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PHD position

Subject

Influence of atmosphere on surface tension of liquid metals - Application to metallic additive manufacturing

Mots clés

Surface tension – Additive manufacturing– Bottom-up approach– laser process - Procédés de arc process – high speed imaging –thermal measures

Encadrants de thèse

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Description

Surface tension of a liquid metal depends on numerous parameters including chemical composition – especially impurities content such as oxygen and sulphur – and temperature [1]. Moreover, experimental measurements of this parameter are difficult since they require measurements at liquid state (~1500°C for steels, more for refractory metals). However, surface tension – its gradient versus temperature especially- plays a key role in convection currents in liquid metal and in fine on the shape of liquid metal. By the way, the surface aspect of an object manufactured using a process which involves fusion and unconfined solidification results from surface tension of the metal at liquid state.

One way to master surface tension of a liquid metal consists in introducing willingly impurities in liquid metal – oxygen especially. For additive manufacturing, the approach will consist in adding oxygen in inert protection gas (argon). [2].

Such as in arc welding processes, gas metal arc additive manufacturing processes call out numerous domains of physics: fluid thermal and mechanics, plasma physics, electromagnetism for electric arc. Thereby, experimental devices have to be developed in order to uncouple phenomena that occur in liquid metal as a function of temperature. These data are necessary for multiphysic modelling of the process.

A bottom-up approach will be used in the frame of this thesis. The PhD student will be part of the following steps:

1. Measurement of surface tension on a sphere of liquid metal melted by laser and levitated using a gas jet.
2. Same measurements on a liquid sphere of metal deposited on a cold substract (cooled copper box) using a laser process
3. Fusion of the end of a bar using a laser process
4. Fusion of a sphere of liquid metal deposited on a cold substract (cooled copper box) using a gas arc process
5. Fusion of the end of a bar using a gas arc process
6. Additive manufacturing in 2 dimensions and then 3 dimensions

For each step, imaging and thermal characterizations will be performed in situ at high temperature in liquid metal. Experimental techniques will be: high speed imaging combined with illumination laser to avoid arc radiation, thermal imaging, multispectral pyrometry and classical metallurgy characterization methods: metallography, microhardness, SEM, WDS to measure oxygen content…

The study will be carried out on a simple alloy first: an austenitic stainless steel. It will be followed on a titanium and its alloys. As these alloys are very sensitive to oxygen contamination, the influence of oxygen in protection gas on final mechanical properties is challenging.

Profile

The candidate must have a master degree in materials science at the beginning of the PhD. He/She has knowledge in metallurgy (alloy categories, phase diagrams, microstructures, mechanical properties, associated characterization methods…) and is interested in experimental sciences. Most of the PhD will be based at "Institut des Matériaux Jean Rouxel" (IMN) in ID2M team. Test campaigns will be carried out at "Institut de Recherche Dupuy de Lôme" (IRDL, Lorient).

Funding

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References

[1] I.Egry, E.Ricci R.Novakovic S.Ozawa Advances in Colloid and Interface Science, 2010 https://doi.org/10.1016/j.cis.2010.06.009

[2] A Berthier, P Paillard, M Carin, F Valensi and S Pellerin Science and Technology of Welding and Joining, 2012, https://doi.org/10.1179/1362171812Y.0000000024