Numerical and Experimental Investigation of Gas Jet Flows Created by Diverse Coaxial Nozzles During Laser Metal Deposition

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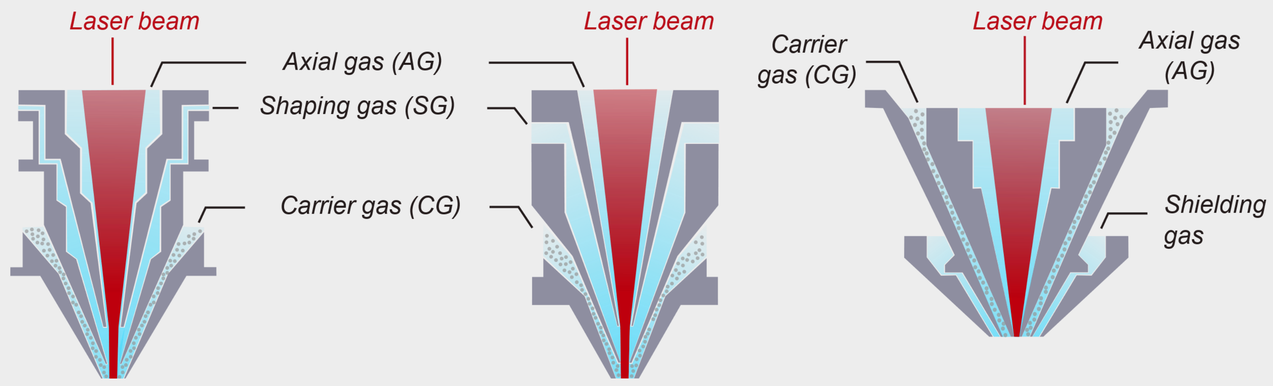
INTRODUCTION

LMD is an additive manufacturing process able to produce new net shape metallic components, repair damaged high value parts and add coating and functions on metallic parts.

The powder stream is a key factor governing the laser cladding process but its structure, focal plan and distribution is partly tailored by the nozzle geometry and gas flow rate [1].

Gas jet ➔ Particle stream ➔ Deposit

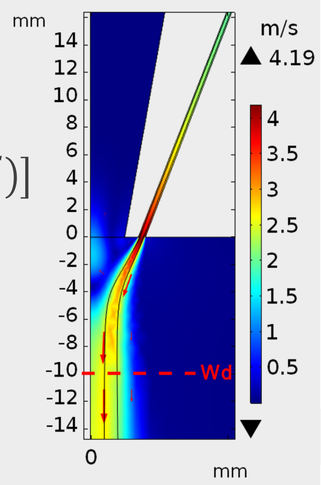


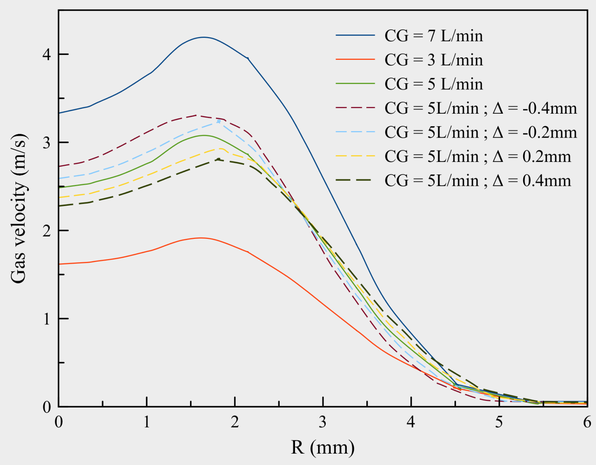
GAS FLOW IN AN INERT ATMOSPHERE

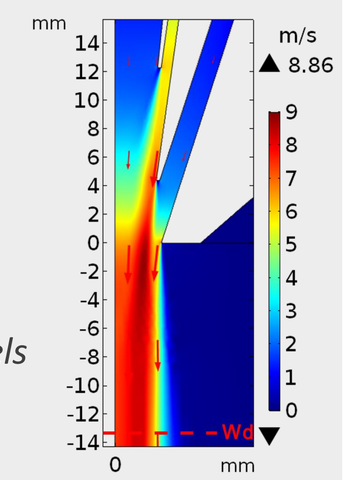
Turbulent incompressible gas [2]

$$\rho \nabla \cdot (u) = 0$$

$$\rho \frac{\partial u}{\partial t} + \rho(u \cdot \nabla)u = \nabla \cdot \left[-pI + (\mu + \mu_T)\left(\nabla_u + \nabla_u{}^T\right)\right]$$







→ *The nozzle design, number of gas channels and their respective flow rate have a considerable impact on the gas flow*

GAS FLOW IN AN AIR-BASED ATMOSPHERE

Convection and diffusion

$$\frac{\partial c}{\partial t} + \nabla \cdot (-D\nabla_c) + u \cdot \nabla c = R$$

$$N = -D\,\nabla c + u_c$$

→ *Kelvin-Helmholtz instabilities : velocity shear at the interface of two fluids with different densities*

