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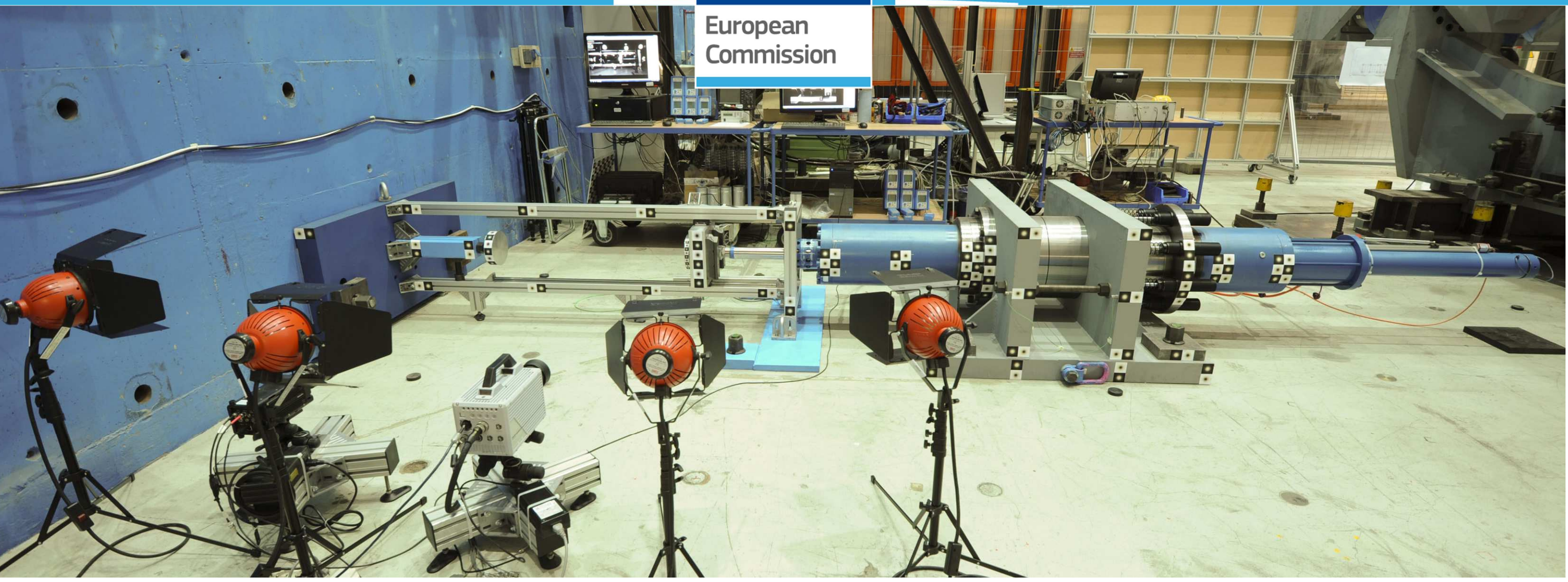

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BLAST Simulator project:

Performance assessment and preliminary tests

Administrative Arrangement No JRC 32253-2011 with DG HOME
Activity A5 – Blast Simulation Technology Development

Marco Peroni
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European Laboratory for Structural Assessment

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1. Introduction

Critical infrastructures in fields such as energy, health, communication, government, transport etc. are made of physical structures, or are housed in physical structures. Such structures may naturally become the target of terrorist bombing attacks. Measures to protect them will certainly be taken, involving prevention, intelligence, detection, deterrence etc, but if everything fails, it is very important that the mechanical structure itself mitigates some effects of the explosion and maintains certain functionalities.

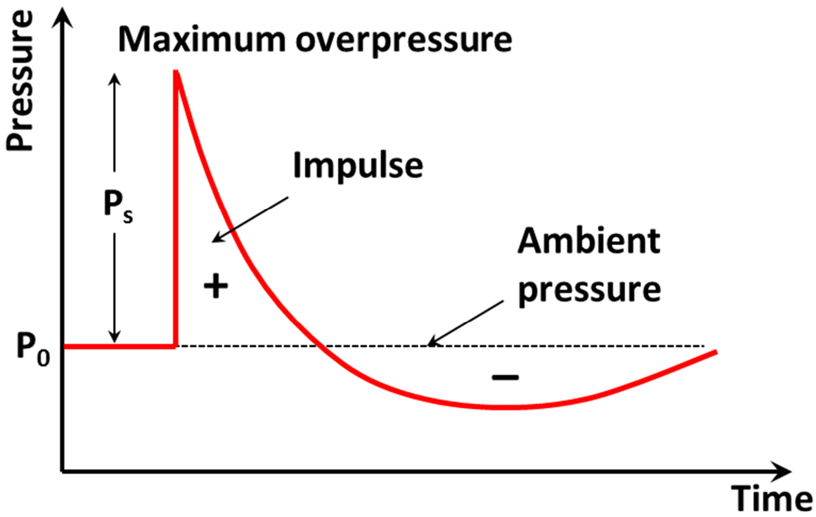

Figure 1. Blast wave pressure curve characteristics in free-air explosions

A typical pressure wave curve (which eventually will load a structure) at some distance from an explosion is shown in figure 1. Its main characteristics concerning damaging effects on structures are the magnitude of the overpressure, the duration of the positive phase and especially its impulse, i.e., the area under the curve over the positive phase. This impulsive load will be delivered to a structure in a few milliseconds forcing it to respond or fail in a peculiar mode. This necessitates that models and design techniques for blast resistant structures be thoroughly validated with reliable data from field tests. However, such tests with actual explosions are expensive and they are usually performed within military grounds. Thus alternative testing methods are desirable, and this has been the case at the University of California in San Diego, where the first blast simulator facility has been built (2006). As claimed, the effects of bombs are generated without the use of explosive materials. The facility produces repeatable, controlled blast load simulations on full-scale columns and other structural components. The simulator recreates the speed and force of explosive shock waves through servo-controlled hydraulic actuators that punch properly the test specimens.

