Characterisation of the dynamic compressive behaviour of ceramic using planar plate-impact and shockless plate-impact experiments

J. Genevois[1a], P. Forquin[1b]

[1]*Univ. Grenoble Alpes, Grenoble INP, CNRS, 3SR laboratory, BP 53, 38041 Grenoble Cedex 9, France*

[a]julia.genevois@univ-grenoble-alpes.fr, [b]pascal.forquin@univ-grenoble-alpes.fr

Keywords: Compression, High loading-rates, Plate-impact, Ceramic, Lagrangian analysis

Abstract. In the present work, “classical” planar plate-impact experiment and shockless plate-impact tests are conducted to characterize the compressive behaviour of ceramic. The shockless plate-impact technique is based on the use of a wavy-machined flyer plate produced by chip-forming which impacts a target made of a buffer plate bounded to the ceramic plate. According to the velocity profiles measured on the rear face, whereas a sharp rising edge is noted in case of flat contact (planar plate-impact), a smooth rising edge is obtained in the case of shockless plate-impact test. Considering a target made up of two ceramic plates of different thicknesses this kind of test provides the possibility to conduct a Lagrangian analysis of data.

Introduction

Ceramic materials are widely used in armour or protective structures. In these conditions they experience extreme damage, micro-plasticity and fragmentation mechanisms. To fully understand these behaviours, characterization under high-strain-rate compression needs to be conducted. Several experimental techniques are used to investigate the dynamic behaviour of ceramic under high compressive loading and one of them is the plate-impact testing technique. During this test, a metallic flyer plate hits the desired target, and some mechanical properties such as the HEL (Hugoniot Elastic Limit) as long as the Hugoniot curve of the material can be deduced thanks to the velocity profile measured at the back of the target. Nevertheless, this test has the inconvenient of not providing a controllable loading-rate in the target and the hardening behaviour cannot be directly deduced. The high-pulsed-power technology, such as the GEPI machine, provides the possibility to perform Lagrangian analysis, which gives access to the whole loading path of the material whereas only one point on this loading path can be obtained after one plate impact experiment [1-2]. This method, based on the integration of the equations of conservation of mass, momentum and energy does not need any assumption on the behaviour of the material. The principle is based on a comparison of velocity signals obtained on two different thicknesses of a material.

An alternative to the GEPI machine in order to apply a Lagrangian analysis is the use of a wavy-machined flyer plate (Fig. 1) impacting a buffer plate taped to the ceramic plate as it is proposed in [3]. However, such test requires the different parts to be well-sized and the flyer and buffer materials to be carefully selected. Indeed, the yield strength of both plates needs to be high enough. Steel being easy machined and providing high yield strength, it was decided to use this kind of metal. Given the very high impact speed required to test ceramics in compression (over 800 m/s), steel without phase transformation needs to be considered.

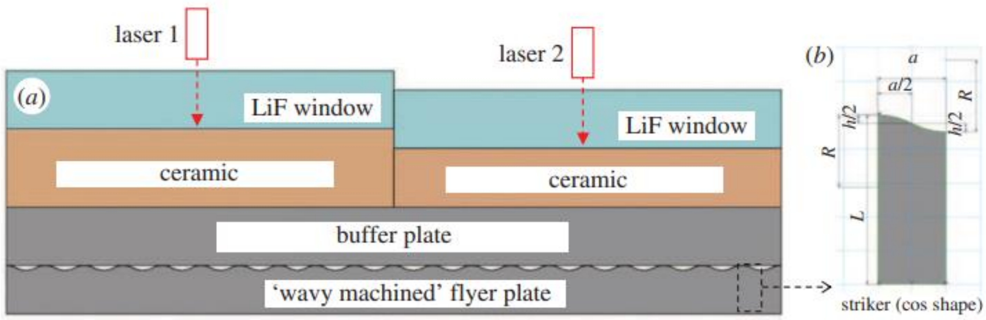

Fig. 1. Experimental technique based on a wavy-machined flyer plate that produces a pulse-shaping effect in order to perform Lagrangian analysis [3].

Experimental work

For these purpose, planar plate-impact and shockless plate-impact experiments were first conducted considering only a buffer plate made of steel as target. “Classical” planar plate-impact tests with flyer and buffer plates made of the same steel were conducted at various impact speeds up to about 900 m/s. Based on these experiments, one steel, the 316L steel, that does not exhibit any phase transformation, was selected. Next, a pulse-shaped plate impact test was conducted considering 316L wavy-machined flyer plate characterised by a wave period of 2 mm and a height of wavy surface of 0.5 mm. Again, a flat plate made of the same steel was used as target. The velocity profile measured on the buffer rear face shows a rising time about 0.4 µs as illustrated in Fig. 2.

