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Simulation of high velocity compaction of powder in a rubber mould with characterization of silicone rubber and titanium powder using a modified split Hopkinson set-up

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Abstract

The paper introduces a method for characterization of silicone rubber and titanium powder in high velocity compaction using the split Hopkinson set-up. The impact test data has been used to estimate parameters in constitutive models for rubber and powder. A finite element study has been performed with different geometrical design of the high velocity compaction of titanium powder against an aluminium mandrel using a rubber mould as pressing medium. One goal of this study is to investigate if and how the manufacturing method can be applied for making dental copings.

A conclusion of the experimental work is that it is possible to characterize rubber material and powder material for high velocity compaction of metal powder by the use of a modified split Hopkinson pressure bar set-up. The numerical simulation shows qualitatively good agreement with the experience from practical tests. In conclusion, the work shows the possibility to numerically study the geometric design and to optimize the densification behaviour of a complex high velocity compaction process.

Keywords: Constitutive behaviour; High velocity compaction; Finite element simulation; Impact testing; Titanium powder; Silicone

1. Introduction

The manufacturing method studied here is high velocity (or high speed) powder forming using a rubber material as pressing medium. High velocity compaction is a mass production technique with the capacity to significantly improve the mechanical properties, and hence expand the applications of powder metallurgy (PM) parts. An overview of the process and its capabilities, and potential applications are discussed in [1]. Experimental investigations with this manufacturing method on iron based powders [2–4] show many interesting aspects of the manufacturing method.

High velocity compaction technique applied to samples of high purity titanium powder shows that a relative green density higher than 98% could be obtained [5]. The titanium material could be used for medical and dental applications [6]. In the process studied here an aluminium mandrel and titanium powder are placed inside a silicone rubber form which is put into a steel die. This is followed by a fast and hard impact compacting the powder. The task of the rubber is to create a nearly isostatie state of loading to compress the powder as uniformly as possible both axially and radially. To find an optimal geometrical design of the tool it is necessary to perform simulations of the compaction process. Therefore knowledge of the mechanical behaviour of the rubber and the powder during high speed loading is required.

This paper deals with characterization, modelling and simulation of a complex system with aluminium and steel

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Fig. 1. Loading tool with punches. Die dimensions d_o=100 mm, d_i=25 mm, length=74 mm.

tools, titanium powder and silicone rubber where loading is applied by a hammer impacting with high velocity.

2. Experiments

The behaviour of a silicone rubber and a high purity titanium powder is characterized by static and dynamic testing. The static testing is performed in a Common static testing machine, DARTEC Ml000 (250 kN) with control unit M9500, by using a loading tool consisting of two cylindrical punches to load the material in axial direction and a die to avoid material flow in radial direction.

The dynamic testing is performed using a modified split Hopkinson pressure bar (SHPB). In a classical compression SHPB set-up, a specimen is placed between two elastic bars (input and output bar), with constant mechanical impedance and loaded by an incoming compressive wave. The stress and strain in the specimen during loading are evaluated from the strain measured on the input and the output bar, see [7]. The classical set-up is here modified by using a loading tool consisting of a cylindrical die and two punches for confining and loading the specimen. The bars and the projectile are made of quenched steel with yield stress of about 500 MPa and have diameters of 25 mm. The projectile has a length of 300 mm. The impact loading is achieved when the projectile is accelerated inside an air gun and impacts the end of the input bar and creates the elastic wave propagation. The incoming and also the reflected wave are measured with two pairs of strain gauges which are mounted on the input bar. The compression force that is transmitted through the specimen is measured with one pair of gauges on the output bar. All strain gauges are of foil type with a gauge length of 6.35 mm. The signals from the gauges pass through the amplifiers and are finally sampled with a frequency of 2 MHz. The amplifiers have a bandwidth of 100 kHz. The same loading tool are used for the dynamic tests as for the static tests. The dimensions of the loading tool are shown in Fig. 1 and the set-up for SHPB is shown in Fig. 2.

The evaluation procedure follows the theory of the classical SHPB as described in [7] except that here the volume is not constant and the radial deformation is negligible compared to the axial deformation.

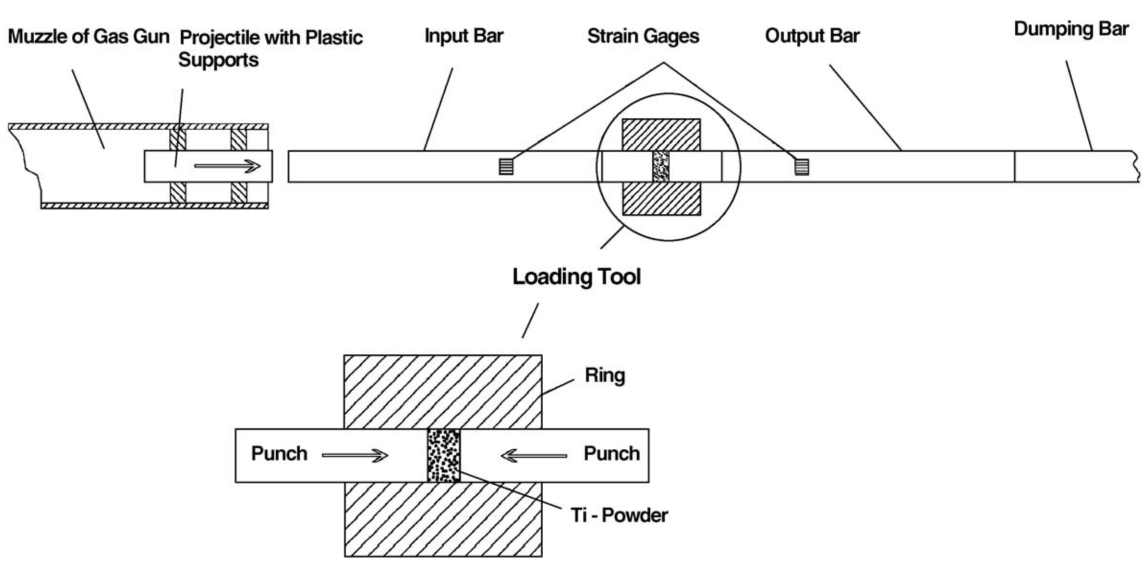

Fig. 2. Split Hopkinson set-up with loading tool—schematic.