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Structural Analysis of a Die for Powder Alloy Compaction

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Abstract: Adequate compaction of metal alloy powders is important to provide raw material with suitable features for post-processing. The compaction degree controls the densification process, which impacts the resistance of the compacted. Therefore, the structural analysis of a die was performed to investigate to which limit load it can be subjected with a safety margin of 50%. The simulation was conducted via the finite element method and demonstrated that the limit load the die can support is 436.84 kN under this safety margin. This result addresses that the die was being underutilized due to lack of knowledge about its resistance. Thenceforth, now a greater load can be applied to improve the densification of the compacted, thus augmenting its resistance.

Keywords: Structural analysis; Die; Powder compaction; Powder metallurgy.

Análise Estrutural de uma Matriz para Compactação de Pó de Liga

Resumo: A compactação adequada de pós de ligas metálicas é importante para fornecer matéria-prima com características adequadas ao pós-processamento. O grau de compactação controla o processo de densificação, que impacta a resistência do compactado. Portanto, a análise estrutural de uma matriz foi realizada para investigar a qual carga limite ela pode ser submetida com uma margem de segurança de 50%. A simulação foi conduzida via método dos elementos finitos e demonstrou que a carga limite que a matriz pode suportar é 436.84 kN sob esta margem de segurança. Este resultado indica que a matriz estava sendo subutilizada devido à falta de conhecimento sobre sua resistência. Então, uma carga maior pode ser aplicada para melhorar a densificação do compactado, aumentando assim sua resistência.

Palavras-chave: Análise estrutural; Matriz; Compactação de pó; Metalurgia do pó.

Introduction

In powder metallurgy (PM), a solid shape is the output from a wet raw powder input. In rare cases, the compacted powder presents mechanical properties that do not require post-processing [1]. Nevertheless, to improve its mechanical properties, the common case addresses to post-processing the compacted, which frequently consists of heat treatments to enhance geometric parameters, metallurgical characteristics, and mechanical properties [2-3]. Alternative post-processing routes include powder conditioning, in which additives are mixed to powder mass to connect, plasticize, and lubricate the particles.

The cold axial compaction via punching requires rigid tooling when compared to the rigidity of the mass to compact. The cavity of the die receives the powder mass to be pressed by a vertical punch in a top-down movement. The load over the particles forces them against: (a) the internal surface of the die; (b) the lower surface of the upper punch; and (c) the upper surface of the base [4-5]. In view of this, die assembly should be analyzed in terms of its structural integrity when pressing metal powder.

Objective

The main objective of this work is to calculate the limit load of a die via the finite element method, when pressing AlCoCrFeNi powder metal alloy [6].

Material and Methods

In this paper, the structural analysis was performed in Ansys®. The mechanical properties of the materials involved, and their dimensions are presented in Table 1. The metal powder elastic modulus corresponds to a porosity of 50%. The symbolic representation of the dimensions and the boundary conditions of the die assembly are represented in Figure 1.

Table 1. Material properties and dimensions of the parts of the die assembly.

Part	Material	Elasticity modulus (GPa)	Poisson's ratio	Density (kg/m^3)	Yield strength (MPa)	Dimensions (mm)
Punch	AISI D2	207	0.28	7700	1500	A = 30; B = 25; C = 20; D = 25.
Base	AISI D2	207	0.28	7700	1500	A = 30; B = 25; F = 15; G = 10.
Die chamber	AISI D3	190	0.27	7860	2000	A = 30; B = 25; H = 50.
Metal powder	AlCoCrFeNi	91.5	0.3	3577	750	B = 25; E = 20.

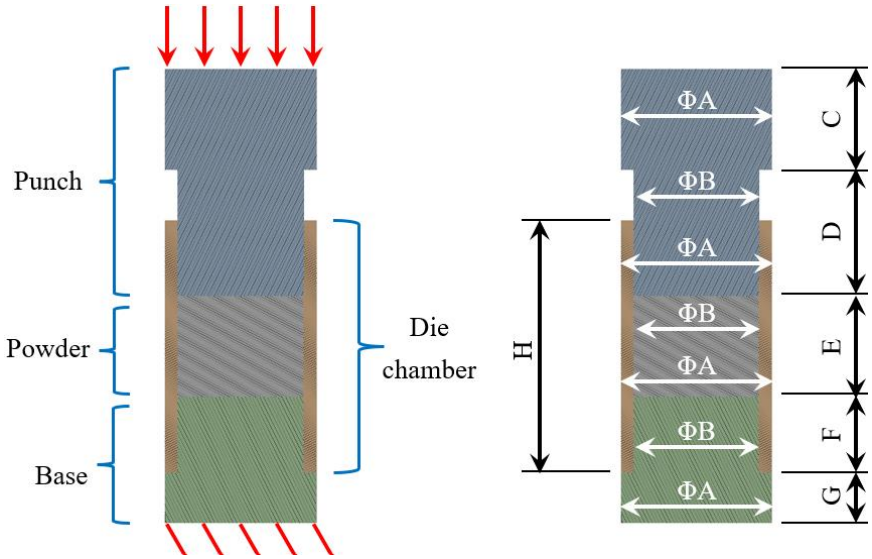


Figure 1. Representation of dimensions and boundary conditions of the die assembly.