With this work a similar blast simulation capability is proposed to be developed within the EU by the JRC. The staff of the ELSA Unit has a long and strong experience in the servo-controlled actuators. In fact some of these devices have been constructed in-house and relevant technology has been transferred to other European laboratories. Concerning the currently required fast actuators, an alternative design concept will be implemented, which is believed to be capable of generating impacting loads resembling closer those of real explosions of figure 1. This will allow the realistic testing of components to “simulated” explosions and will provide the necessary data for the verification and validation of the computer tools.

The development of this technology will be important both for the research and the practicing engineers and architects who need design rules and guidelines. Besides characterizing blast effects on structural systems, the methodology will contribute to evaluating technologies for hardening and retrofitting buildings and bridges against terrorist bomb attacks. Further, it will help in the investigation of the problem of progressive collapse, i.e., the phenomenon where a local failure propagates in a disproportionate manner to lead to global failure (Oklahoma City bombing case).

2. Experimental setup

The blast simulator, as designed at the moment, is a pneumatic/hydraulic facility and the sketch below summarizes the main parts of the equipment (figure 2).

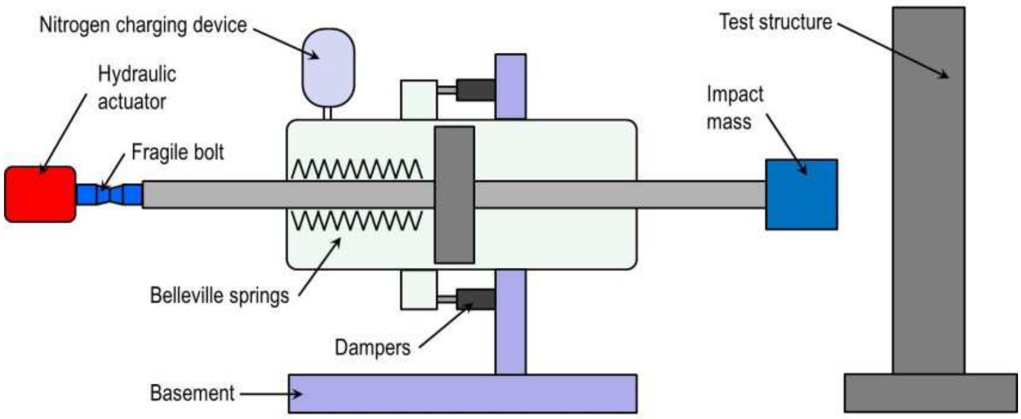

Figure 2. Sketch of blast simulator

The operating principle of the testing rig is quite simple: the shaft is pulled to the starting position with a hydraulic jack and this action compresses a series of Bellevile springs inside the blast actuator; at this point the piston is kept in this initial position by a fragile bolt made of high strength steel; to start the test the pressure inside the active chamber of the blast actuator is increased by charging it with nitrogen (maximum pressure 100 bar).

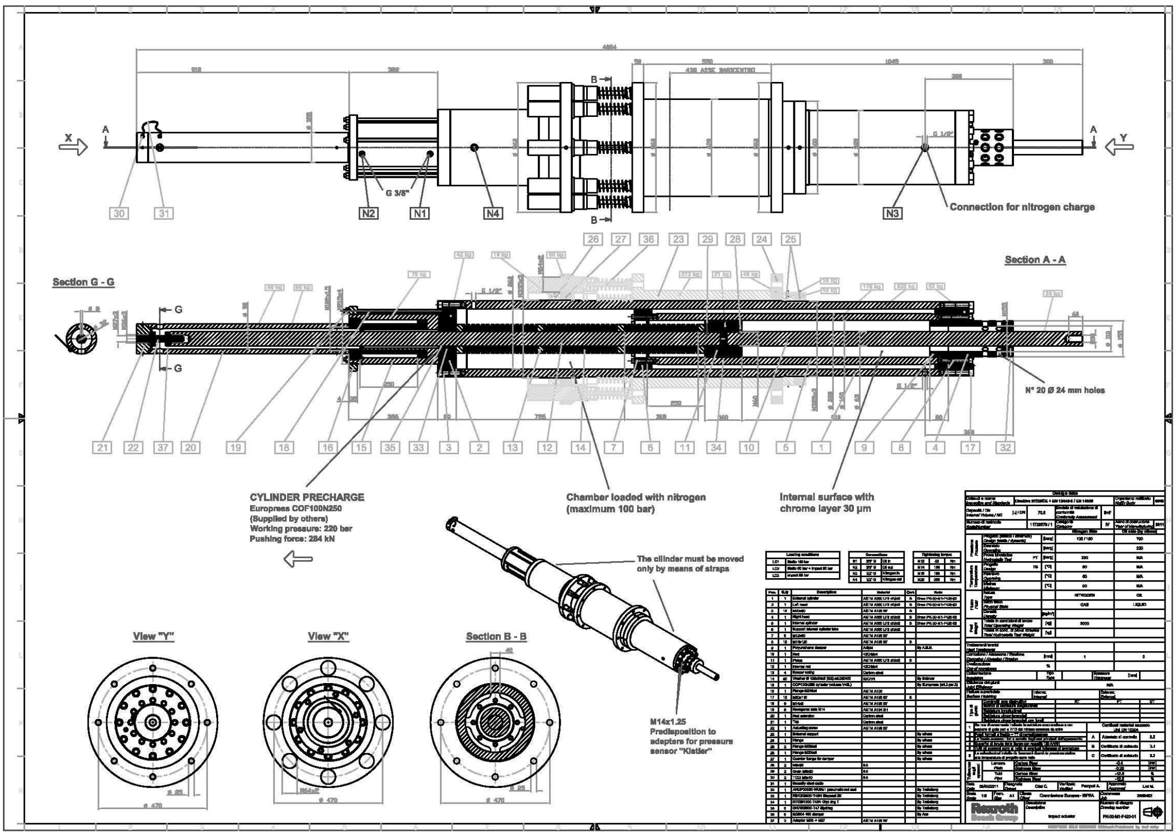

Figure 3. Prototype design

When the pressure load produces a force greater than the strength of the fragile, the bolt suddenly breaks and the piston and shaft of the blast actuator rapidly accelerate pushing the impacting mass, attached at the other extreme of the shaft. When the piston has done most of its stroke, it starts to decelerate (with a combined pneumatic and rubber device) and transfers its remaining energy to the whole actuator, which is supported with a series of high performance dampers. When the shaft of the actuator decelerates the impacting mass is detached from it and collides with the tested structure reproducing local pressure similar to that of a blast wave.

