

## EQUIPMENT FOR DYNAMIC COMPACTION OF METAL POWDERS

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### **Abstract**

*The processing of nanostructured metal powders via powder metallurgy encounters the problem of excessive grain growth during sintering. Alternative techniques are investigated to obtain densities close to theoretical. Cold dynamic compaction by shock wave offers a possibility to achieve this goal without grain growth. This communication describes a light gas gun able to generate shock wave with sufficient energy to result in an efficient compaction without the necessity of heat application.*

**Keywords:** *dynamic powder compaction, light gas gun, nanostructured metal powders*

### INTRODUCTION

The compaction of work-hardened metal powders produced by high energy ball milling or mechanical alloying is frequently not viable by cold pressing due to their low compressibility. Hot pressing or hot isostatic pressing can not be applied if nanostructure has to be maintained. One of the possibilities to obtain densities close to theoretical is dynamic compaction by a shock wave [1]. Shock waves in the velocity range of 700 - 1000 ms<sup>-1</sup> are necessary to obtain sufficient densification [2]. Essentially two methods can be applied to produce shock waves in a material: explosion and impact of a projectile. In this work a light gas gun for dynamic compaction of mechanically alloyed aluminium-based powders is described.

### SHOCK WAVE GENERATION IN A LIGHT GAS GUN

A shock wave is a transient phenomenon that occurs when a sudden pressure variation, as in an explosion, propagates with supersonic speed through a medium. The properties of the medium (pressure and temperature) are changed during the shock wave propagation, returning to a similar state, but slightly altered from the medium original state.

The changes caused during the shock wave propagation into the medium are significant. If the shock wave propagates in a gaseous or liquid medium, ionization and plasma formation is detected. In a solid or powdered medium, the shock wave propagation will cause severe changes in the interaction between metallic crystals or particles, and, as a consequence, in the mechanical properties of the material. In particulate materials densification occurs as a result of rearrangement, deformation and micromelting [3].

To generate a shock wave, various methods can be used: chemical explosions, combustion, pressure accumulative devices. All of these methods are characterised by the extremely fast pressure increase, due to a fast valve opening, the rupture of a diaphragm or the chemical liberation of the kinetic energy stored in some combustible materials.

## DESCRIPTION OF THE EQUIPMENT

In this paper, the accumulative device developed to study the dynamic powder compaction is described. Based in a similar technology as the used in some types of shock tubes and tunnels, and in ballistic devices, the device is known as Light Gas Gun (LGG) [4] and is largely used as a source for a single pulse of high pressure, high temperature compressed gas. This condition is desirable when operating a shock tube or tunnel, or in a ballistic launcher, as an economical method to achieve some critical conditions of driver gases.

The small LGG, 40 mm piston diameter (Fig.1), developed for the compaction of mechanically alloyed Al-Ti powders is composed of a high pressure reservoir, dimensioned to operate at 100 MPa static pressure at room temperature, a fast opening piston valve, a free piston and a honed tube, in which the free piston runs, Fig.1.

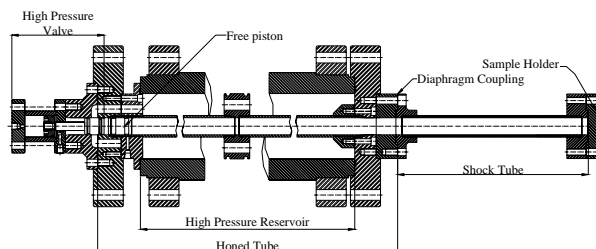


Fig.1. Scheme of the 40 mm diameter light gas gun with shock tube.

All the components are medium carbon steel, except the free piston and the valve, both hardened due the high accelerations they will be submitted. The high pressure reservoir was fabricated from a cold rolled 0.45 % C steel, machined from a 250 mm ext. diameter bar and 4000 m length. This piece was drilled to 152.4 mm internal diameter. The reason for this thick wall (48.8 mm) is an alternative operation mode, since it was designed originally for the UNIVAP Hypersonic Shock Tunnel [5]. This piece is therefore used in this equipment without any geometrical change.

A fast opening valve is specially designed for this work. Composed by a pneumatic actuator, which pulls a bulk head in a monolithic construction, the valve closes an annular gap in the coupling of the support flange and the honed tube, Fig.2a, isolating the high pressure reservoir from the free piston.

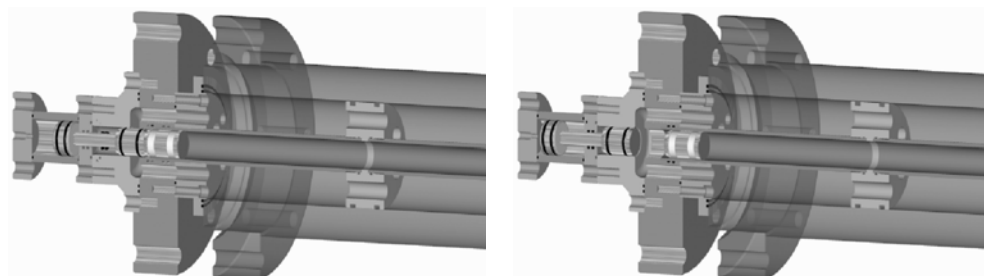


Fig.2. Schematic drawing of the high pressure valve, a) closed, b) opened.

## OPERATION MODE

When the valve is opened, Fig.2b, the highly pressurised gas flows through the annular gap and pushes the free piston along the honed tube, in the shock tube direction. During the movement, the free piston converts the accumulated energy in the high pressure reservoir in kinetic energy accelerating the free piston against a second amount of light molecular weight gas, such as helium or hydrogen. The kinetic energy converted as pressure and temperature increasing in the light gas is suddenly liberated when a thin membrane, known as diaphragm, bursts.

The diaphragm rupture causes the shock wave generation and propagation in the shock tube gas. A quasi-planar one-dimensional shock wave is attained only after an approximate length of ten times the shock tube diameter, so the need to attach the shock tube at the LGG end. The sample holder, placed at the shock tube end, receives the incident shock wave, transmitting it to the sample and generating the Dynamic Compaction Process.

## CONCLUDING REMARKS

Using different gases in the driver of the light gas gun, or by changing the gas pressure behind the free piston, the final velocity can be easily changed and so the operational conditions are continuously controlled in the desired parameter range.

The energy transferred by the gas in this system enables different operation modes: the direct impact of the piston against a stopped sample, the impact of the moving sample holder against a solid wall, or the impact of a propagating shock wave against the sample, generated by the light gas gun used as a free piston compressor are the principal operational modes in the system presented in this paper. The operation mode must be determined as a choice of one from these three methods, according to the expected result in the powder sample.

The above mentioned advantages of the use of cold highly compressed gases (near ambient temperature) to launch a small piston against the powder sample in comparison with gun powder or chemical driven systems compensate the larger time required to prepare the light gas gun.

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