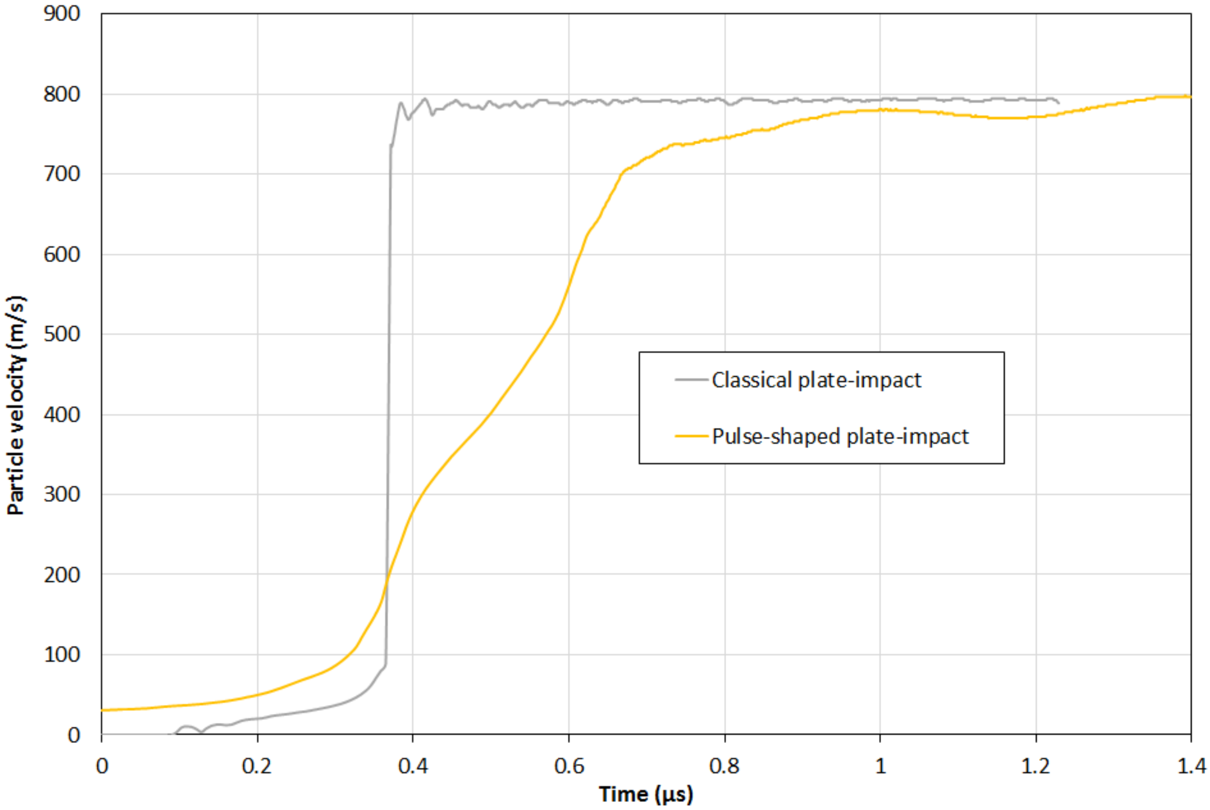

Fig. 2. Comparison of the velocity profiles measured on the rear face of buffer plate made of 316L steel considering planar plate-impact and pulse-shaped plate-impact configurations.

In a second stage, planar plate-impact and shockless plate-impact testing techniques were applied to ceramic material. In case of planar plate-impact, flat flyer plate is directly projected against the ceramic plate. The velocity profile is measured by means of laser interferometer pointing the specimen rear face. Furthermore, wavy-machined flyer plate was launched against a target made of 316L buffer plate taped to two SiC ceramic plates of different thicknesses. Two probes directed toward the rear face of each ceramic plate provided the velocity profiles to be used in Lagrangian analysis.

Conclusion

The present experimental work aims to provide a first experimental validation of the technique proposed in [3]. After careful selection of steel to be used as material of both flyer plate and buffer plate, the impact of the wavy-machined flyer plate against plane buffer plate is seen to provide a pulse-shaping effect due to the “wavy-shape” leading to a smooth loading pulse applied to the sample with a rising time about 0.4 µs. This loading pulse offers the possibility to perform a Lagrangian analysis of data in which the sample’s axial stress-axial strain response may be obtained based on two measurements of particle velocity on the rear face of each ceramic sample in contact with the buffer. An identification of the ceramic behavior constitutes the next step of this experimental work.

References

[1] J.L. Zinszner, B. Erzar, P. Forquin. (2017) Shockless characterization of ceramics. In: Casem D., Lamberson L., Kimberley J. (eds) Dynamic Behavior of Materials, Volume 1, pp 229-236, DOI: /10.1007/978-3-319-41132-3_32. Book series: Proceedings of the Society for Experimental Mechanics Series, Springer.

[2] J.L. Zinszner, B. Erzar, P. Forquin. (2018) Shockless Characterization of Ceramics Using High-Pulsed Power Technologies, DOI: 10.1002/9781119579311.ch12, In book: Dynamic Damage and Fragmentation. Edited by Lambert D., Pasiliao C., Erzar B., Revil-Baudard B., Cazacu O., Civil engineering and Geomechanics series, Wiley.

[3] P. Forquin, J.-L. Zinszner. (2017) A pulse-shaping technique to investigate the behaviour of brittle materials subjected to plate-impact tests. Phil. Trans. R. Soc. A 20160333. DOI: 10.1098/rsta.2016.0333.