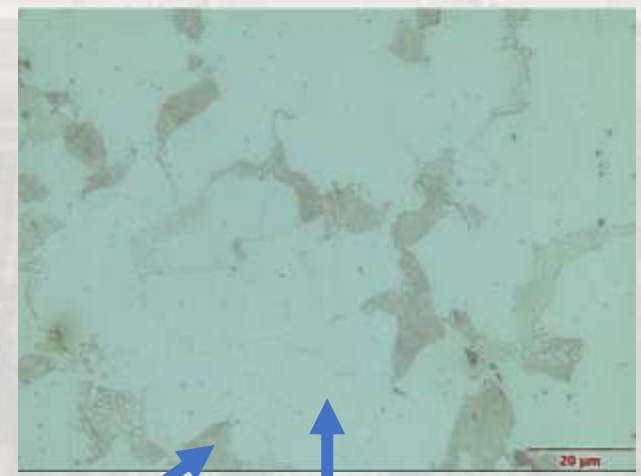


Pearlite Structure
Ferrite Grains

Forged Steel Bar - EN08

Slightly larger Crystals, High strength but reduced ductility and toughness due to larger pearlite structures

Shown by the reduced elongation compared to printed Material

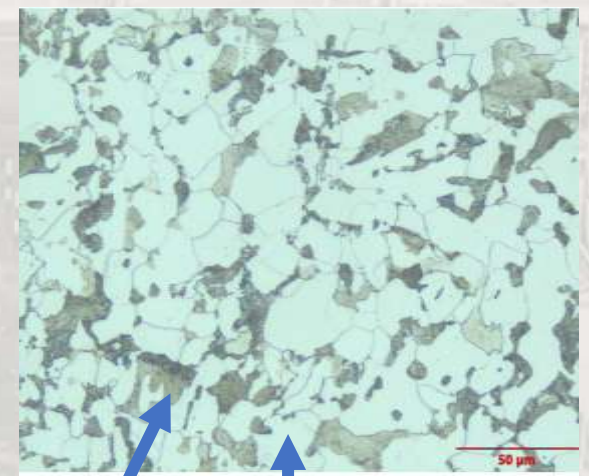


Pearlite Structure
Ferrite Grains

Cast Steel – A216 WCB

Small Crystals, High strength but reduced ductility and toughness due to the large quantity of pearlite structures

Shown by the reduced elongation compared to printed Material

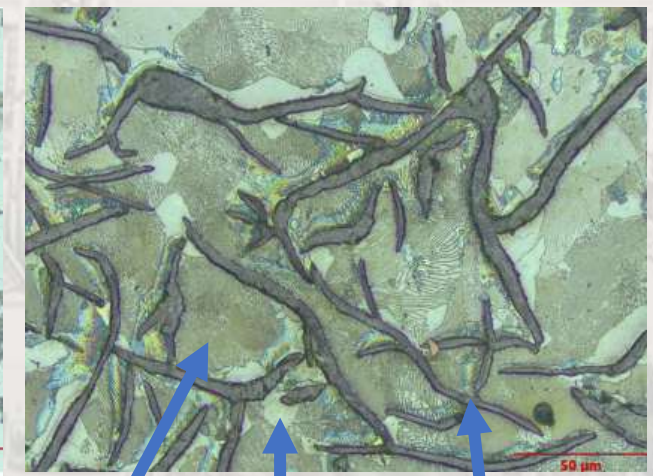


Pearlite Structure
Ferrite Grains

Cast Iron

Large Crystals, High strength but low ductility and toughness

This structure shows large graphite grains between ferrite grains increasing brittleness