The cylinder has been designed with the supports of the ELSA researchers by Bosh Rexroth and the final design of the prototype is shown in figure 3.

Figure 4. a) Blast actuator as manufactured by Bosh Rexroth b) nitrogen charging system

The actuator has been supplied with a declaration of conformity to directive 97/23/CE (PED) for what concerns the pressure devices (figure 4a). The nitrogen charging system has been supplied by Interfluid S.p.a., it uses an air-operated gas booster (I Curtiss Wright Flow Control Company), and is accompanied by a certified test report (figure 4b).

The mechanical base, for holding the actuator and for fixing the whole system to the floor, has been designed by the ELSA technicians and it is made of high stiffness steel plates, as shown in figure 5a. The connection between blast actuator and steel base is made by means of a series of dampers which will absorb the kinetic energy transmitted by the piston to the cylinder at the end of the test.

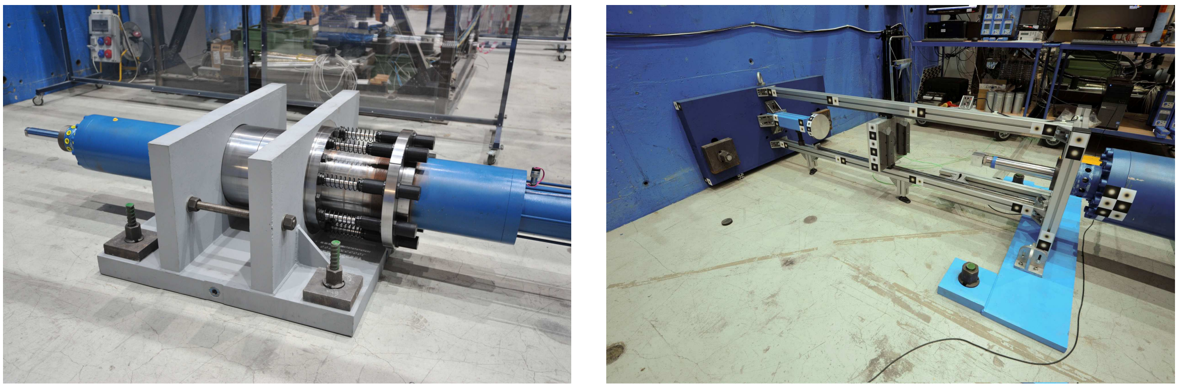

Figure 5. a) Detail of high stiffness steel base and damping system and b) aluminum frame with linear bearings

To verify the performances of blast actuator it is also essential to accelerate a variable mass to the design velocity and to ensure, for safety reasons, that the mass was guided during all the test execution. To do this a modular aluminum frame was designed that supports two linear bearing (THK) and an instrumented aluminum/lead mass. The two linear bearings ensure a frictionless movement of the mass in the test direction and a high stiffness in the other directions. For these reasons this structure ensures the safety requirements of a testing laboratory.

The impact mass is made in three different parts as shown in figures 6. The main structure is made of a high strength aluminum alloy (plate 300x300x60 mm in 7075T6) that is connected to the linear bearings with two carriages leading to a high stiffness moving structure. The mass can be varied adding to the back of the aluminum plate some modular lead blocks rigidly connected to the aluminum part with bolts. In this way the impacting mass can be easily modified in the range between 20 to 60 kg. The aluminum mass does not impact directly but an aluminum plate is placed before the main mass to protect the structure. The circular plate is connected to the main mass with two load cells that allow a noiseless measurement of the impact force.

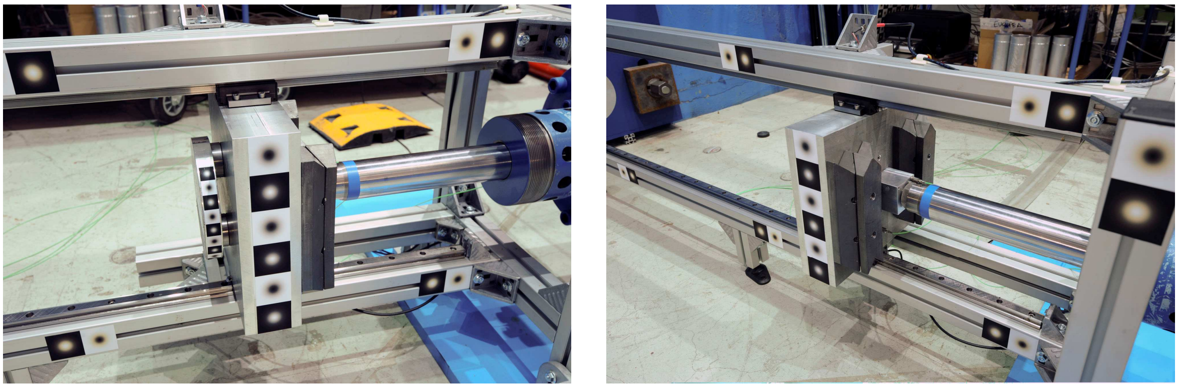

Figure 6. Details of the impacting mass

3. Instrumentation

Figure 7 presents the final experimental setup to assess the performances of blast actuator with the main instrumentation adopted during the test campaign. A test performed with the blast actuator reach a high level of complexity due to the great number of sensors involved and to the several devices that must be simultaneously controlled.

