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Elastic-plastic waves in UVO,2 Uranium alloy

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Résumé - Les ondes de détente issues de la face arrière d'un projectile, lors de son impact sur une cible de même nature sont utilisées pour déterminer certaines caractéristiques dynamiques de l'alliage d'uranium UVo,2.

Dans le domaine de pression couvert expérimentalement ($\lesssim$ 29GPa), la vitesse du précurseur élastique est d'environ 3,45 km/s, et la limite élastique d'hugoniot est de 1,15 GPa.

La baisse de pression derrière l'onde de choc d'intensité 20GPa (29GPa) débute par une onde quasi élastique dont la vitesse est de 3,9 km/s (4,2 km/s) et le saut de pression de 3GPa (3,7GPa).

Abstract - Release waves coming from the back face of an uranium alloy projectile in a symmetric collision are used to estimate some dynamic characteristics of this material.

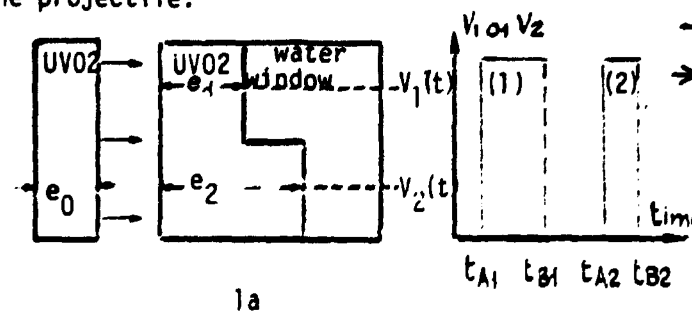
In the pressure range experimentally covered ($\lesssim$ 29 GPa) the velocity of the elastic precursor is about 3,45 km/s, and the hugoniot elastic limit (HEL) is 1,15GPa.

The pressure decrease behind the 20GPa (29GPa) shock wave begins with a quasi-elastic wave which velocity is 3,9 km/s (4,2 km/s), and pressure jump of 3GPa (3,7GPa).

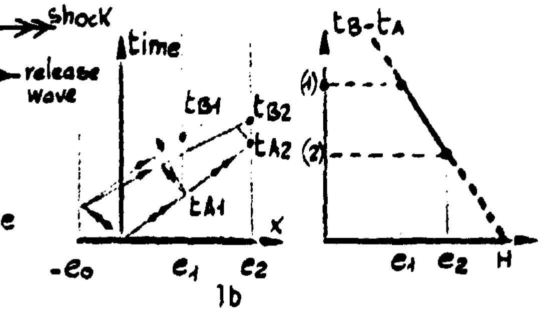
I - INTRODUCTION

Using an UVo,2 projectile launched on an UVo,2 target showing two steps on its face opposite to the impact one, we record, with a Perot Fabry interferometer, the velocity of the boundary surface between these two steps and a transparent material (water).
This set-up is intermediate between those recently presented by R. G. Mc Queen and al [1] and C.E. Morris and al [2].

From these records we deduce for two different thicknesses of the target the velocities of the elastic-plastic release waves coming from the back face of the projectile.



1a



1b

The shock impedance of the target being greater than that of the water, the schematic drawing of the waves is shown on fig 1 b (lagrangian velocities)

$$t_{B1} - t_{A1} = \frac{c_2 - U_2}{c_2 U_1 (c_L - U_2)} \left[e_0 (c_L + U_1) + e_1 (U_1 - c_L) \right] \; ; \; c_L = U_1 \cdot \frac{\frac{H}{e_0} + 1}{\frac{H}{e_0} - 1}$$

II - EXPERIMENTAL SET-UP

II.1 - The projectile launcher

The projectile is launched by an explosive device shown on figure 2.

