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Microstructural evolution of ER70S-6 and 316L Steels under build orientations in LWAM

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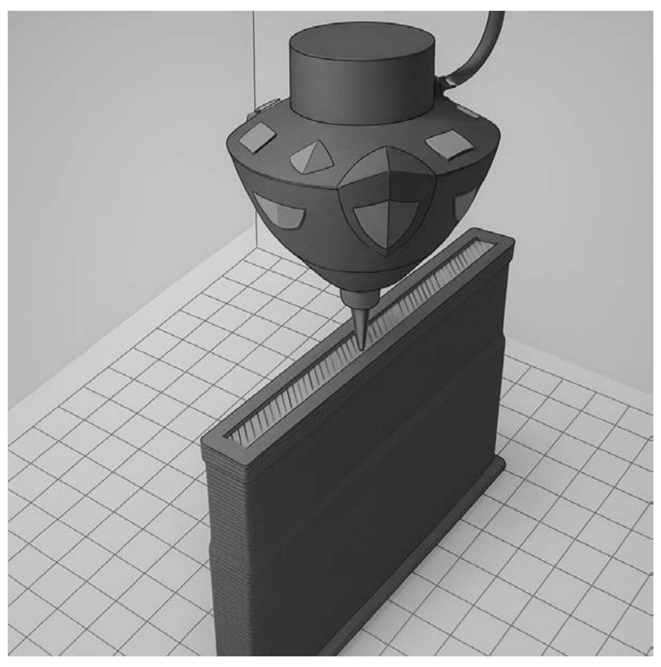
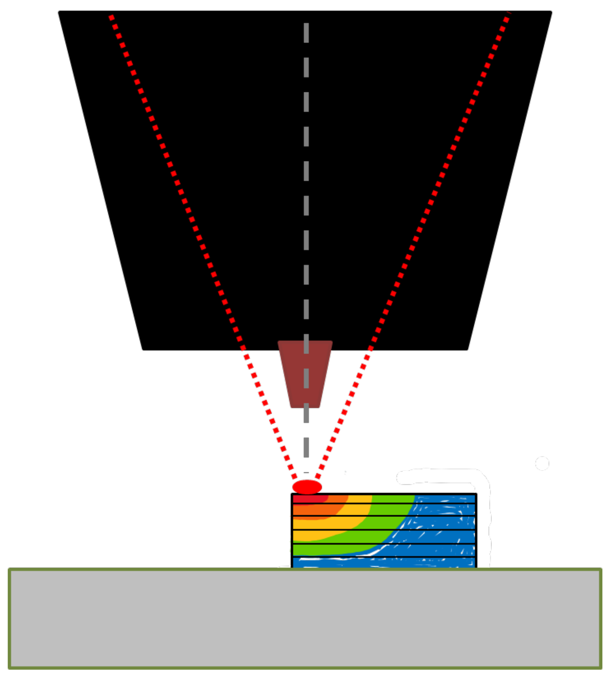
INTRODUCTION & AIM

DED is an additive manufacturing process using **focused energy to melt metal** feedstock (**wire** or powder) as it deposits onto surfaces. Builds parts **layer-by-layer** through controlled material melting, enabling creation and repair of large, complex metal components beyond conventional 3D printer limitations (Roman-Calderero, 2025; Lalegani Dezaki, 2022; Smith, 2016; Kawalkar, 2022).

The process was studied under different build orientations (**XY-plane** versus **XZ-plane**). Two types of wire feedstock are being compared: **ER70S6** (a common carbon steel welding wire) and **AISI 316L** (a corrosion-resistant austenitic stainless steel). The heating source comes from **6 laser beams** and is printed in an **argon** atmosphere. This research focused on understanding the impact of thermal history related to printing orientation on microstructure. The study continues previous investigations (Gomez-Lendinez, 2025).