→ *Appear below the usual working distance (Wd) of the nozzles*

Laminar compressible flow

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho u) = 0$$

$$\rho(u \cdot \nabla)u = \nabla \cdot \left[-pI + \mu\left(\nabla u + (\nabla u^T)\right) - \frac{2}{3}\mu\,(\nabla \cdot u)I\right]$$

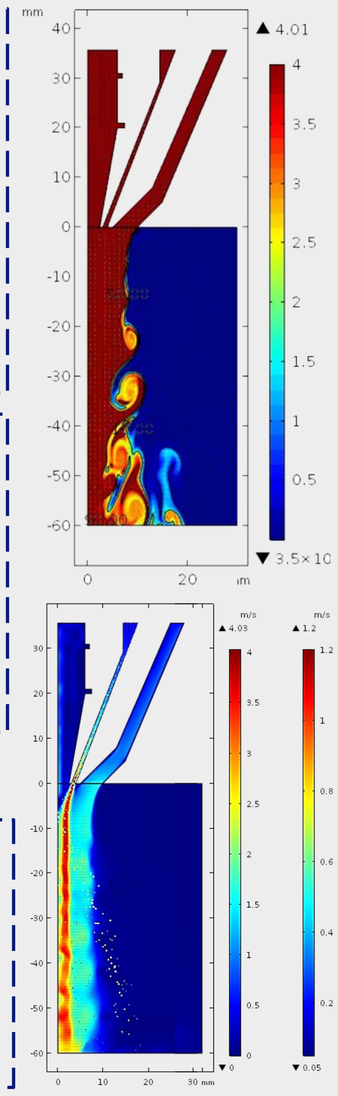
→ *Instabilities don't affect the gas velocity fields*

One way coupling

Particle Tracing

$$\frac{d(m_p v)}{dt} = F_t$$

→ *Powder stream trajectory depends on the particle diameter*



EXPERIMENTAL SETUP

Continuous differential pressure measurement below the nozzle tips with a Pitot tube

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Bernouilli's equation : $v = \sqrt{\frac{2\,\Delta P}{\rho}}$

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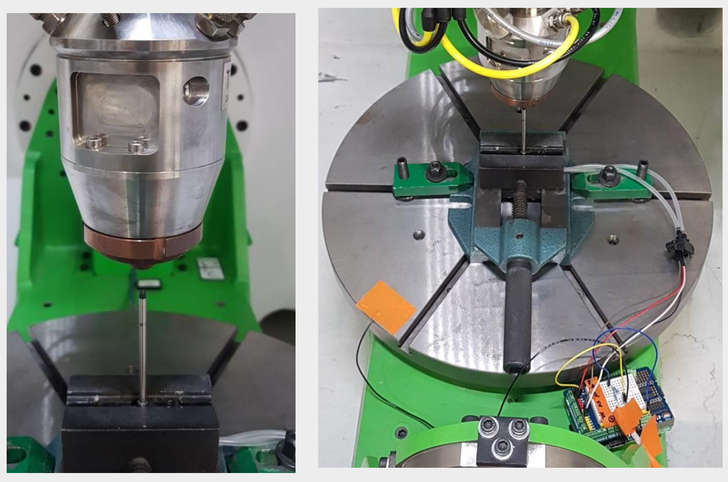
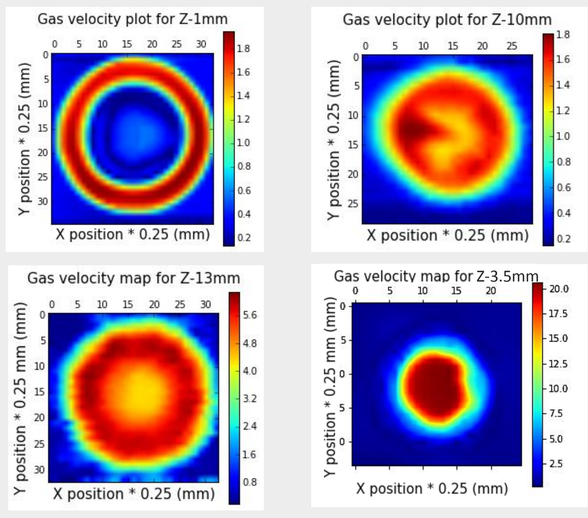
Velocity field and structure of the gas flow below the nozzle tips





CONCLUSION

- The air-based external atmosphere doesn't need to be considered to estimate the gas and particle behavior
- Structure of the gas flows, influence of the flow rate parameter and design of the nozzle obtained by CFD module were confirmed by pitot tube experimental setup (with 1.1 to 2.5 correlation factor)

REFERENCES

[1] J. Maisonneuve, "Fabrication directe de pièces aéronautiques en TA6V et IN718: projection et fusion sélective par laser," 2008.

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