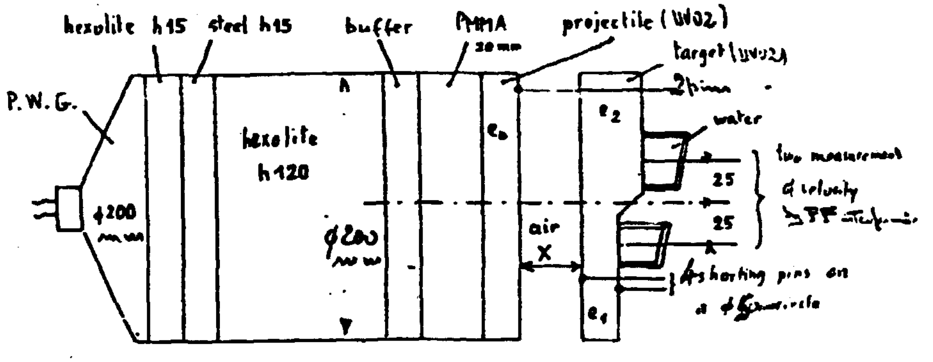


Figure 2

In preliminary experiments, the velocity vs time of the projectile $V_p(t)$ has been recorded, in order to choose the distance X of the air gap between target and projectile at rest which corresponds to the beginning of a plateau on the $V_p(t)$ curve.

The different thicknesses and distance X used in our experiments are given in Table I

Shot number	Buffer		y mm	e_0 mm	e_1 mm	e_2 mm
	material	thickness (mm)				
1	Copper	20	0,78	1,52	3,02	5,04
2	UVo,2	15	0,54	1,52	3,06	5,04

Table 1

II.2 - The target

As shown on figure 2 each step of the target - deplated UVo,2 uranium alloy -, is partially covered with a transparent material (water) used as window in order to record the motion of the interface uranium-water during the shot.

For an experiment, the best window is the one which has the same shock impedance as the target. Unfortunately, in our case, water is far from this condition. But we chose it mostly to avoid spalling in the target, and because its variation of refractive index versus pressure is known from H.C. Pujols' data 3 . In the pressure range of our experiments, the correction to introduce for u (material velocity of the interface) is

$$u_r \approx 0{,}95 \; u_i$$

u_r is the real velocity, u_i the velocity deduced from the interferometric record. (assuming vacuum instead of transparent window)

III - THE MEASUREMENT METHODS

III.1 - Chronometric pins

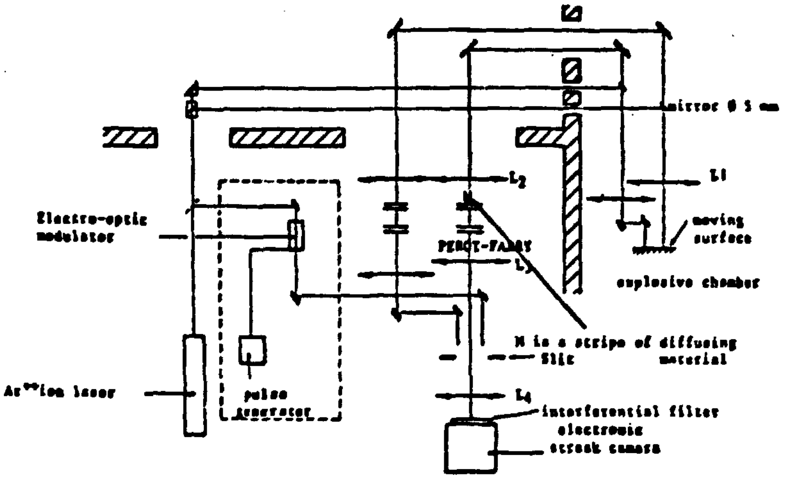
Two shorting pins (with caps) in contact with the front face of the projectile (at rest) give the beginning of its motion.

Four other shorting pins-two groups of two for each thickness of the target- give the transit time of the shock wave in the two parts of the target.

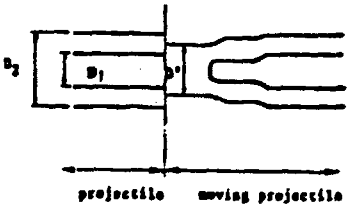
The signals delwered by these pins are recorded on an electronic digital chronometer (precision ± 1 ns).

III.2 - The Perot Fabry velocimeter

This apparatus has been described in [4]. The general drawing of an experiment is presented figure 3.

