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▶ **To cite this version:**

F. Villaret, X. Bounat, P. Aubry, D. Fabregue, Y. de Carlan. Development of an austenitic/martensitic gradient steel by powder metallurgy, HIP / SPS and additive manufacturing. Euromat 2019, Sep 2019, Stockholm, Sweden. cea-02394091

HAL Id: cea-02394091

https://hal-cea.archives-ouvertes.fr/cea-02394091

Submitted on 21 Feb 2020

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Development of an austenitic/martensitic gradient steel by powder metallurgy, HIP / SPS and additive manufacturing

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Introduction

In this study, we focused on a gradient from a 316L austenitic stainless steel to a 9Cr-1Mo martensitic steel. These steels are widely used for nuclear applications. Due to their chemical composition differences, welding them is uneasy, requiring nickel based filling metal and post-welding heat treatments.

Methods

Whether by "conventional" powder metallurgy (Spark Plasma Sintering or Hot Isostatic Pressing) or additive manufacturing (Direct Metal Deposit), it is possible to consider the construction of a coupling sleeve between 316L and 9Cr-1Mo. The chemical composition of this part will gradually change from 316L to 9Cr-1Mo, allowing homogeneous welding at each end and thus simplifying the assembly step.
In the graded part, the coefficient of thermal expansion will vary gradually, reducing the mismatch between the two parts [1]. The chemical gradient through the connector allows also a gradual change of the carbon chemical potential instead of sharp variation [2]. Therefore, this graded component retards carbon diffusion under service conditions.

Results

In SPS assemblies, very few diffusion occurs between powders. Thus, bi-materials with a sharp interface are made such as one shown on the figure. In this kind of material, a sharp hardness drop is observed from a side to another. An option to smoothen this hardness gradient is to sinter a multi-layered material made with different powder mixes.

In Hipped materials, longer consolidation time involves higher diffusion between the two materials, so a smoother gradient is expected. A composite behavior in tensile test is obtained with hipped powder mix.

Additive manufactured samples were also built, and present a graded zone where the composition is controlled by the powder mix**.**

Conclusions

The feasibility of building 316L to 9Cr-1Mo gradient materials is shown. Further studies such as building parameters optimization, evaluation of tensile mechanical properties and ageing heat treatments will be performed to complete these microstructural analyses.

References

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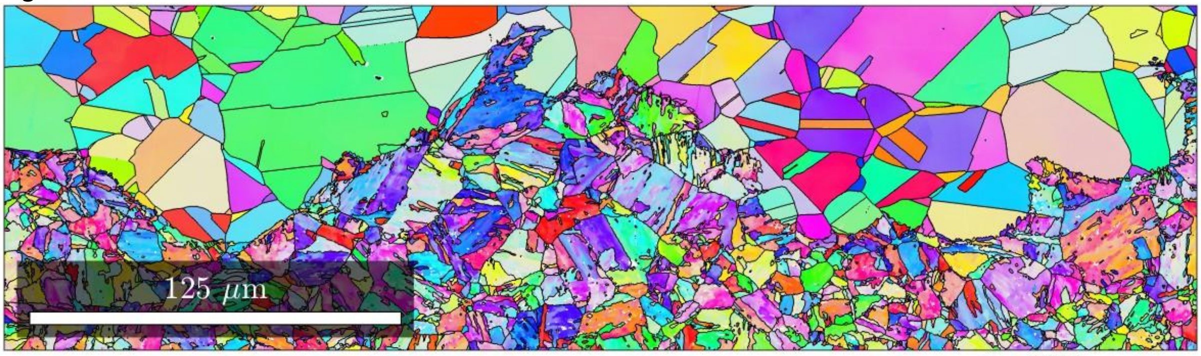
[2] J. S. Zuback, T. A. Palmer, et T. DebRoy, « Additive manufacturing of functionally graded transition joints between ferritic and austenitic alloys », *J. Alloys Compd.*, vol. 770, p. 995‑1003, janv. 2019.

Figure:



EBSD map (IPFZ) on austenitic/martensitic bi-material made by SPS