The results from shear cell tests can be graphically represented in several ways. The most reliable representation is a plot of the measured Shear Stress (τ) as a function of Applied Normal Stress (σ), as these data are genuine representations of a powder's ability to flow following consolidation.

A common way of presenting multiple results is to use a Flow Function (FF) graph - a plot of the Unconfined Yield Strength (UYS) as a function of the Major Principle Stress (MPS) derived from Mohr's circles analysis. However, generating these parameters can introduce variability into the data due to the mathematical models applied in the derivation. It is therefore possible for an analysis of the Flow Function to suggest differences or variability that are not truly representative of a powder's shear properties.

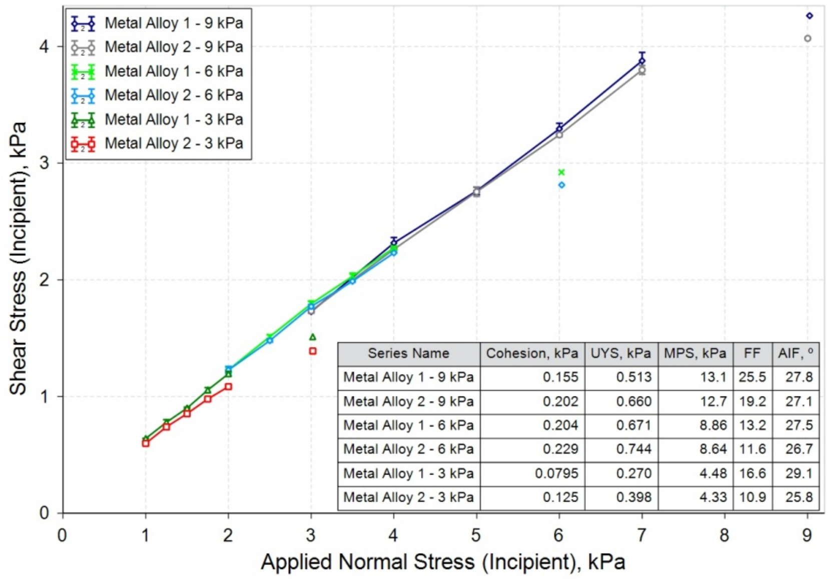
VARIATION IN FLOW FUNCTION

Two samples of a metal alloy powder were observed to perform differently in process, resulting in a variation in the properties and quality of the final product. A range of traditional characterisation techniques were employed, but did not differentiate between the samples.

The two powders were analysed using the range of methodologies available with the FT4 Powder Rheometer®. This included Shear Cell tests at 3, 6 and 9 kPa Pre-Shear stress, in order to determine the measured Shear Stress values, as well as the derived parameters of MPS, UYS and FF as proposed by Jenike[1].