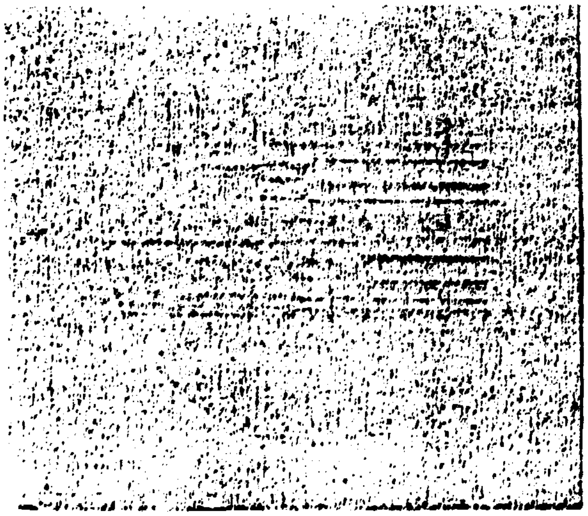


3.a Velocimeter



$$v = \frac{c\lambda}{4e}\left[n + \frac{D'^2 - D_1^2}{D_2^2 - D_1^2}\right]$$

3.b Result



3.c Record of shot n° 2

Fig. 3a - The streak camera is a THOMSON TSN 503, the laser is a COHERENT RADIATION CR 18 or a SPECTRA PHYSICS 171 (of approximatively 5 w monomode power), The distance between the plates of the interferometer can be 1000 mm.

Fig. 3b - In the formula is the wave length (usually 514,5 mm), c the celerity of light, e the distance between the plates of P.F. If the wave length is when the projectile is at rest and when it moves, then n is the integer value of (2e/ - 2e/)

Fig. 3c - Shows the raw record of shot n° 2. The focal length L_3 was 1000 mm, e was 50 mm, the time between markers 400 ns. The accuracy of the measurement is ± 7 m|s and ± 10 ns.

IV - THE RESULTS

IV.1 - Shock velocity in the target

It is obtained by three ways :

a) the shorting pins located in front and on the back face of the target give the transit time for the thicknesses e_1 and e_2

b) the Perot Fabry velocimeter - gives on the same record, the beginning of the motion of the interface target - water for each thickness e_1 and e_2.The time delay between these two values is the transit time for the shock wave to travel the distance $(e_2 - e_1)$.

c) Knowing the shock polars of the target and water, the measurement of the interface target-water velocity gives all the characteristic values of the shock in the target.

IV.2 - The interface target-water velocity vs time.

The schematic diagram of the waves in our experiments is presented figure 4

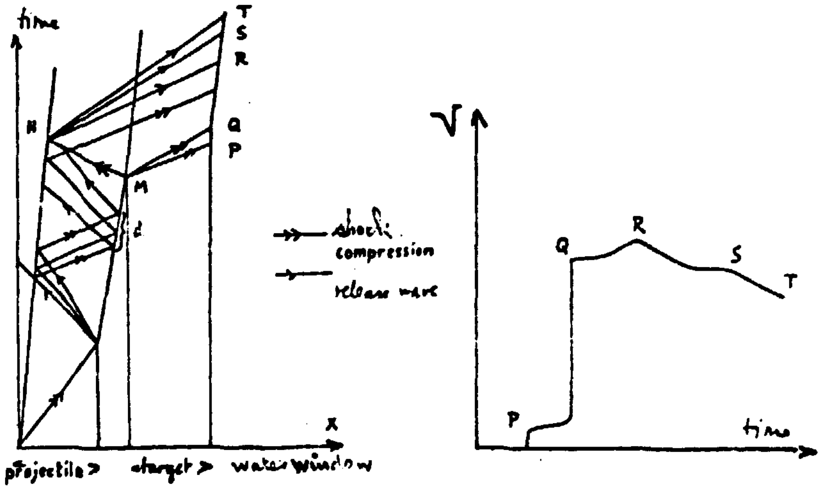


Figure 4

4.a - Diagram t(x) - 4.b Velocity vs time of the interface target-water.

