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Shearing Properties of Hard Metal Powder and Iron Powder in the Low Density Range

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Abstract

Both plastic and elastic properties change dramatically from the beginning to the end of the compaction phase. Previous investigations have shown that powder transfer and high powder flow during initial compaction at low density affects the strength of the final component significantly. Investigated here are shear failure and elastic shear modulus in the low density range for hard metal powder and for pre-alloyed water atomized iron powder. Direct shear test equipment for sand and clay has been modified to measure the shearing properties of powder for an axial loading between 1 kPa and 500 kPa.

Keywords: Powder, Shear Failure, Elastic Shear Modulus, Low Density Range, Powder Flow

1. Introduction

Powder pressing is often a complicated process as the behaviour of the powder material changes with increasing density. Manufacturers tend to produce components with more complicated shapes which demand complex pressing equipment and methods. This implies a better knowledge of the material response during the pressing process. Both plastic and elastic properties change dramatically from the beginning to the end of the compaction phase. Previous investigations have shown that powder transfer and high powder flow during initial compaction at low density affects the strength of the final component significantly. Investigated here are cohesion, shear failure, elastic shear modulus, shear compaction and dilatation in a density range between 3.42 – 4.04 g/cm^3 for a hard metal powder mix (tungsten carbide with 10% cobalt and 2% PEG) and 3.60 – 4.08 g/cm^3 for a pre-alloyed water atomized iron powder mix, Distaloy AE with 0.5% carbon and 0.6% Kenelube. In simulation of powder pressing, advanced models and proper indata are often required. A number of tests have been developed to characterize powder behavior [1]. The consolidation phase in a pressing process covers a large density range. Almost all tests demand some densification to detect material properties. To cover the low density range, data from the mid density range has to be extrapolated. Both models and tests have to be developed to better describe low density characteristics. The aim of this study is to investigate and determine shear properties of powder in the low density range.

2. Experimental Setup and Results

The direct shear test is a well established test for geotechnical materials like sand and clay, [2]. Powder is filled into a cylindrical container with a side wall of thin latex reinforced with a thin copper thread. In this study the original equipment is modified with extra support to the latex wall close to the top and bottom surface. To prevent slip during testing the top and bottom surfaces have 4.05 mm spikes 5.0 mm apart. The total sample height is h and the distance between the spikes called active sample height, h_a, is 11 – 15 mm during a test. A vertical force, F_v, is applied on the top surface. The shearing is then induced with a movement, d, applied on the top surface. The shear force, F_h, together with F_v, h, and d are recorded during a test. In Fig. 1 are the direct shear test and its properties illustrated.

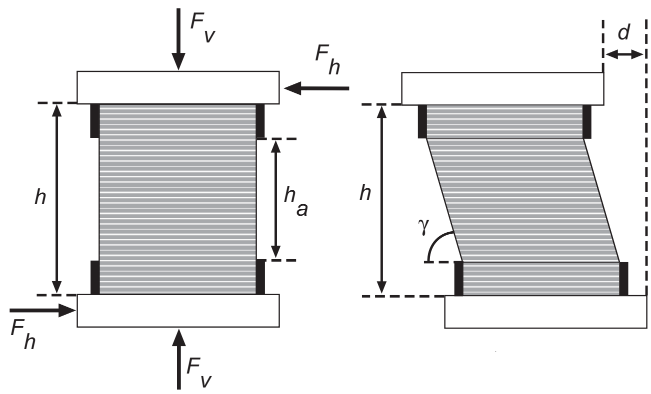

Fig. 1 The Direct Shear Test of powder.

From the recorded properties are the shear angle, γ, normal stress, σ_n, shear stress, τ, elastic shear modulus, G_{sec} and density, ρ, calculated. Typical response from a direct shear test is illustrated in Fig. 2. Curve 1 in Fig. 2 has a clear shear failure, where τ_{fu} is the shear failure stress at γ =

0.10 rad, but, Curve 2 has no failure point. If not a clear shear failure is found $\gamma = 0.15$ rad is used to define the shear failure. In Fig. 2 G_{sec} is also presented for the curves. In this study G_{sec} is a secant value and defined as a straight line from the origin that inclines with the curve at $\tau = \tau_{fu}/2$.

