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Material Anisotropy of Non-heat-treated Inconel 718 Additively Manufactured by Wire Arc Additive Manufacturing

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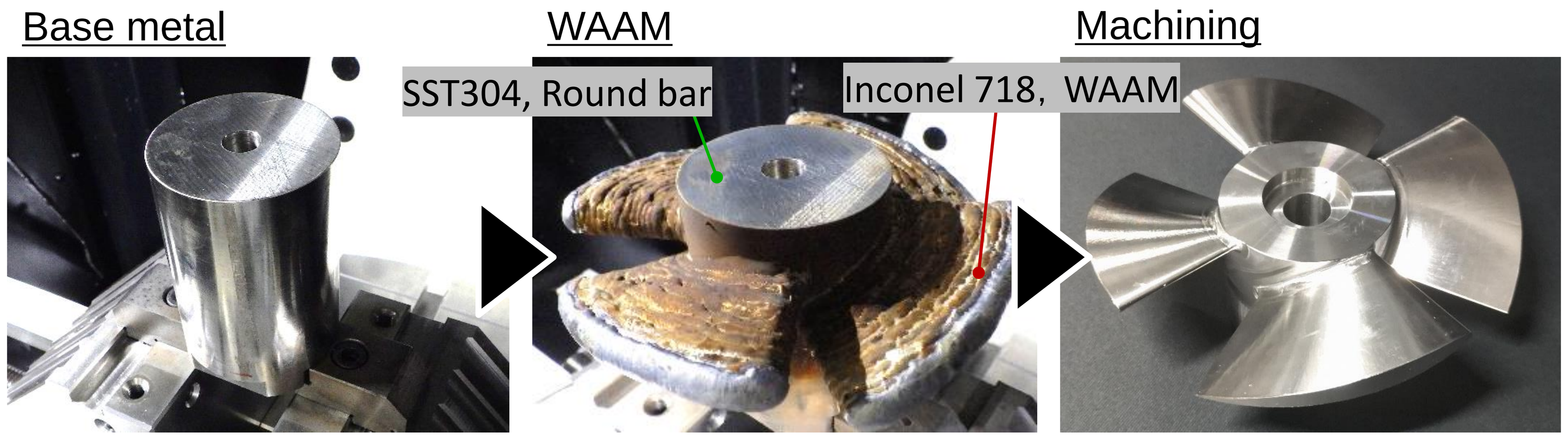
INTRODUCTION & AIM

Material anisotropy is an important topic to consider when using additive manufacturing for industrial applications. Since the products fabricated by **Wire Arc Additive Manufacturing (WAAM)**, a metal additive manufacturing technology used to fabricate large parts, are sometimes used in parts that require a specific level of strength required by industry, it is essential to clarify the characteristics of these products for their industrial application.

Furthermore, it should be noted that the fabrication of complex shapes such as blades by WAAM cannot be used for industrial applications because of defective fabrication if appropriate fabrication conditions are not used. However, many studies have focused on simple shapes such as flat plates, thus there is a problem in that evaluations have not always been conducted under conditions that enable the fabrication of complex shapes

In this study, an investigation was conducted on the material anisotropy of Inconel 718 under conditions where impeller blades can be fabricated by WAAM.

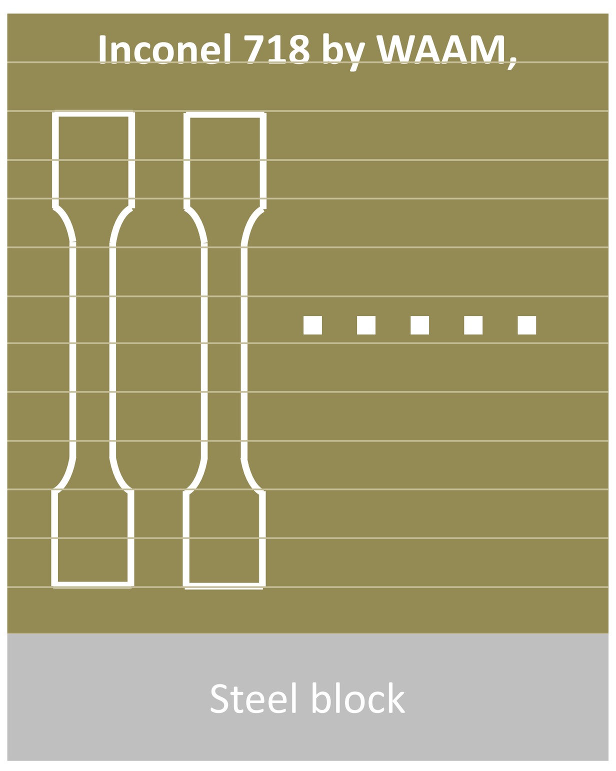
Overview of impeller fabrication by WAAM and machining[1]