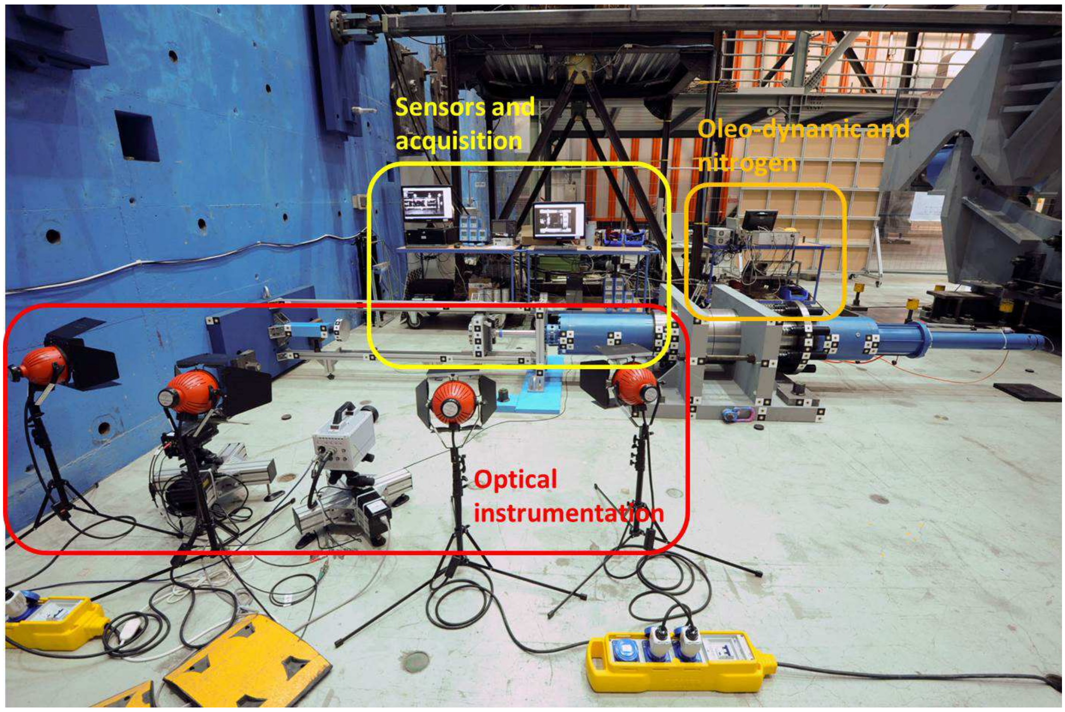

Figure 7. Final experimental setup and instrumentations

The instrumentation that equips the blast actuator can be divided in three main categories: oleo-dynamic and nitrogen charging devices, sensors and acquisition devices and optical instrumentation.

Oleo-dynamic and nitrogen devices

This category consists of all instrumentation necessary for the propulsion of the equipment in order to accelerate the impacting mass to the design velocity. As described in section 2 the blast actuator is essentially an energy accumulator that converts potential energy (elastic energy of Belleville spring and nitrogen) into kinetic energy. To accumulate elastic energy in the Belleville springs it is necessary to design an oleo-dynamic servo-system able to pre-load the springs. The servo-system is composed essentially of a manifold connected to the ELSA oleo-dynamic power station and a servo-valve that controls the oil flux between the two chambers of the oleo-dynamic pre-load cylinder. The servo-valve is controlled by an electronic controller developed by ELSA/ITU technicians using Ethercat technology. The servo-system is provided with a displacement sensor placed on the blast actuator (MTS Temposonic) that closes the feedback control chain. This solution allows a displacement/force control strategy with a cycle time of 2 ms.

The device that drives the nitrogen part of the blast actuator is simply composed of a pneumatic booster connected to a 200 bar nitrogen tank. The gas part is provided by several valves able to charge and discharge the active chamber of the blast actuator during the experiments.

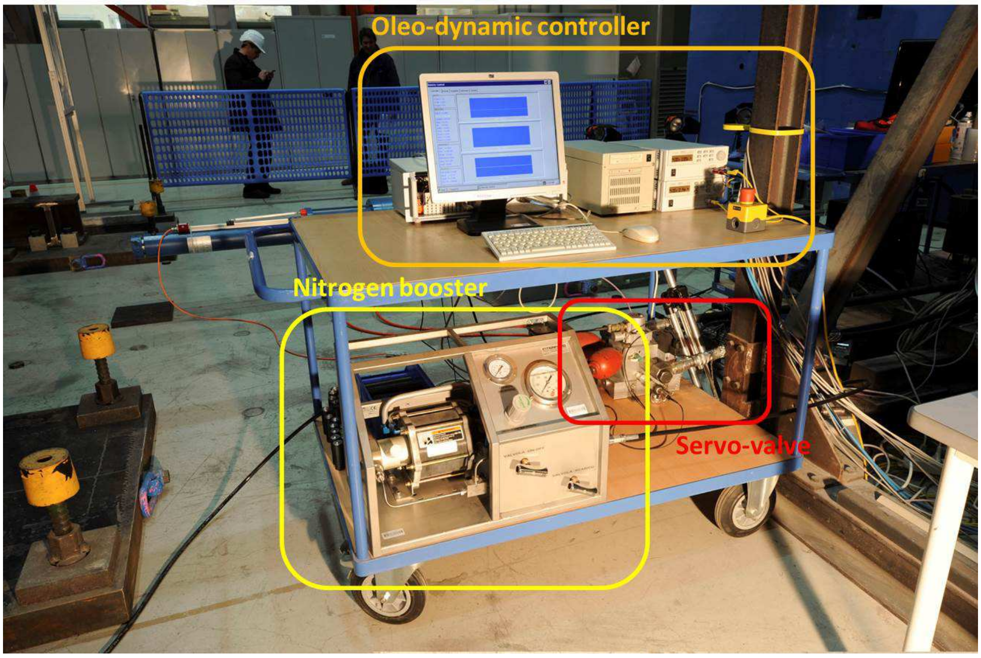

Figure 8. Oleo-dynamic and nitrogen devices

Sensors and acquisition devices

The experiments performed with the blast actuator last normally less that 1 second and some phenomena, that take place during the mass impact, can be studied only via special sensors and instrumentation.