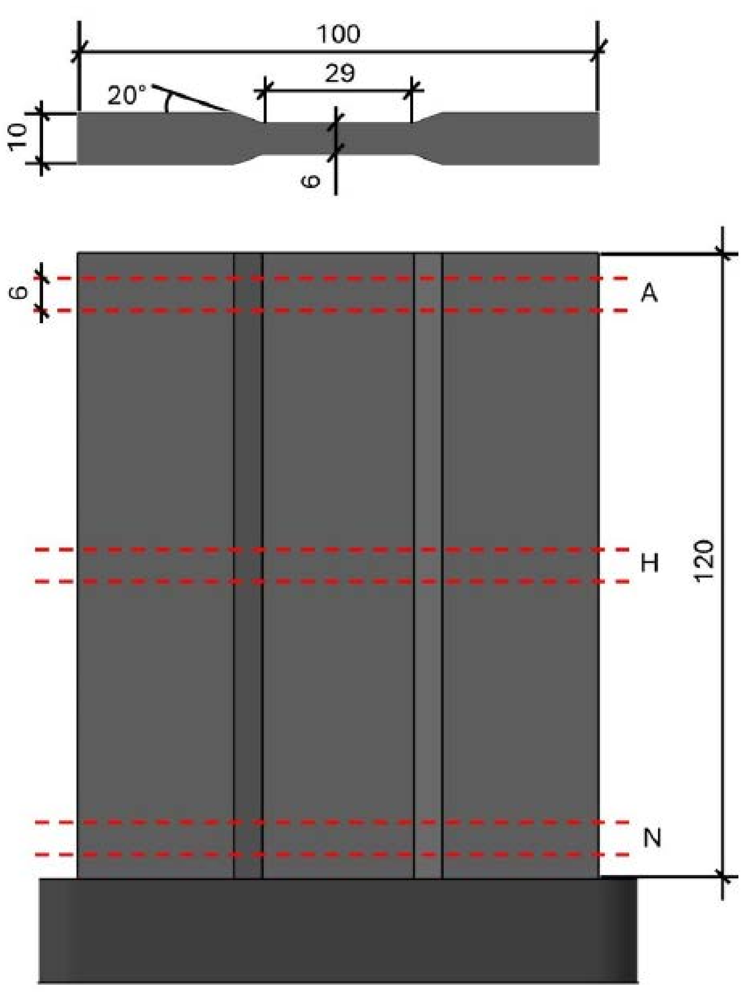


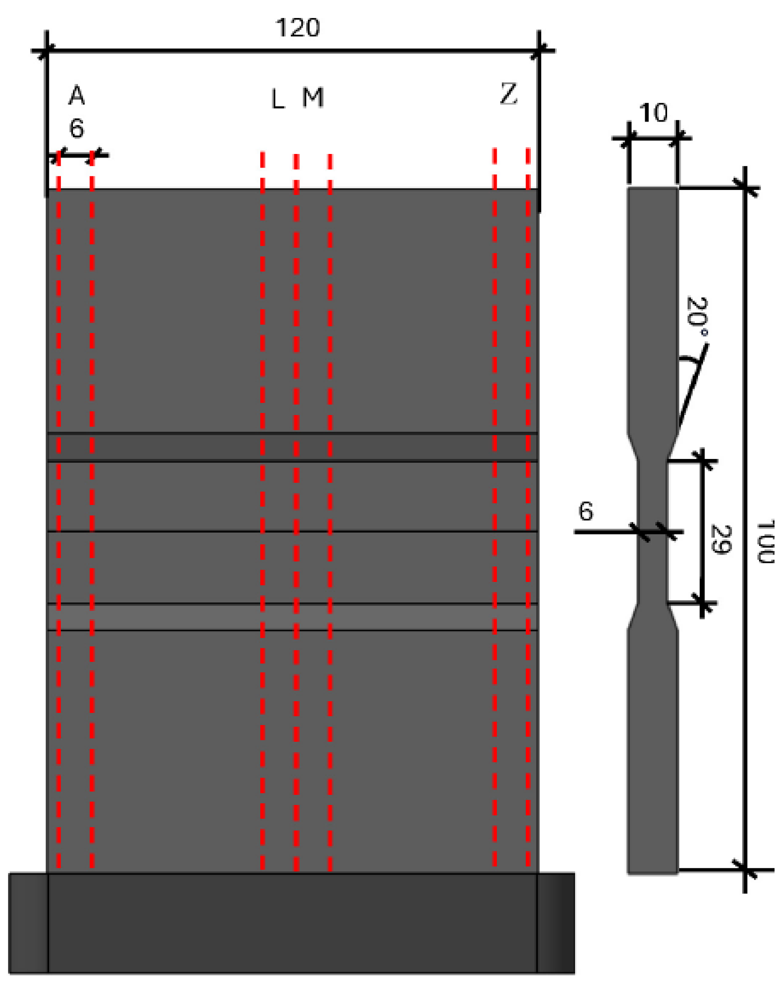


METHOD

The experimental methodology involves creating samples using a Meltio M450 system as a solid block. After printing, test samples are obtained by cutting the printed block.

The critical variable under investigation was the geometric orientation of the build: horizontally (XY) samples and vertically (XZ) samples. See figures.





These different orientations have **distinct heat dissipation rates** and **thermal histories** for the material as it solidifies**. Vickers microhardness** tests are done and, also grain size analysis following the standard procedure set out in ASTM E112.

	ER70S-6 (carbon steel)	AISI 316L (aust. stainless steel)
Chemical composition (% wt)	C: 0.07, Mn: 1.45, Si: 0.85, S: 0.02, P: 0.01, Fe: balance	C: 0.02, Cr: 18.5, Ni: 12.0, Mo: 2.7, Mn: 1.7, Si: 0.9, Fe: balance
Tensile strength (MPa)	480 - 600	485 - 655
Yield strength (MPa)	200 - 480	170 - 430
Density (kg/m³)	7800	8000
Thermal conductivity (W/m·K)	50 - 54	16.3
Melting point (°C)	1425-1485	1375 - 1400

RESULTS & DISCUSSION

The results demonstrated a clear, **material-dependent relationship between building orientation and resulting properties**. A thermal treatment is applied of 1h at 850 ºC.

AISI 316L HV05 XZ:

HV05	Average	Deviation
Ave. Lower	205.5	2.2
Ave. Central	205.6	1.8
Ave. Upper	205.7	1.8

AISI 316L HV05 XZ thermally treated:

HV05	Average	Deviation
Ave. Lower	202.8	4.1
Ave. Central	201.3	4.3
Ave. Upper	199.2	4.4

ER70S6 HV05 XZ:

HV05	Average	Deviation
Ave. Lower	168.1	5.4
Ave. Central	161.1	4.0
Ave. Upper	159.2	4.6

ER70S6 HV05 XY:

HV05	Average	Deviation