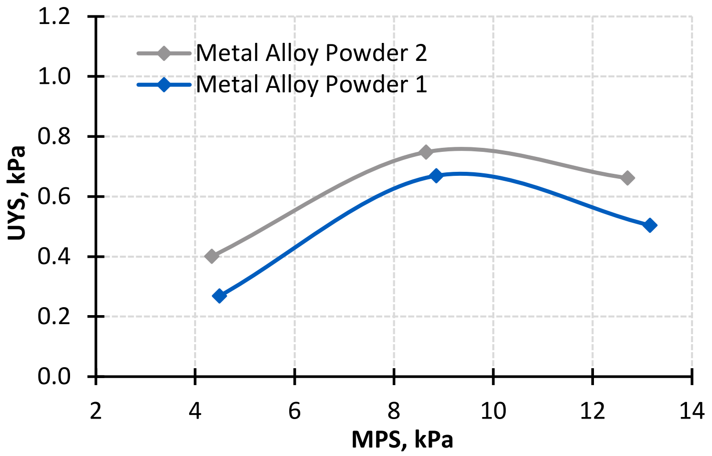
TEST RESULTS

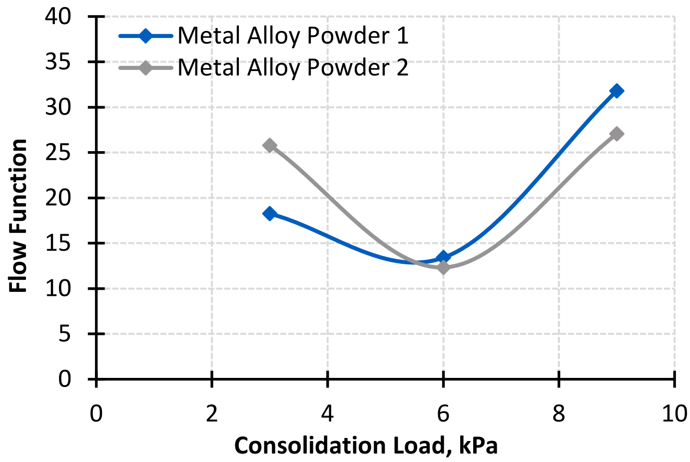
Shear Cell Testing



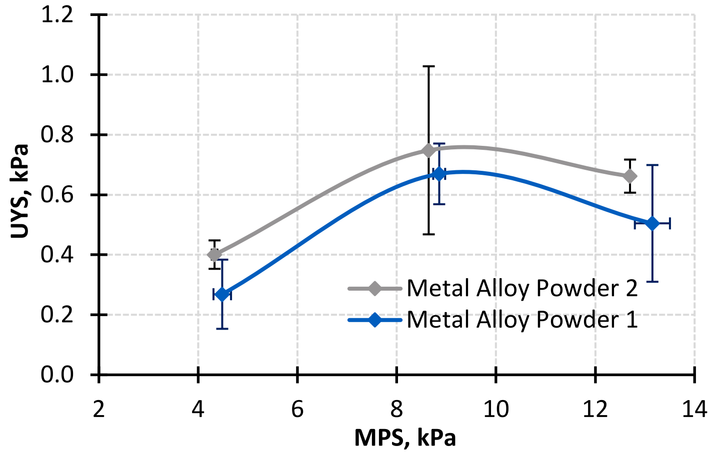
Series Name	Cohesion, kPa	UYS, kPa	MPS, kPa	FF	AIF, °
Metal Alloy 1 - 9 kPa	0.155	0.513	13.1	25.5	27.8
Metal Alloy 2 - 9 kPa	0.202	0.660	12.7	19.2	27.1
Metal Alloy 1 - 6 kPa	0.204	0.671	8.86	13.2	27.5
Metal Alloy 2 - 6 kPa	0.229	0.744	8.64	11.6	26.7
Metal Alloy 1 - 3 kPa	0.0795	0.270	4.48	16.6	29.1
Metal Alloy 2 - 3 kPa	0.125	0.398	4.33	10.9	25.8

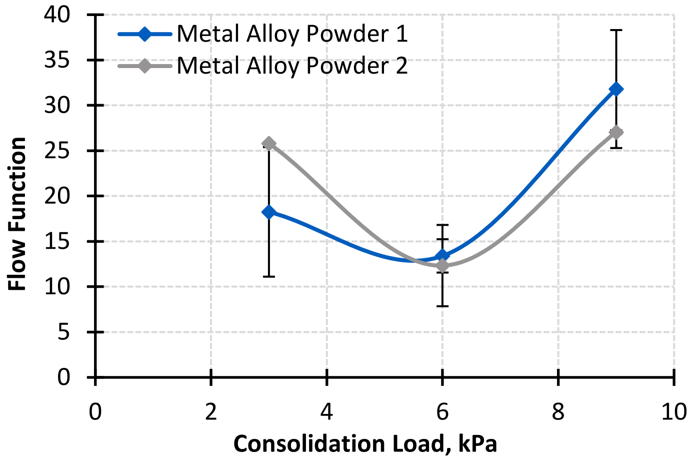
At the three different levels of Pre-Shear stress, the Yield Loci revealed negligible differences between the materials, suggesting that both would exhibit similar behaviour in terms of flow from large hoppers. However, minor variations in the attitude of the best-fit lines applied during Mohr's circle analysis caused significant differences in the values generated for Cohesion and UYS at each Pre-Shear stress, resulting in large differences in the Flow Function values.