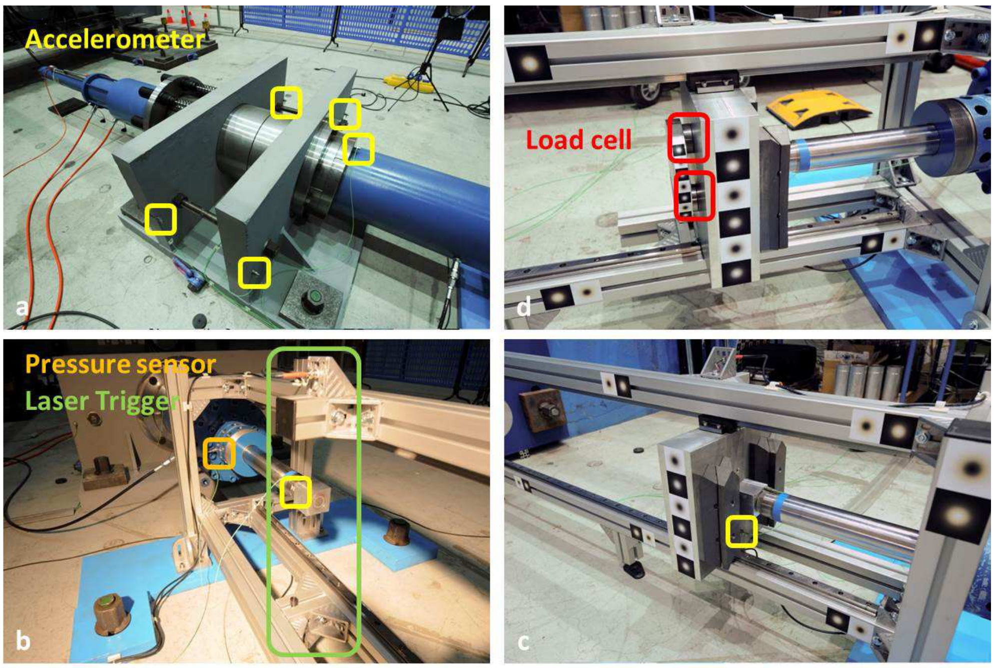

Figure 9. Sensors placed on blast actuator

Blast actuator is mainly equipped with fast response piezoelectric sensors as presented in figure 9.
In detail:

- four accelerometers have been placed on the base to evaluate the structure deformation during the test and to assess possible rigid movements of the whole facility (figure 9a);
- two accelerometers have been placed on the blast actuator to measure the movement of the piston (figure 9b) and the external part of the actuator (figure 9a);
- a couple of pressure sensors have been adopted to acquire the trend of the pressure in the two gas chambers of the actuator (figure 9b);
- two load cells have been placed on the mass to measure the impacting force (figure 9d) and an accelerometer to measure the mass deceleration (figure 9c);
- finally to start the acquisition a laser trigger has been adopted (figure 9b).

All the piezoelectric sensors just mentioned need a charge amplifier to convert the electrical charges accumulated in an electrical signal proportional to the acquired measurement. Charge amplifiers adopted (Kistler 5015A) have a high cut-off frequency (more than 200 kHz) and are able to operate with different types of piezoelectric sensors (accelerometers, load cells, pressure sensor, etc.).

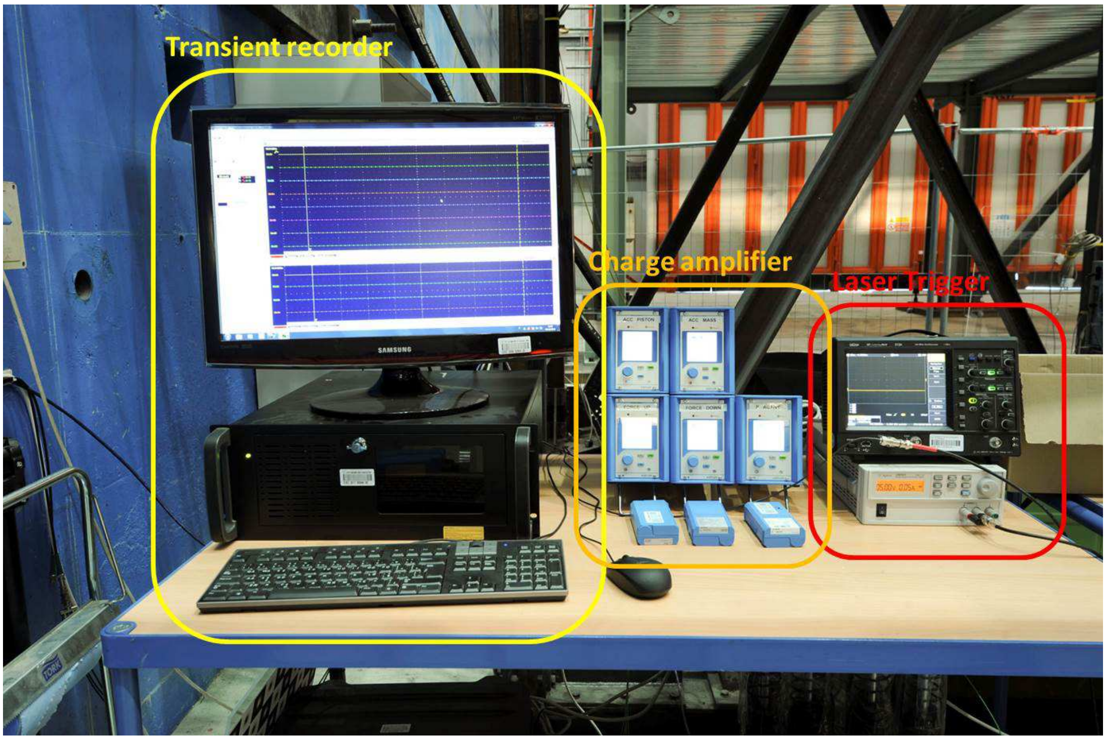

Figure 10. Charge amplifiers and transient recorder

All the electrical transducer signals are acquired with a transient recorder (industrial PC with acquisition boards Gage Octopus) able to sample simultaneously 16 channels at 10 MHz and 16 bit. For the blast actuator tests the sampling frequency has been set to 100/200 kHz.