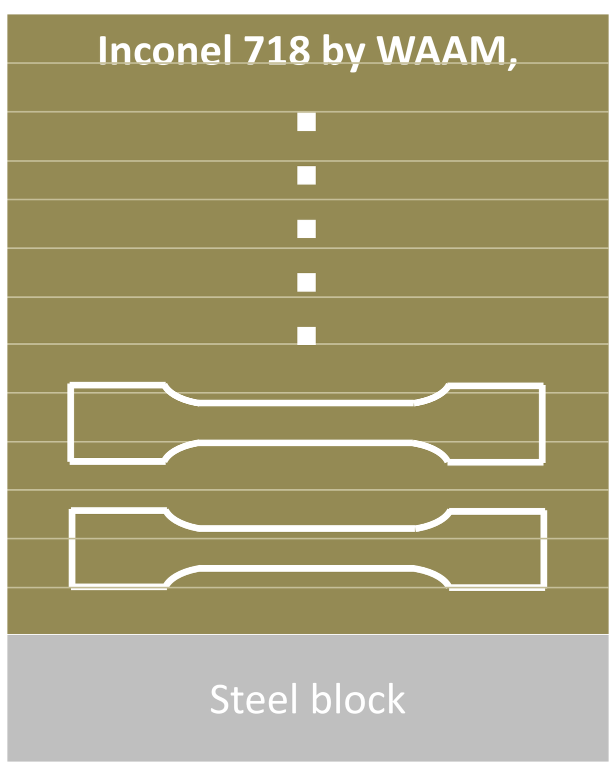
METHOD

1. WAAM walls are fabricated according to the conditions under which the near-net shape of the impeller blades can be fabricated.
2. Cut out tensile specimens vertically, 90 degree to the layering direction, and horizontally ,parallel to the layering direction, from the WAAM walls then finish by machining.
3. Conduct tensile test to obtain stress-strain diagram.