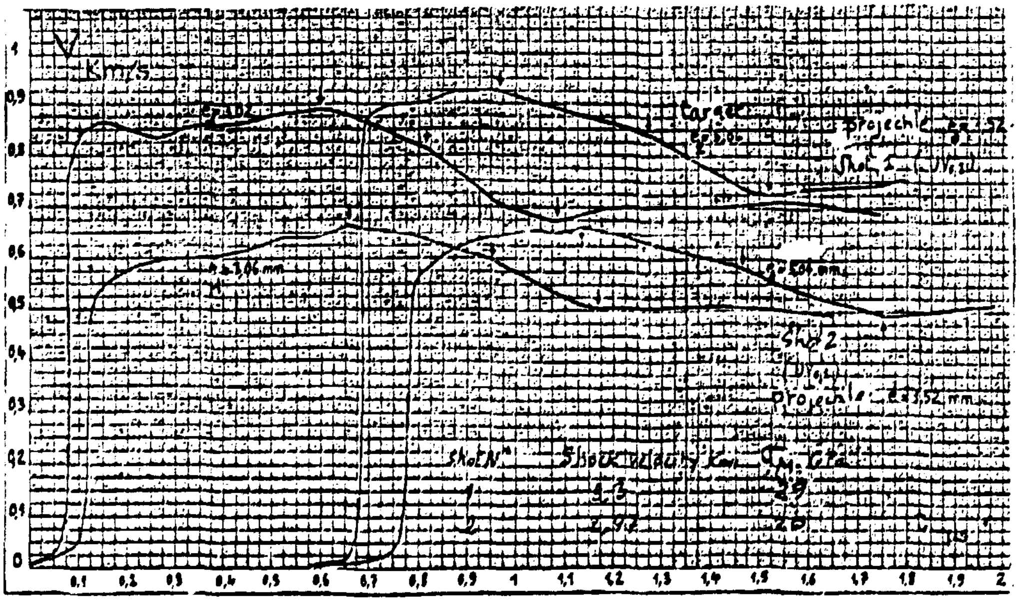


Figure 5

The results obtained - velocity versus time of the interface target-water in the experiments are shown on figure 5. The time of arrival of waves on the interface are shown by arrows.

V - DATA ANALYSIS

V.1 - Elastic precursor

The recorded curves show that the shock in the target is preceded by an elastic precursor. Assuming that UVO,2 alloy has a linear elastic behaviour and obeys to the Von Mises criterion, one obtains 3,45 km|s for the elastic wave velocity, 1,15 GPa for the hugoniot elastic limit, a material velocity of 18 m|s, a compression ratio (= 1 - $V|V_0$) of 0.0052, a Poisson's ratio ν of 0,19 and a yield stress of 0,85 GPa.

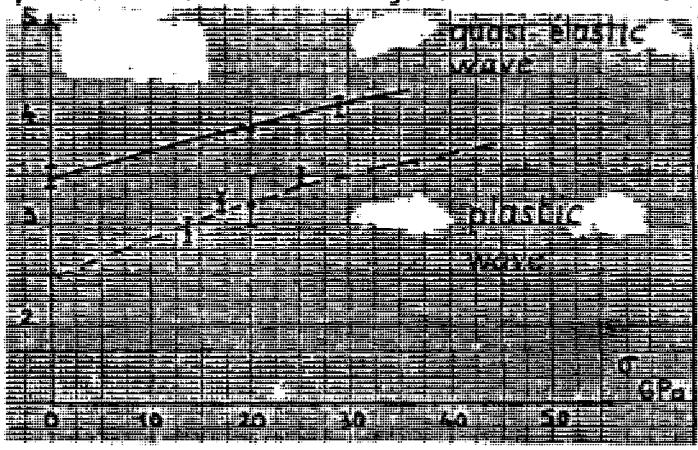
V.2 - Quasi elastic release waves

From the records, the velocities of the quasi elastic and plastic waves vs pressure are shown on fig. 6. The dashed curve is obtained with the assumption that, in the pressure-material velocity diagram, the isentropic release curves are mirror-images of the hugoniot curve. So, one obtains for the plastic wave velocity :

$$c_s = A \frac{V}{V_0} \sqrt{1 + \frac{4PB}{\rho_0 A^2}}$$

using the linear relation U=A+BU between the shock velocity(U) and the material velocity (u) along the hugoniot. For UVO,2, the coefficients used for this relation are A = 2,445 km/s. B = 1,665 with ρ_0 = 19.0 g/cm^3.

Figure 6



From the ratio between longitudinal c_L and plastic c_s waves, (c_L/c_S = k), we get the Poisson coefficient ν ($\nu = 3-k^2/3+k^2$). The Poisson ratio value so obtained is 0,40 for the maximum stress of 20GPa, and 0,43 for 29GPa.

Using the relations between velocity and stress jumps [5] , the characteristics of the quasi elastic waves are : velocity 3,9 km/s (4,2 km/s), pressure jump 3GPa (3,7GPa) for a maximum shock pressure of 20GPa (29GPa).

VI - ACKNOWLEDGMENTS

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VII - REFERENCES

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