Optical instrumentation

In addition to standard instrumentation for the blast actuator tests, extensive use of optical methods has been made in order to detect and identify possible unexpected phenomena and to precisely measure the velocity of the several moving parts of the actuator. The optical instrumentation adopted is essentially composed of two high-speed cameras (IDT Y4 and Photron SA1) and a set of halogen lamps to provide the necessary light for a high speed photo capture (Figure 11). For the range of velocity of the moving parts reached during the tests the sample rate of the two cameras does not exceed 5000 fps.

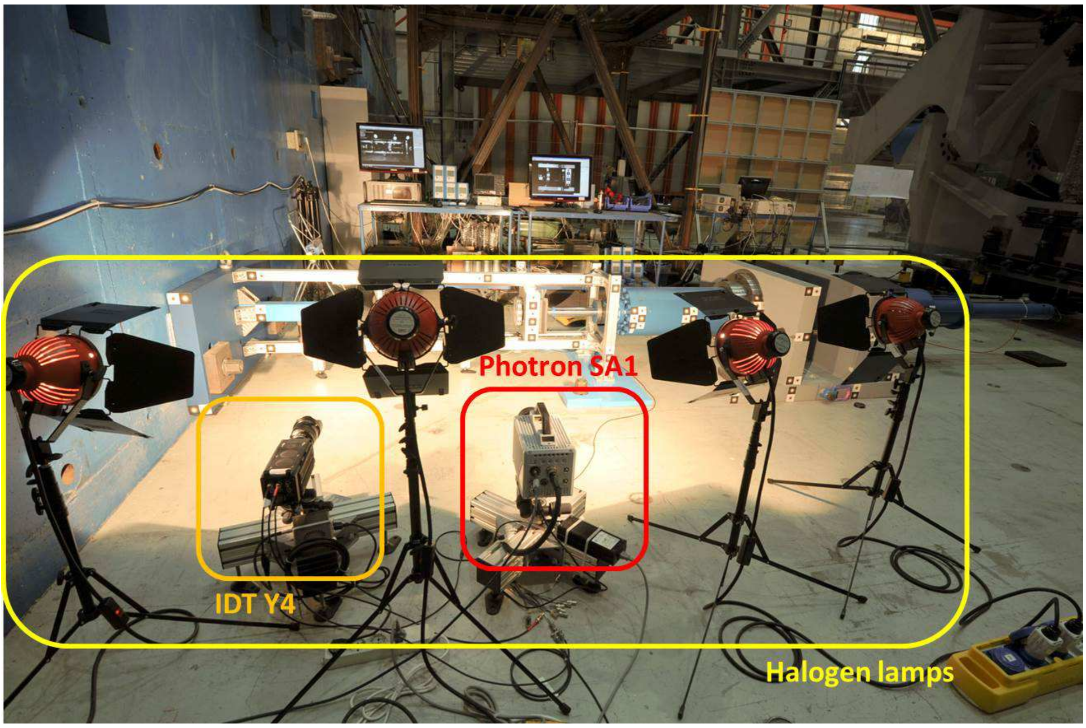

Figure 11. Optical instrumentation

To compute the trajectories of moving parts a tracking algorithm, implemented in Matlab, has been largely used. This numerical procedure is based on specific targets (figures 7, 9c, 9d) directly attached to the structures that must be tracked. The use of these targets allows an accurate evaluation of their positions (5/100 of pixel dimension) with a relatively low time-consuming numerical procedure. The operating principle of this algorithm is rather simple: a well-known grey profile (the grey trend of the target) is tracked in the pictures series with an optimization algorithm. In this way the information captured by several pixels are elaborated simultaneously (usually at least a 10x10 grid of pixels), thus increasing substantially the measurement accuracy.

4. Experimental tests

This section summarizes the preliminary tests performed with the blast actuator in order to assess its performance. Table 1 presents schematically the tests carried out and the test type with some additional information.

Table 1. Experimental tests performed

Tests name	Accelerated mass	notes
Blast 1	No mass	Only spring, fragile bolt 5 mm
Blast 2	No mass	Only spring, fragile bolt 8 mm
Blast 3	No mass	Only spring, fragile bolt 10 mm
Blast 4	No mass	Check ole-dynamic part
Blast 5	23.4 kg	Only spring, fragile bolt 5 mm
Blast 6	23.4 kg	Only spring, fragile bolt 8 mm
Blast 7	40.3 kg	Only spring, fragile bolt 8 mm
Blast 8	40.3 kg	Spring+nitrogen (10 bar), fragile bolt 10 mm
Blast 9	40.3 kg	Spring+nitrogen (15 bar), fragile bolt 10 mm
Blast 10	40.3 kg	Only spring, fragile bolt 5 mm
Blast 11	40.3 kg	Only spring, fragile bolt 5 mm

The test campaign has been conducted taking into account safety issues due to the high level of energy stored and quickly released during the experiments. For this reason the complexity level and the energy stored during the experiments has been increased gradually.

In the firsts three experiments only the actuator has been tested with an increasing velocity to verify the correct functioning of the equipment and possible damages to seal and mechanical structures. After each test the blast actuator has been inspected.

Experiment Blast 4 involved only the oleo-dynamic pre-load system to investigate the performances of a new controller generation (ethercat technology) developed in the ELSA/ITU laboratory.

Experiments Blast 5-7 involved for the first time the acceleration of a mass only with the springs propulsion. Finally, greater velocities have been reached in experiments Blast 8-9 using for propulsion both the spring and the pressurized nitrogen.