Vertical cutout



Horizontal cutout

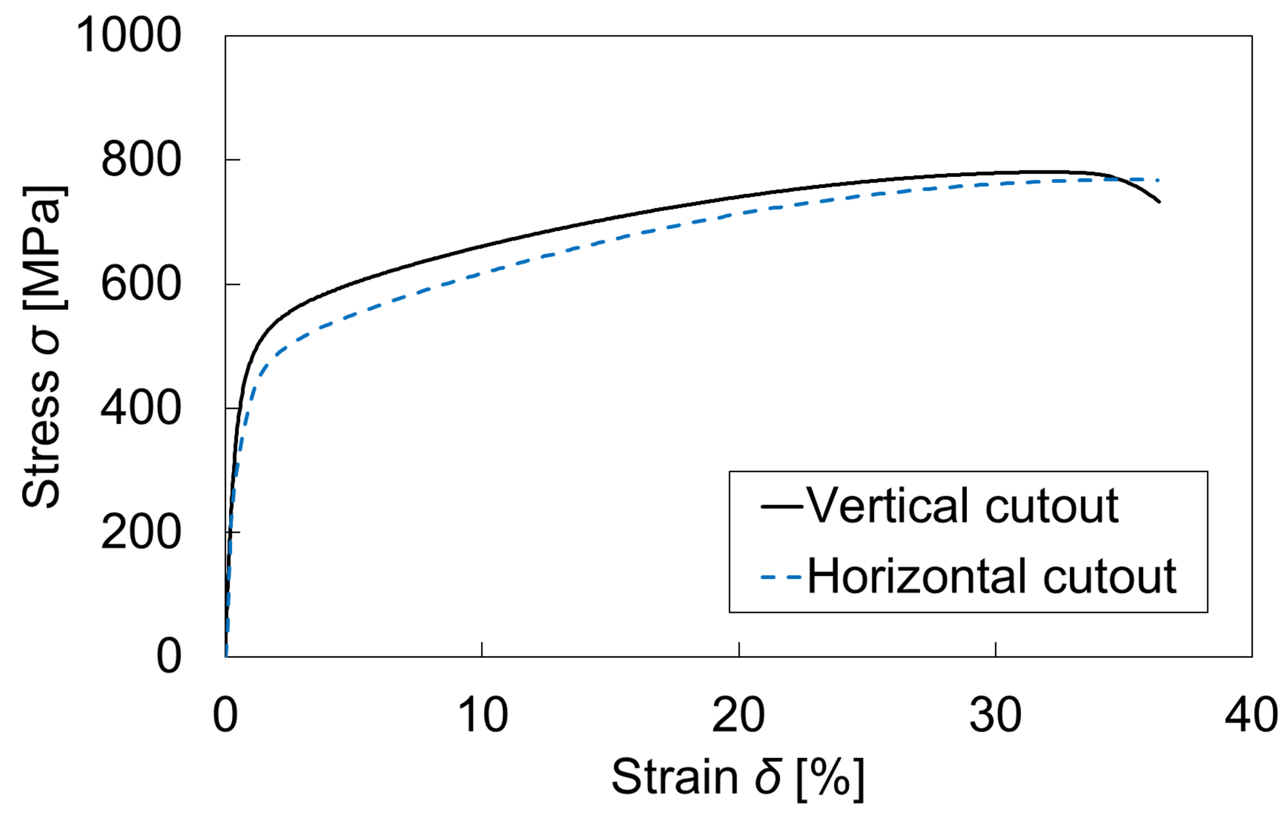


WAAM conditions

Current [A]	196
Voltage [V]	17
Wire feed [m/min]	9
Torch feed [mm/min]	600
Shield gas	Ar

RESULTS & DISCUSSION

Stress-strain diagrams were obtained by conducting tensile tests using multiple specimens. An example of a stress-strain diagram is shown in the figure below.



There is no significant difference in tensile strength and breaking elongation, but it can be confirmed that the elastic range is smaller in the horizontal direction than in the vertical direction. Comparing the 0.2% proof stresses, the vertical and horizontal values are 541 MPa and 508 MPa, respectively, with a difference of about 30 MPa, confirming the material anisotropy with respect to the 0.2% proof stress.

The tensile strength and breaking elongation obtained in this study were compared with those of other WAAM materials. WAAM Inconel 718 material anisotropy is confirmed to be small compared to WAAM aluminum alloys and austenitic stainless steels.

	Cutout Direction	Tensile strength σ_B [MPa]	σ_B difference [%]	Breaking elongation δ [%]	δ difference [%]
Inconel 718 by WAAM, Non-heat-treated, This study	Vertical	786	**2.1**	35	**2.8**
	Horizontal	770		36	
Ref.: A5052 by WAAM, Non-heat-treated [2]	Vertical	260	13.5	25	127.3
	Horizontal	229		11	
Ref.: SST316L by WAAM, Non-heat-treated [3]	Vertical	558	8.8	32	22.0
	Horizontal	513		41	

Note: These results are for additively manufactured materials by the same machine.

CONCLUSION / FUTURE WORK

Tensile tests showed that the material anisotropy of non-heat-treated Inconel 718 fabricated by WAAM is smaller than that of other materials fabricated by WAAM. The mechanism of this anisotropy will be the subject of future work, including observation of the metallurgical microstructure. In addition, cases with heat treatment are also to be studied for industrial applications.

REFERENCES

[1] S. Ejiri, *Turbomachinery*, **2024**, 52-6, pp. 367-373. (in Japanese)
[2] H. Anzai, et al., *Industrial Technology Institute Fukushima Prefectual Government Test and Research Report*, **2022**. (in Japanese)
[3] H. Anzai, et al., *Industrial Technology Institute Fukushima Prefectual Government Test and Research Report*, **2023**. (in Japanese)