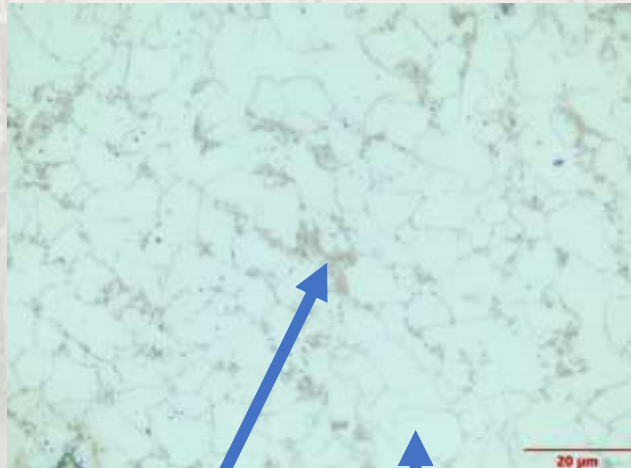


Pearlite Structure
Ferrite Grains
Graphite Grains

Microstructure analysis

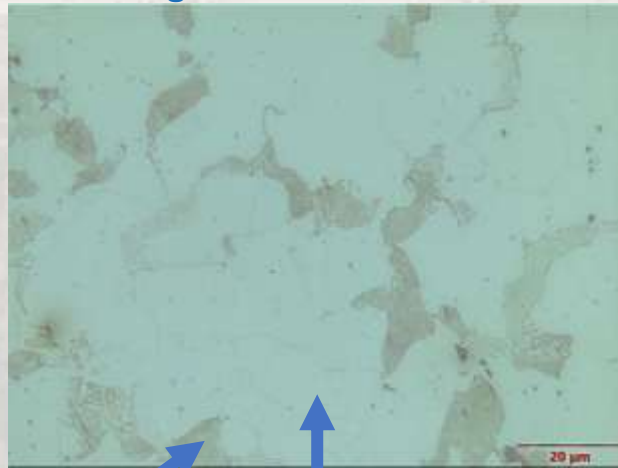
The reason for pearlite structure quantity is related to the rate of cooling experienced following creation; faster rates of cooling create less clusters of pearlite structures improving the toughness characteristics as discussed by Firoozbakht *et al.*, (2026)

Printed ER70S-6 Microstructure



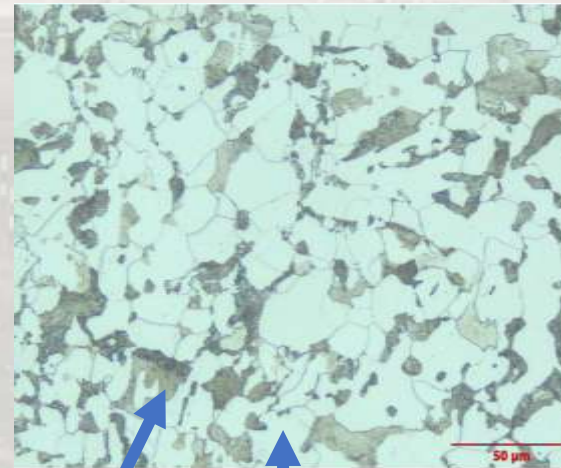
**Pearlite
Structure** **Ferrite
Grains**

Forged Steel Bar - EN08



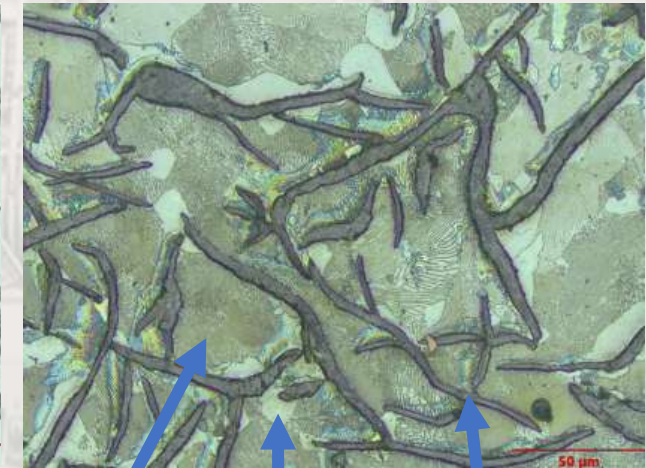
**Pearlite
Structure** **Ferrite
Grains**