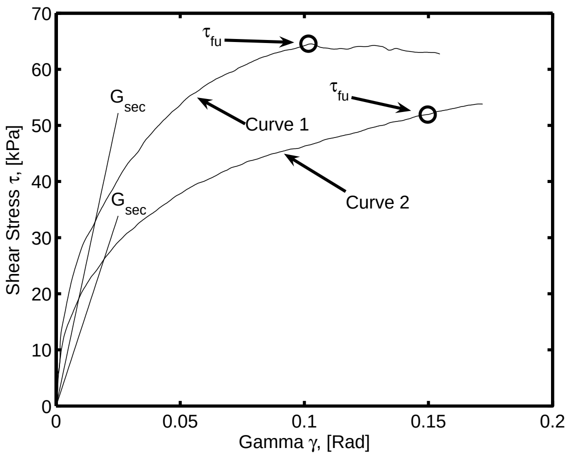

Fig. 2 Typical response of a direct shear test, τfu is the shear stress at failure. In curve 2 shear failure can not be found, γ = 0.15 rad is used to define the shear failure.

In Table 1 main results from the direct shear tests are shown. For Iron powder the lowest applied normal stress was 1.23 kPa at a density of 3.60 g/cm^3 and the highest normal stress was 481.56 kPa at a density of 4.08 g/cm^3. For hard metal powder the lowest normal stress was 6.18 kPa at a density of 3.42 g/cm^3 and the highest normal stress 481.56 kPa at a density of 4.04 g/cm^3. The stiffness from the latex wall is measured and compensated for in the calculation of shear stress τ.

Table 1. Shear failure τ_{fu} at different normal stresses σ_n, density ρ, shear angle γ and the elastic shear modulus G_{sec} are presented.

Powder	σn [kPa]	ρ [g/cm3]	τfu [kPa]	γ [Rad]	Gsec [kPa]
Distaloy	1.23	3.60	2.74	0.150	28.2
Distaloy	5.63	3.71	3.51	0.150	31.9
Distaloy	11.42	3.83	5.61	0.150	89.8
Distaloy	23.43	3.92	9.13	0.056	690
Distaloy	95.49	3.96	64.56	0.102	2088
Distaloy	481.56	4.08	332.05	0.150	5596
WC-Co	5.95	3.42	6.18	0.150	166
WC-Co	23.97	3.57	15.41	0.082	594
WC-Co	95.17	3.70	51.92	0.150	1355
WC-Co	481.56	4.04	202.64	0.150	4037

In Fig. 3 and Fig. 4 response curves from direct shear tests of Distaloy AE and WC-Co powder are shown.

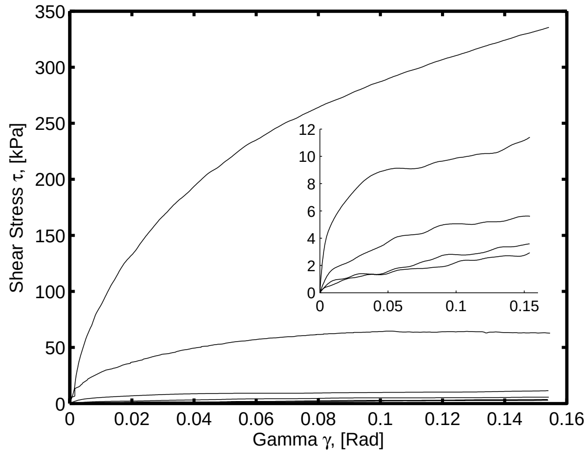

Fig. 3 Direct shear test of Distaloy AE powder for different normal force loads. Magnified axes for the low shear stress measurements inside the figure.

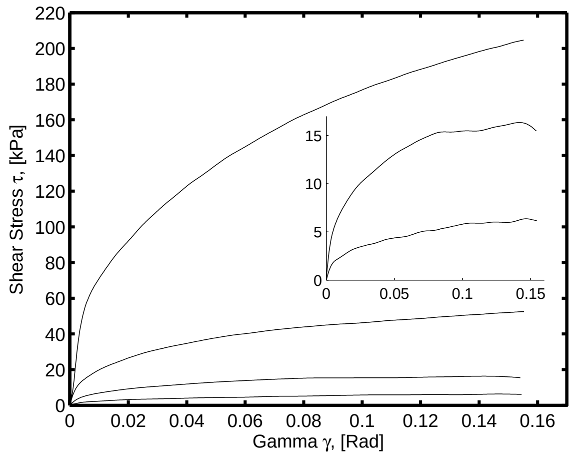

Fig. 4 Direct shear test of WC-Co powder for different normal force loads. Magnified axes for the low shear stress measurements inside the figure

3. Summary

In powder compaction, powder behaviour at the low density affects the properties of the final component. Direct shear equipment for sand and clay have been modified to measure shear properties of powder in the low density range. Shear failure stress, τ_{fu} at different normal stresses, σ_n, density, ρ, shear angle, γ and elastic shear modulus, G_{sec} are presented.

4. References

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