氏　　　　　名	郭　妍伶 (クオ　イェンリン)
所　　　　　属	理工学研究科　機械工学専攻
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学 位 論 文 題 名	Microstructure and Mechanical Properties of Ni-based Superalloy Alloy718 Fabricated by Selective Laser Melting and Hot Isostatic Pressing 選択的レーザー溶融と熱間等方加圧により作製したニッケル基超合金 Alloy718 の組織と機械的特性（英文）
論 文 審 査 委 員	主査　教　授　筧　幸次 委員　教　授　北薗　幸一(システムデザイ研究科 航空宇宙システム工学域) 委員　准教授　髙橋　智

【論文の内容の要旨】

Powder metallurgy (PM) is a term covering a wide range of ways in which materials or components are made from metal powders. PM processes can avoid, or greatly reduce, the need to use metal removal processes, thereby drastically reducing yield losses in manufacture and often resulting in lower costs. There are several kinds of processes, i.e., hot isostatic pressing (HIP), additive manufacturing (AM) and metal injection molding (MIM), and so on. The HIP process subjects a component to both elevated temperature and isostatic gas pressure in a high pressure containment vessel. Metal powders can also be turned to compact solids by this method. However, the presence of prior particle boundaries (PPBs) have a strong and detrimental effects on the mechanical properties. Various efforts have been made to mitigate the detrimental effects of PPBs to extend the life of such products in applications in the aerospace industry, an effective and reliable method is yet to be desired. Hence, an additive manufacturing (AM) process such as selective laser melting (SLM) has capability to eliminate the abovementioned problems and reduces lead-time and investment cost. However, the microstructure and mechanical properties after AM processing are different from those after conventional cast or wrought processes. Furthermore, the obvious mechanical properties of AM materials include anisotropy which plays a role in influencing material’s ductility. It also questionable if the post-process, originally recommended for the cast or wrought alloys, would lead

to the same performance.

Based on the above description, the present study has been implemented in order to attain the following objectives:

1. To investigate the effect of the prior particle boundary (PPB) on the microstructure and mechanical properties of hot-isostatic-pressed IN718 alloy which is a precipitation hardenable nickel-based alloy designed to display exceptionally high yield, tensile and creep-rupture properties at temperatures up to 700°C. This alloy has excellent weldability when compared to the nickel-base superalloys hardened by aluminum and titanium. This alloy has been used for jet/rocket engines and industrial gas turbine.
2. To understand the microstructure–mechanical property relationships in IN718 built up by AM processes, as well as the effects of the post-processes on the microstructure and mechanical properties of AM materials.
3. To compare the microstructures and properties between solid-state sintering alloy and fully-melting-process alloy

Furthermore, the outline of the present study is composed of the following chapters:

Chapter 1: This chapter presented the introduction to Ni-based superalloy and powder metallurgy as well as the basic concept of mechanical properties in Ni-based superalloys. At the end, the objectives of the research were detailed.

Chapter 2: This chapter aimed to clarify the effects of powder surface contamination and PPB on the microstructure and mechanical properties of hot-isostatic-pressed IN718. The thermal plasma droplet refining (PDR) technique was adopted to reduce the surface contamination, i.e., the oxygen, nitrogen, and carbon contents, in the gas-atomized (GA) powder. Regardless of the surface contamination of specimens, the strengths of the heat-treated specimens were comparable to those of the wrought specimen both at room temperature and 650°C; however, the ductility of the HIPed and heat-treated specimens was much lower than those of the wrought specimen at 650 °C. The presence of PPB led to premature rupture due to the process of crack nucleation and propagation along the PPB take place more easily at high temperatures.

Chapter 3: The influences of build-up direction (BD) and heat treatment on the tensile properties of SLM parts using IN718 have been described in this chapter. The aim of the current chapter is to investigate the effect of unexpected particles on the tensile properties of SLM parts at room temperature (RT) and 650°C. The tensile strengths of heat-treated materials produced by SLM were comparable to those of cast and wrought specimens; however, when the horizontal- and vertical-directions specimens were subjected to solution treatment and aging (STA) at 650 °C, the horizontal-direction specimen exhibited one-fourth the ductility of the vertical-direction specimen because of the interdendritic δ-phase precipitates, which were arrayed perpendicular to the stress axis in the former specimen. The morphology and a row of interdendritic δ-phase precipitates with incoherent interfaces were found to affect tensile ductility at a high temperature.

Chapter 4: An additive manufactured Ni-base superalloy was examined to investigate the effects of build-up direction and heat treatment on the creep properties at 650 °C. The creep rupture lives of materials produced by SLM were lower than those of conventionally wrought material. The horizontal-direction specimen exhibited inferior creep life and worse ductility than the vertical-direction specimen because of the direction of the interdendritic δ-phase precipitates, which were arrayed perpendicular to the stress axis in the former specimen. The morphology and a row of interdendritic δ-phase with incoherent interfaces were found to affect the materials' creep life. In this chapter, the creep properties of specimens built up by electron beam melting (EBM) were compared with those of the SLM specimen.

Chapter 5: Previous chapters have explained the factors which affect tensile ductility and creep lives of SLM parts from several perspectives—e.g., the row of interdendritic precipitates, high dislocation density, and subgrain boundary. In order to achieve isotropic mechanical properties which are comparable or even superior to those of conventional counterparts, a post process for the AM parts is required. Thus, this chapter focus on the effect of hot isostatic pressing (HIP) on the microstructure and mechanical properties of IN718 built up by the SLM process.

Chapter 6: In order to gain a deep understanding of the powder metallurgy, the microstructure and mechanical properties were compared between solid-state sintering and fully-melting processes. IN718 specimens were fabricated by hot isostatic pressing (HIP) process and selective laser melting (SLM) processes, respectively. A clearly continuous precipitates were localized along the prior particle boundary (PPB) in the HIP specimens, while SLM specimens showed a microstructure free of PPB. The brittle particles along the PPB were found to affect the HIP materials' creep life and ductility during the solid-state sintering.

Chapter 7: This chapter contains the summary of the results obtained in the present study as well as some suggestion for future work in the fields of powder metallurgy and Ni-based superalloy.