Cast Steel – A216 WCB



**Pearlite
Structure** **Ferrite
Grains**

Cast Iron



**Pearlite
Structure** **Ferrite
Grains** **Graphite
Grains**

Project Limitations and Recommendations

Limitations

- **Time** – With limited time and many activities being reliant on third party vendors time needed to be managed effectively to ensure a successful outcome.
- **Costs** – The costs associated with this project were limited, information on the reliability of the technology was needed before more investment can be made to ensure the technology is fit for purpose in this industry.
- **Testing Materials** – the availability of items that could be destroyed for testing was limited, the items eventually found to perform the testing for A216WCB were late on in this project and some of the test samples couldn't be returned to site due to time constraints.

Recommendations

- **Time** – ensuring sufficient time for booking in services and having information ready early in the project helped with the success of this research.
- **Costs** – A future should be created with milestones for researching individual materials and gaining the confidence in the technology to secure future research and development funding.
- **Testing Materials** – Gathering all the materials up front will help to ensure the smoothness of the project.

Additive Manufacturing for traditionally cast components

Conclusion

The material tested from producing Wire Laser Direct energy deposition is encouraging especially when compared to cast iron and steel, the printing technology is mainly focused on replacing these materials due to the restrictions in casting from cost to lead time.

Printed ER70S-6 outperformed the Cast alternatives and is comparable to forging in many ways.



Factors that effect a Metal 3d Print When comparing technologies and need to be managed include;

- Deposition Method – Arc or Laser, Wire or Powder
- Material Testing – ensuring the part geometry is designed with the weaknesses in mind.
- Cooling Rates – The cooling has a major impact on the characteristics of the materials mechanical properties.



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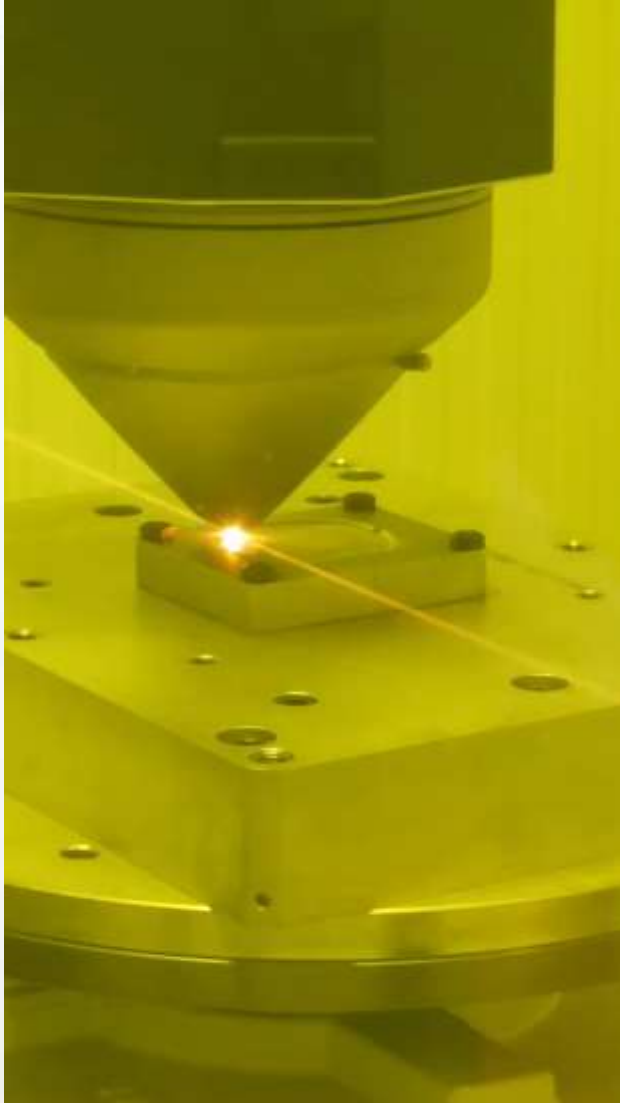
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Additive Manufacturing for traditionally cast components



MELTIO
Robot Cell

Thank you For Listening
Are there any Questions?

