Proposition Thèse de doctorat 2021

Titre	**Determination of the aging treatment suitable for sintered maraging steel from milled powders**
Cadre de Recherche	A. Bolsonella as part of his doctoral thesis demonstrated the existence of stability in the plastic domain when maraging steels are prepared by Powder Metallurgy compared to the same steels produced by traditional processes. To understand this "very particular" behavior, it is essential to study the chemical composition as well as the microstructure at each stage of the process, from high-energy milling of the powder to obtaining a dense material for which an optimization of the aging treatment conditions is also sought.
Objectifs	The objective of this work is to produce a high elastic limit steel (> 2000MPa) with a ductility greater than 3%. More precisely, it is a question of understanding the tensile behavior of these sintered steels but also of determining a structural hardening treatment adapted to the microstructure of the sintered parts. Indeed, understanding the formation mechanisms of formation its intermetallics within sintered materials constitutes the first challenges. The second challenge is to understand what is the origin of this stability on the plastic domain.
Sujet	*1.1. Powder analyses* Two main actions will be initiated: (i) a bibliographic study associated with an analysis of the maraging powders (suppliers, producers, etc.), then (ii) powder characterizations. It is planned to establish their "identity card" but also to study their behavior in temperature. *1.2. Sintering conditions* This involves to determine, on the one hand, the milling conditions of the various powders within a high-energy planetary mill and, on the other hand, the SPS sintering conditions of the latter. It is planned to work on D60H10 samples in order to perform tensile tests at Nexter Munitions laboratory. Likewise, sintering using Hot Isostatic Compaction (HIP) will be tested as an exploratory study. *1.3. Hardening treatment* After the manufacturing stage (forging, additive manufacturing or sintering), heat treatments are necessary such as homogenization and an aging treatment. A study of heat treatment influence in particular that of aging which allows the precipitation of intermetallics will be approached. The main objective of this step is to identify the processing temperature to be applied to sintered parts. In fact, the microstructure and the phases obtained after sintering are totally different from those obtained via traditional methods. This requires a good knowledge of the "sintered state" in order to find the temperature range allowing precipitation of intermetallics responsible for hardening while avoiding any return to the austenitic phase. Here again, it is planned, in addition to the SPS, to test the HIP: (i) as a means of manufacturing by sintering via the use of a capsule but also to carry out the heat treatments within the same enclosure and (ii) as a post- SPS, in this case the HIP could be used to conduct the aging treatment on the shaped parts machined after the sintering step. 1.4. Understand the origin of a stability in the plastic domain The sintered samples exhibit a finer microstructure and a 100% martensitic structure with post-processing mechanical characteristics superior to the reference materials prepared by forging. In addition to an increase in mechanical strength, sintered samples from milled powders exhibit a stability in the plastic domain which suggests great potential for the development of nanostructured maraging steel. However, this behavior never demonstrated phenomenon on these steels remains to be explained. Finding the origin of this stability in the plastic domain is the scientific challenge to be taken up.
Moyens	Implementation on the one hand of the various processes (ball mill, SPS, HIP, …) in order to produce dense steels with a controlled microstructure and, on the other hand, the means of physicochemical characterization of materials in terms of chemical composition, phases and morphology (SEM, TGA, XPS, XRD, XRF).
Formation souhaitée	Good knowledge in Metallurgy and, more broadly, in Material Sciences. Good knowledge of physico-chemical characterization techniques.
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