According to Figure 1, the computational model was built up considering the base clamped. The axial pressure of 618 MPa was applied to the upper surface of the punch directed downwards aiming at pressing the powder mass which, in turn, reacts against all other parts. The minimum safety factor considered herein is 1.5. Therefore, the stress analysis was conducted in order to determine the limit load of the die assembly, observing the aforementioned safety. The safety factor was calculated by the ratio between the yield strength and the maximum von Mises stress. The limit load was obtained by multiplying the applied pressure by the area of the upper face of the punch.

Results

The results are directly expressed in terms of the maximum von Mises stress in Table 2. Based on this stress, the calculated safety factor, and the limit load of the die assembly are also presented in Table 2. The plot of von Mises stresses is shown in Figure 2.

Table 2. von Mises stress, safety factor, and limit load for the die assembly.

Result	Value
Von Mises stress (MPa)	999.56
Safety fator	~1.50
Limit load (kN)	436.84

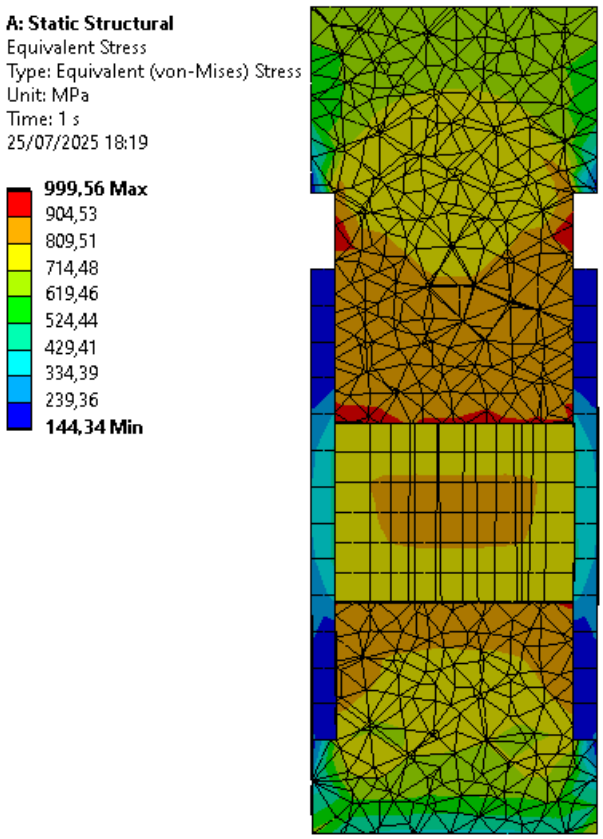


Figure 2. Von Mises stresses plot of the die assembly.

Discussion

The results were obtained for the pressure of 618 MPa, which corresponding von Mises stress was obtained, observing the safety factor of approximately 1.5. The stress distribution over the parts is according to the expected, where the highest stress (999.56 MPa, shown in red color in Figure 2) occurs at the interface between the punch and the AlCoCrFeNi powder, preponderating at the lower surface of the punch. This is the reason why the material of the punch should be more resistant than the material of the powder to compress.

In what refers to the punch, the region located in the outer surface of the punch (between the upper surface of the die chamber and the lower surface of the head of the punch), also shown in red color, are prone to be improved by reducing its exceeding length. In addition, the stresses at the corners could be reduced by chamfering or rounding, except for the lowest corner, which should be kept without any smoothing because of the characteristics of the compacted.

The analysis related to the AlCoCrFeNi alloy powder addresses that its boundaries are within the range from 714.48 to 809.51 MPa, which probable leads to the plasticization of the boundaries of the powder. The remaining part of the powder (core) was found to be between 809.51 and 904.53 MPa, which assures the plasticization of the core part of the powder. In the case of non-plasticization, only thin boundaries of the powder are not guaranteed to plasticize. However, as already discussed in the introduction, post-processing may improve the densification of the compacted.

The wall at half height of the die chamber presents stresses between 239.36 and 429.41 MPa, which corresponds, respectively, to only 11.97 and 21.47% of its yield strength. The stresses at both ends of the die chamber (the safest regions of the part) go from 144.34 to 239.36 MPa, which represent, respectively, 7.22 and 11.97% of the material yield strength of the die chamber.

The base presents its highest level of stress at its upper surface and at its outer surface in contact with the die chamber (from 809.51 to 904.53 MPa), which represent, respectively, 53.97 and 60.30% of the yield strength of the material. On the other hand, the stresses at the lower part of the base range from 429.41 to 809.51 MPa (28.63 to 53.97% of the yield strength), safer than the upper part of the base.

In view of the results presented in Figure 2, and supposing the dimensions of the metal alloy powder cannot be modified, several improvements can be implemented to optimize the usage of the material:

(a) Punch: the length of its lower part can be reduced if the length of the die chamber is also reduced. The upper part can also be reduced in length. Rounding or chamfering should be implemented at the eligible corners.

(b) Base: changes analogously to those described for the punch.

(c) Die chamber: the thickness can be reduced. The length can also be reduced if the lengths of the punch and the base are also reduced. A material with a lower yield strength can also be selected.

Conclusions

The general objective of obtaining the limit load for the die assembly has been reached. In compliance with the discussion, if the objective is to keep 50% of safety margin, the limit load of 436.84 kN should not be surpassed.

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