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铬镍铁合金 IN939

概述

类似于IN或HX这类型的合金是典型的耐高温耐腐蚀镍合金，通常情况下，这些合金包含的元素除了镍之外还有铬、铁、铌、钼以及其他合金元素，他们通常也被称为超合金。相较于钢材而言，经过表面弥散硬化、沉淀硬化以及固溶强化的镍合金可以承受更高的温度并且有很好的可焊性。镍合金展现出很好的机械特性如优秀的拉伸强度和疲劳强度。IN可以在最高700 °C的环境中工作，HX可以在最高1200 °C的条件下工作。这让它们非常适合应用在航空航天工业以及发动机零件等方面。同时，镍合金还可以用来制作工具，也很适合进行热处理或者机械后处理。

General

Materials like IN or HX are examples of highly heat-resistant and corrosion resistant nickel-based alloys. In most cases, these alloys contain chrome, iron, niobium and molybdenum and other alloy components and they are often known as superalloys. Nickel-based alloys withstand higher temperatures than steels and they are also highly weldable. Their resistance to temperature is achieved through a mixture of dispersion hardening, precipitation hardening and solid solution strengthening. Nickel-based alloys exhibit good mechanical characteristic values such as high tensile strength and good endurance strength. Inconel can be used at temperatures of up to 700 °C. HX can even be used at temperatures of up to 1200 °C. This makes these alloys ideally suited for aerospace technologies and for turbine production. Another area where nickel-based alloys are used is toolmaking. These alloys are also suitable for sustained heat treatment and mechanical post treatment.

概述

经过SLM工艺处理的IN939零件展现出各向同性、近乎无孔的结构，因此其机械特性可以参考概述中对于IN939合金的性能描述。同时，如有对零件性能的特殊要求，也可以通过硬化、热处理或热等静压（HIP）等后处理来实现。

Material Structure

Following the SLM-process, nickel-based components exhibit a homogeneous, nearly poreless texture, whereby the mechanical characteristic values lie within the range of the material specifications. Through subsequent post treatment, such as hardening, heat treatment or hot isostatic pressing (HIP), the components' properties can be adapted to meet specific requirements. In the SLM process of IN939 are theoretical build-up rates of 9.1 cm³/h (layer thickness 30 µm) and 16.4 cm³/h (layer thickness 50 µm) achieved.

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物理/化学 性质
Physical and Chemical Properties

材料密度 *Material Density*	8,2 g/cm³			
打印件密度[1] *Build Part Density[1]*	层厚 30 µm[2] *Layer Thickness 30 µm*	> 99,5 %	层厚 50 µm[3] *Layer Thickness 50 µm*	> 99,5 %

化学成分(wt%)[4]
Chemical Composition (wt%)[4]

Element *Element*	**Min.** *Min.*	**Max.** *Max.*
Ni	Balance	Balance
Cr	22,00	23,00
Co	18,00	20,00
Ti	3,00	4,50
W	1,00	3,00
Al	1,00	3,00
Ta	1,00	1,80
Nb	0,50	1,50
Mn	-	0,50
Si	-	0,50
C	-	0,15
Zr	-	0,10

颗粒大小分布（范围)[4] *Particle Size Distribution[4]*	10 – 45 µm *10 – 45 µm*
晶粒形状[5] *Grain Shape[5]*	球状 *Spherical*

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机械特性[6]
Mechanical Data[6]

拉伸测试[7] *Tensile Test[7]*		层厚 30 µm[2] *Layer Thickness 30 µm[2]*	层厚 50 µm[3] *Layer Thickness 50 µm[3]*
拉伸强度 *Tensile Strength*	R_m [MPa]	1009 ± 35	928 ± 72
弹性模量 *Yield Strength*	R_e [MPa]	735 ± 41	633 ± 33
断裂伸长率 *Elongation Break*	A [%]	30 ± 4	23 ± 10
断面收缩率 *Contraction at Fracture*	Z [%]	45 ± 7	28 ± 9
弹性模量 *Young's modulus*	E [GPa]	177 ± 8	156 ± 12

硬度测试[8] *Hardness Test[8]*		层厚 30 µm[2] *Layer Thickness 30 µm[2]*	层厚 50 µm[3] *Layer Thickness 50 µm[3]*
维氏硬度 *Vickers Hardness*	[HV10]	302 ± 3	305 ± 7

粗糙度测试[9] *Roughness Measurement[9]*		层厚 30 µm[2] *Layer Thickness 30 µm[2]*	层厚 50 µm[3] *Layer Thickness 50 µm[3]*
平均粗糙度 *Mean Roughness Index*	R_a [µm]	6 ± 1	7 ± 1
平均表面粗糙度 *Average Surface Roughness*	R_z [µm]	42 ± 6	48 ± 7

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热处理后的机械特性[10]
Mechanical Data after Heat Treatment[10]

