THE XLLGG – A HYPERVELOVITY LAUNCHER FOR IMPACT CRATERING RESEARCH.

B. Lexow[1], A. Bueckle[1], M. Wickert[2] and S. Hiermaier[2]
[1]Fraunhofer Institute for High-Speed-Dynamics, EMI, Am Klingelberg 1, 79588 Efringen-Kirchen, Germany
[2]Fraunhofer Institute for High-Speed-Dynamics, EMI, Eckerstrasse 4, 79104 Freiburg i. Br., Germany

Introduction: Hypervelocity launchers are used to accelerate projectiles that simulate impacting meteorids or asteroids. These hypervelocity launchers are **l**ight **g**as **g**uns (LGGs) which are able to achieve velocities above 3000m/s. Using hydrogen as a propellant projectiles can be accelerated up to velocities far more than 5 km/s.

The XLLGG (e**X**tra **L**arge **L**ight **G**as **G**un) at the EMI (**E**rnst-**M**ach-**I**nstitute) [1] (Fig. 1) is actually the most powerfull light gas gun placed in Europe, so that it was used within the MEMIN (**M**ultidisciplinary **E**xperimental and **M**odeling **I**mpact Crater Research **N**etwork) program [2].

Fig. 1: The XLLGG at the EMI test site in Efringen-Kirchen.

Hypervelocity Launchers: Hypervelocity impact experimentation requires launchers that are able to accelerate macroscopic objects to velocities of several km/s while maintaining the structural integrity of the impacting object i.e. the projectile. Gun-type accelerators (single stage launchers) sketched in Fig. 2 make use of the fast release of chemical energy available in gun powder. During the explosive burning of the gun powder high pressures build up within milliseconds in the powder chamber. The projectile is accelerated until it reaches the end of the launch tube and exits it. Due to the high mass of the molecules that results from reaction products in the ignited gun powder, the maximum velocity of a projectile for this type of single-stage accelerator is limited to the order of 3 km/s. In order to achieve velocities beyond 3 km/s a two-stage launcher concept is used (Fig. 2), where the projectile is accelerated by a light gas under high pressure. For a light gas like hydrogen the molecular weight of the gas is much lower compared to the reaction products of gun powder. Thus for the identical mean kinetic energy of an individual gas particle the light gas will move much faster, and substantially higher projectile velocities can be reached.

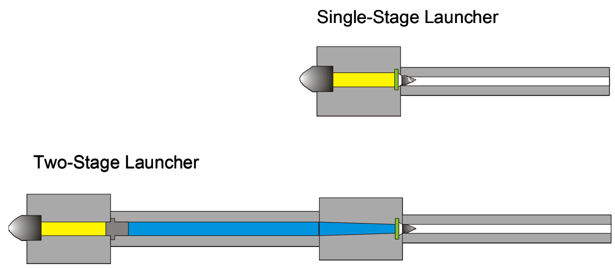

Fig. 2: Comparison of a single-stage launcher concept with a two-stage launcher concept.

In this case, instead of driving a projectile in the first stage, it is now a heavy piston (with respect to the projectile mass) that is accelerated and compresses the light gas filled in the pump tube. While the piston is still moving a membrane or diaphragm at the end of the pump tube ruptures at a pressure of about 200 bar and the projectile then begins to be accelerated. This way, the projectile, which is often encased in a "sabot" is accelerated relatively smoothly within the first 2-3 milliseconds. During the next 3-5 milliseconds the pressure in the high pressure section increases up to top values in the order of 10000 bar. The dynamics of this procedure is illustrated in Fig. 3.

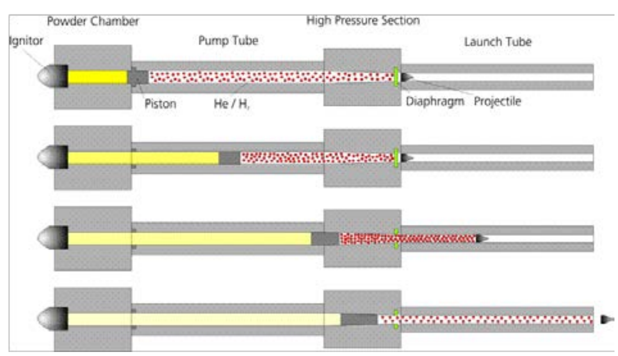

Fig. 3: Function principle of a two-stage light gas gun.

Flexible setup of the XLLGG: Depending on the requirements for the impact tests, the accelerator can be set up in different configurations as a two-stage light gas gun or even a single stage launcher (Table 1). As a single stage launcher only a small powder chamber and a launch tube with a maximum diameter of 50 mm is used. Table 1 lists different configurations based on two different pump tubes with either 100 or 154 mm caliber.

Table 1: Different possible pump and launch tube configurations of the XLLGG

	Pump tube		Launch tube	
Configuration	Length [m]	Caliber [mm]	Length [m]	Caliber [mm]
1	7	100	6	25-50
2	8	154	6-12	35-70
3	14	154	6-12	35-70
4	22	154	6-12	35-70

For configurations 2-4 in Table 1 a different high pressure chamber is used than for configuration 1 because of the different pump tube calibers and different pistons required.

Performance optimization of the XLLGG: Neural networks (Fig. 4) are used to capture the performance especially of the XLLGG at EMI ([3], [4]) with the intention to further optimize the gun performance. Neural networks are able to “learn” correlations while being trained with datasets from former XLLGG experiments. Such a well trained network can then be used to carry out parameter studies with the goal of getting optimized parameter sets to perform further tests with the XLLGG.

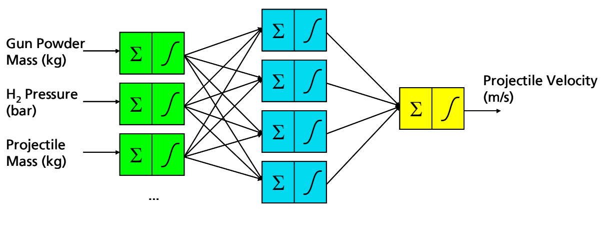

Fig. 4: Sketch of part of a neural network for light gas gun test parameter optimization. The colored boxes symbolize the artificial neurons of the neural network.

Future extension of the XLLGG: Further development of the accelerator performance by neural networks is still part of ongoing research, especially to reduce the mechanical load on the projectile during the acceleration. These results will also allow to access higher velocities for impact crater research with the MEMIN project. As a first step launch tubes with a length of 20 m and a caliber of 50 mm had been ordered as a result of optimization calculations using neural networks. It is expected to reach velocities far more than 8 km/s with cylindric projectiles with a total mass of 100 g made of macrolone and more than 6.5 km/s with structured projectiles as used for MEMIN impact tests [5].

Conclusion: The two-stage light gas gun XLLGG at the EMI proving ground Efringen-Kirchen is an ideal hypervelocity launcher to accelerate MEMIN meteorite simulating projectiles.

It presents an indispensable tool for the experimental assessment within the MEMIN program and allows for gaining insights into the fundamental physical processes that occur during impact cratering. Up to now projectile velocities of up to ~5500 m/s have been reached. In the future higher velocities for MEMIN cratering experiments might be possible, as significant improvements by using neural networks for performance optimization have taken place since the first tests for the MEMIN experimental series.

References:

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