Ave. Left	169.4	10.1
Ave. Central	166.8	6.6
Ave. Right	165.1	7.0

For **AISI 316L** in the as-built state, the hardness (averaging 205.6 HV) is uniform across the entire build height (Lower, Central, Upper), with **minimal deviations**, indicating a very stable and homogeneous microstructure. Moreover, **thermal treatment** slightly decreases the overall hardness (201.1 HV) and shows significantly higher deviations.

The **ER70S6** alloy demonstrates different behavior, possessing significantly lower overall hardness (160-170 HV). In the **XZ** (vertical) plane, a **noticeable gradient is observed**, with hardness decreasing by nearly 9 HV from the Lower to the Upper section (168.1 HV to 159.2 HV). This strong positional dependence suggests that cooling rates or thermal accumulation differed substantially along the Z-axis during the build process, leading to microstructural variations.

The ER70S6 measured in the XY (horizontal) plane exhibits similar average hardness values but the highest deviations (up to 10.1), while the average hardness across the horizontal locations (Left, Central, Right) is relatively consistent. Higher deviations signifies a local heterogeneity in the microstructure of the ER70S6 alloy built in the XY orientation.

CONCLUSION

Significant difference between **position and orientation** in **carbon steel ER70S6. XZ orientation has a clear microstructure gradient.**

No difference using **stainless steel 316L** at any position.

No significant difference with **heat treatment** using **stainless steel 316L.**

FUTURE WORK

Thermal gradient and orientation study and strength testing.

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