拉伸测试[7] *Tensile Test[7]*		层厚 30 µm[2] *Layer Thickness 30 µm[2]*
拉伸强度 *Tensile Strength*	R_m [MPa]	1247 ± 76
屈服强度 *Yield Strength*	R_e [MPa]	749 ± 21
断裂伸长率 *Elongation Break*	A [%]	13 ± 3
断面收缩率 *Contraction at Fracture*	Z [%]	12 ± 3
弹性模量 *Young's modulus*	E [GPa]	201 ± 3

热处理以及HIP后的机械强度[11]
Mechanical Data after Heat Treatment and HIP[11]

拉伸测试[7] *Tensile Test[7]*		层厚 30 µm[2] *Layer Thickness 30 µm[2]*
拉伸强度 *Tensile Strength*	R_m [MPa]	1348 ± 57
屈服强度 *Yield Strength*	R_e [MPa]	957 ± 18
断裂伸长率 *Elongation Break*	A [%]	11 ± 2
断面收缩率 *Contraction at Fracture*	Z [%]	12 ± 2
弹性模量 *Young's modulus*	E [GPa]	195 ± 6

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本表中的测试性能与机械特性的粉末是由SLM Solutions测试及销售的，测试是在使用SLM Solutions提供的参数和机器的情况下，根据适当的操作指令（包括机器状况和维护）进行的。零件的性能是严格实验的结果，如需了解更多细节可以与SLM Solutions沟通询问。
本表中阐释的材料特性来源于最新的知识体系以及实际经验总结，但不足以支撑整个零件设计体系。一些产品或零件的特定性能以及特殊应用中的零件并不在保证范围以内。产品或部件的制造商负责对特定应用的性能及其适用性进行资格验证。产品或部件的制造商负责保护任何第三方的专有权利以及遵守现有的法律和法规。

The properties and mechanical characteristics apply to powder that is tested and sold by SLM Solutions, and that has been processed on SLM Solutions machines using the original SLM Solutions parameters in compliance with the applicable operating instructions (including installation conditions and maintenance). The part properties are determined on the basis of specified procedures. More details about the procedures used by SLM Solutions are available upon request.
The specifications correspond to the most recent knowledge and experience available to us at the time of publication and do not themselves form a sufficient basis for component design. Certain properties of products or parts or the suitability of products or parts for specific applications are not guaranteed. The manufacturer of the products or parts is responsible for the qualified verification of the properties and their suitability for specific applications. The manufacturer of the products or parts is responsible for protecting any third-party proprietary rights as well as existing laws and regulations.

SLM Solutions Group AG
Materialentwicklung / Material Development
Lübeck, den 08.02.2017

[1] Optische Dichtebestimmung mittels Lichtmikroskopie. / *Optical density determination by light microscopy.*

[2] Materialdatei / *Material data file:* Inc_SLM_BP2.1_30_Stripes-US_T200_S09-02_V4101

[3] Materialdatei / *Material data* file : Inc_SLM_BP2.1_50_Stripes-US_T0_S32-04_V4101

[4] Bzgl. pulverförmigen Ausgangsmaterial. / *With respect to powder material.*

[5] Gemäß DIN EN ISO 3252. / *According DIN EN ISO 3252.*

[6] Materialprüfung wie gebaut, ohne Nachbehandlung/ as built, without post-processing.

[7] Zugprüfung gemäß ISO 6892-1: 2009 B (DIN 50125 – B6x30); Ausrichtung: 0° und 90°; Wärmebehandlung: keine; Prüfmaschine: Zwick 1484; Lastbereich: 200 kN; Prüfgeschwindigkeit 0,008 1/s; Prüftemperatur: Raumtemperatur; Prüflabor: EWIS GmbH/EADS. Die Proben sind vor dem Zugversuch abgedreht worden. / *Tensile test according to ISO 6892-1: 2009 B (DIN 50125 – B6x30); Orientation: 0° und 90°; Heat treatment: None; Testing machine: Zwick 1484; Load range: 200 kN; Testing speed: 0,008 1/s; Testing temperature: room temperature; Test laboratory: EWIS GmbH/EADS. Test samples were turned before Tensile test.*

[8] Härteprüfung gemäß DIN EN ISO 6507-1. / *Hardness testing according to DIN EN ISO 6507-1.*

[9] Rauheitsmessung gemäß DIN EN ISO 4288: 1998; λc = 2,5 mm. / *Roughness Measurement according to DIN EN ISO 4288: 1998; λc = 2,5 mm.*

[10] Wärmebehandlung / heat treatment: 1107°C/2h + cool3°C/min to 899°C + 913°C/8h + 982°C/6h + 802°C/4h

[11] Wärmebehandlung / heat treatment: 1107°C/2h + cool3°C/min to 899°C + 913°C/8h + 982°C/6h + 802°C/4h + HIP

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