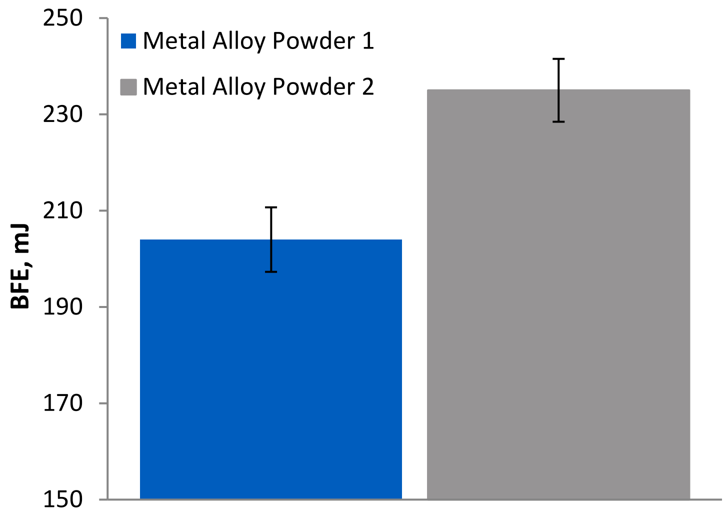
The Flow Function graphs show a separation between test results that might be interpreted as a genuine difference between the two powders, which could then rationalise the observed process performance. However, the Yield Loci have indicated negligible differences between the two samples in terms of actual measured Shear Stress. The apparent separation is a consequence of the mathematical model applied to derive the UYS and MPS values.

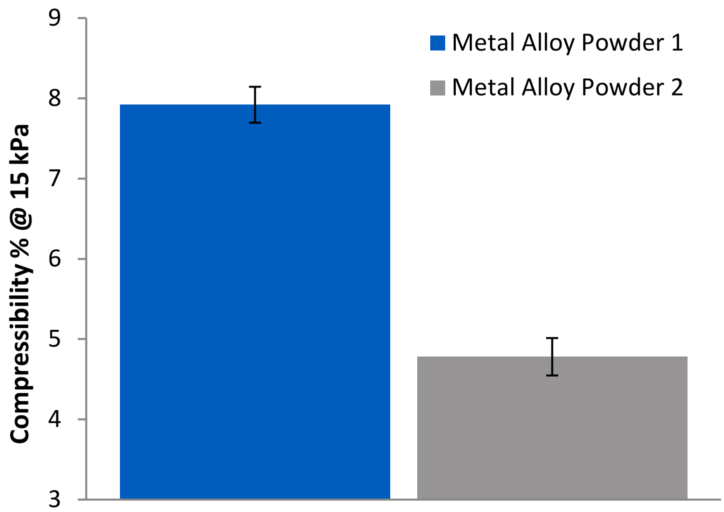




Furthermore, when the variation from repeat tests is considered, the differentiation becomes considerably less robust. The error values in the derived parameters mean that a statistically significant difference is not observed. The right-hand graph also confirms that Flow Function is dependent on consolidating load, and therefore cannot be used as a universal property to describe a powder's flowability.

Dynamic Flow & Bulk Testing





Dynamic Flow and Bulk tests using the FT4 produced statistically significant differences between the two powders. Powder 1 has a lower Basic Flowability Energy (BFE) and higher Compressibility than Powder 2, suggesting that Powder 1 is likely to exhibit more cohesive behaviour manner in lower stress, dynamic processes such as pouring and dispensing.

CONCLUSIONS

Shear cell testing is an important technique that can provide valuable information, but has greater relevance to certain unit operations. It should not be relied on alone to understand performance in a range of unit operations that subject a powder to different conditions. Shear cell tests that return similar values for measured Shear Stress indicate comparable performance in high stress, low flow operations such as hopper discharge. Any differences subsequently reported by the derived parameters should be used with caution, as the example above demonstrates why they may be a function of the model applied to the data.

Powder flowability is not an inherent material property. It is about the ability of powder to behave in a desired manner in a specific piece of equipment. Successful processing demands that the powder and the process are well-matched and it is not uncommon for the same powder to perform well in one process but poorly in another. This means that several characterisation methodologies are required, the results from which can be correlated with process ranking to produce a design space of parameters that correspond to acceptable process behaviour.

For further information, please contact the Applications team on +44 (0) 1684 851 551 or via support@freemantech.co.uk.

[1] A.W. Jenike: Storage and flow of solids. Bulletin 123, Engineering and Experiment Station, University of Utah, USA (1964).