The last two experiments involved the reproduction of a blast pressure profile using a foamed material to “smooth” the pressure profile generated by the impact of the accelerated mass.

In the next pages a schematic overview of the signals acquired during the tests will be presented and some additional detail of the tests will be provided.

Blast 1

Blast 1 experiment as mentioned before involved only the blast actuator without any accelerated mass. The energy has been accumulated only in the springs and the fragile bolts adopted had a notched section of 5 mm diameter. A velocity of approximately 4.5 m/s has been reached and no substantial accelerations have been recorded on the mechanical base.

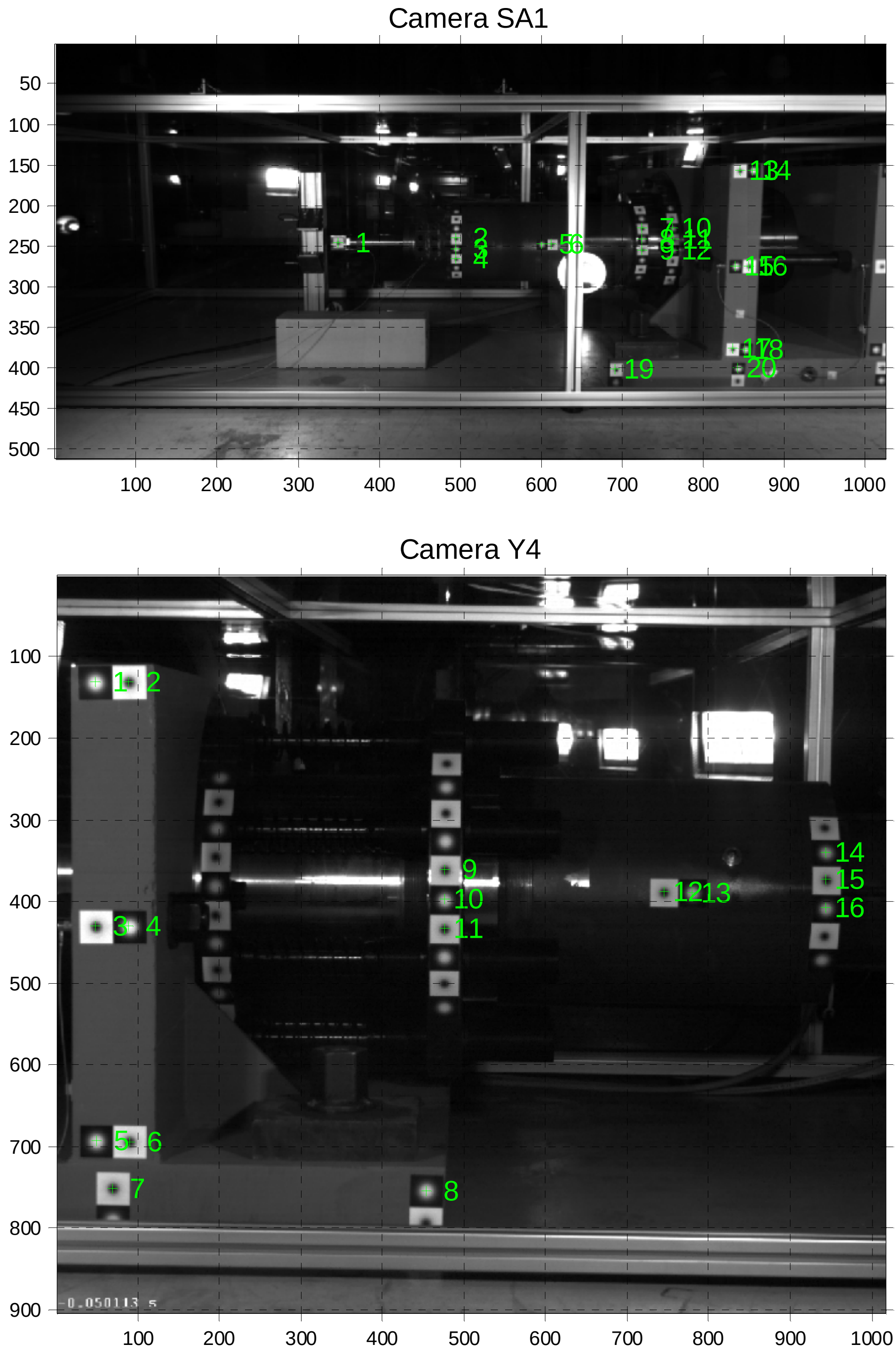

Figure 12. Camera acquisitions and computed targets

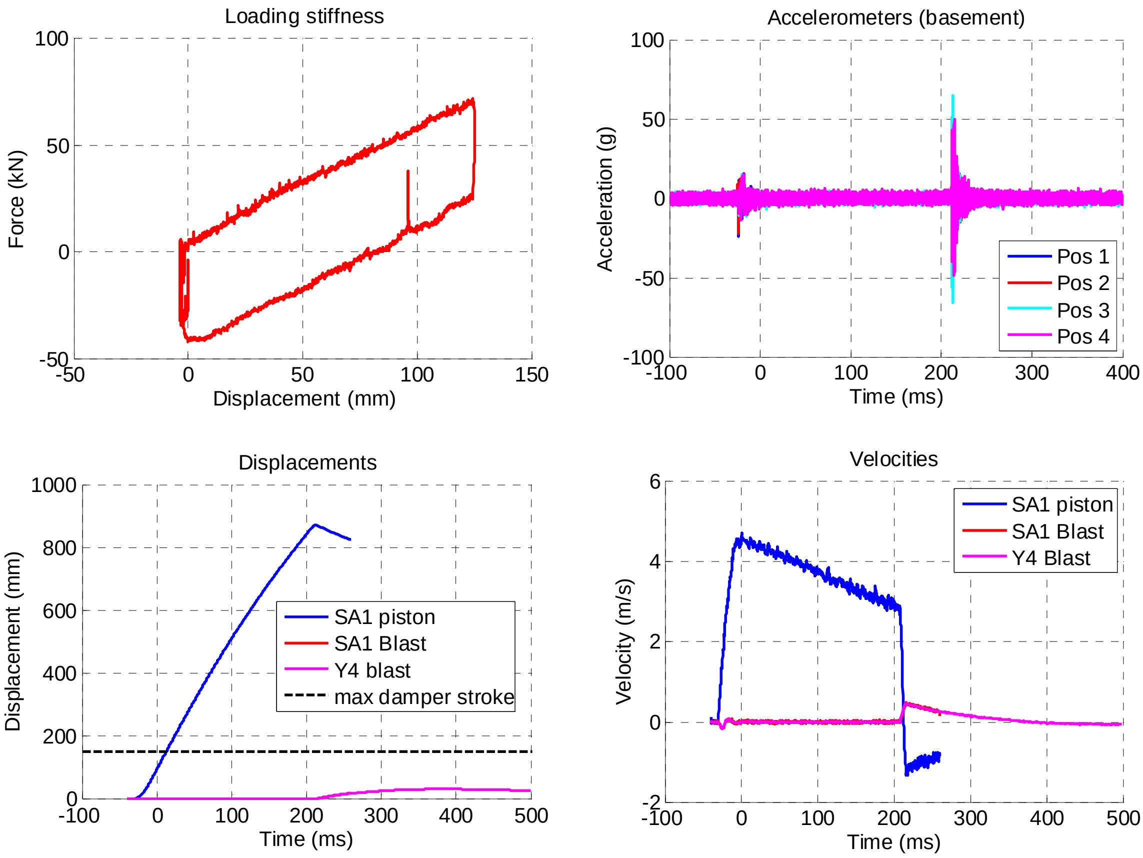

Figure 13. Experimental data

Blast 2

Blast 2 experiment has the same setup as BLAST 1 but the stored energy has been increased using a notched fragile bolt with a diameter of 8 mm. A velocity of approximately 8.5 m/s has been reached and no substantial accelerations have been recorded on the mechanical base.

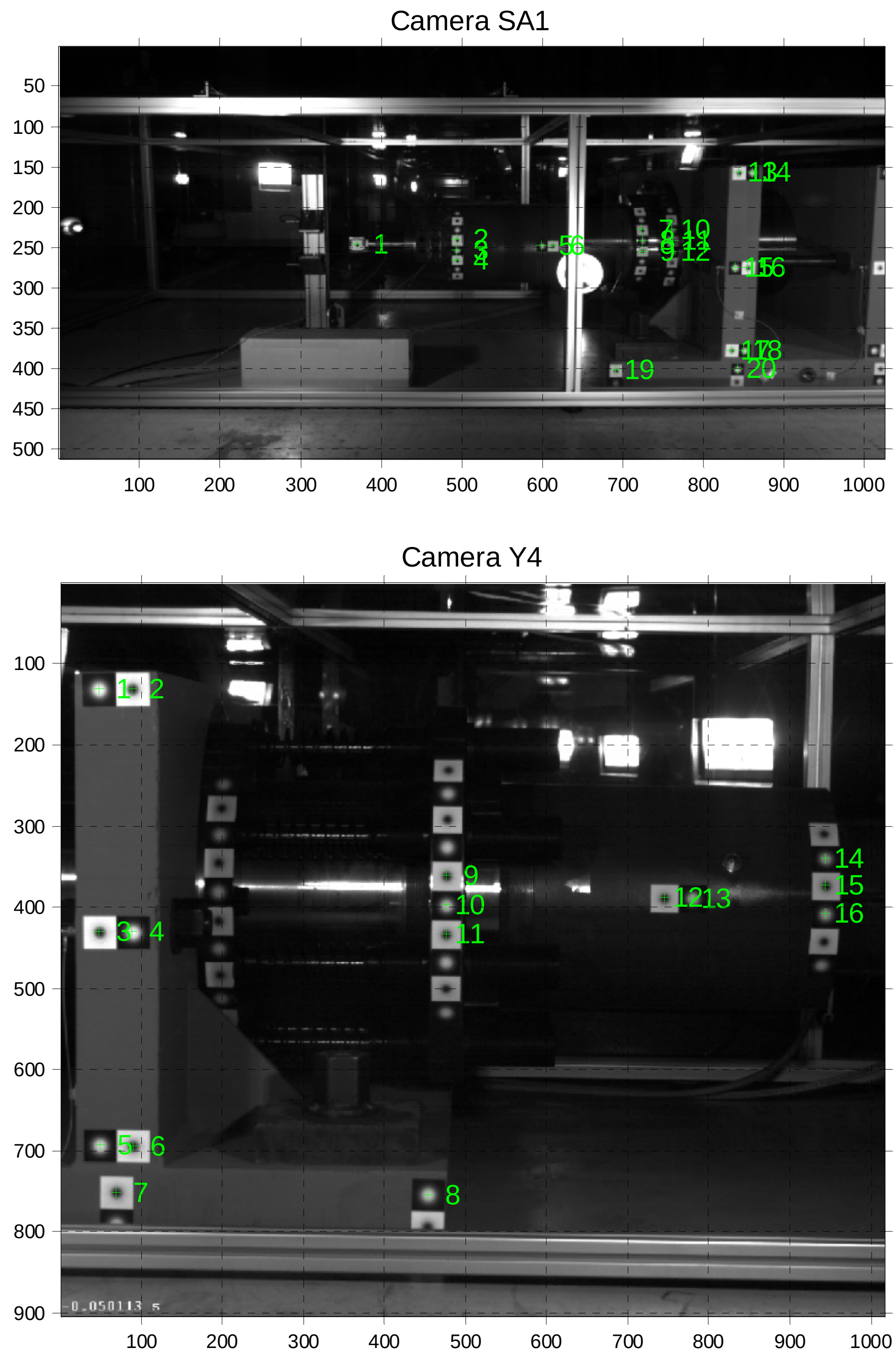

Figure 14. Camera acquisitions and computed targets

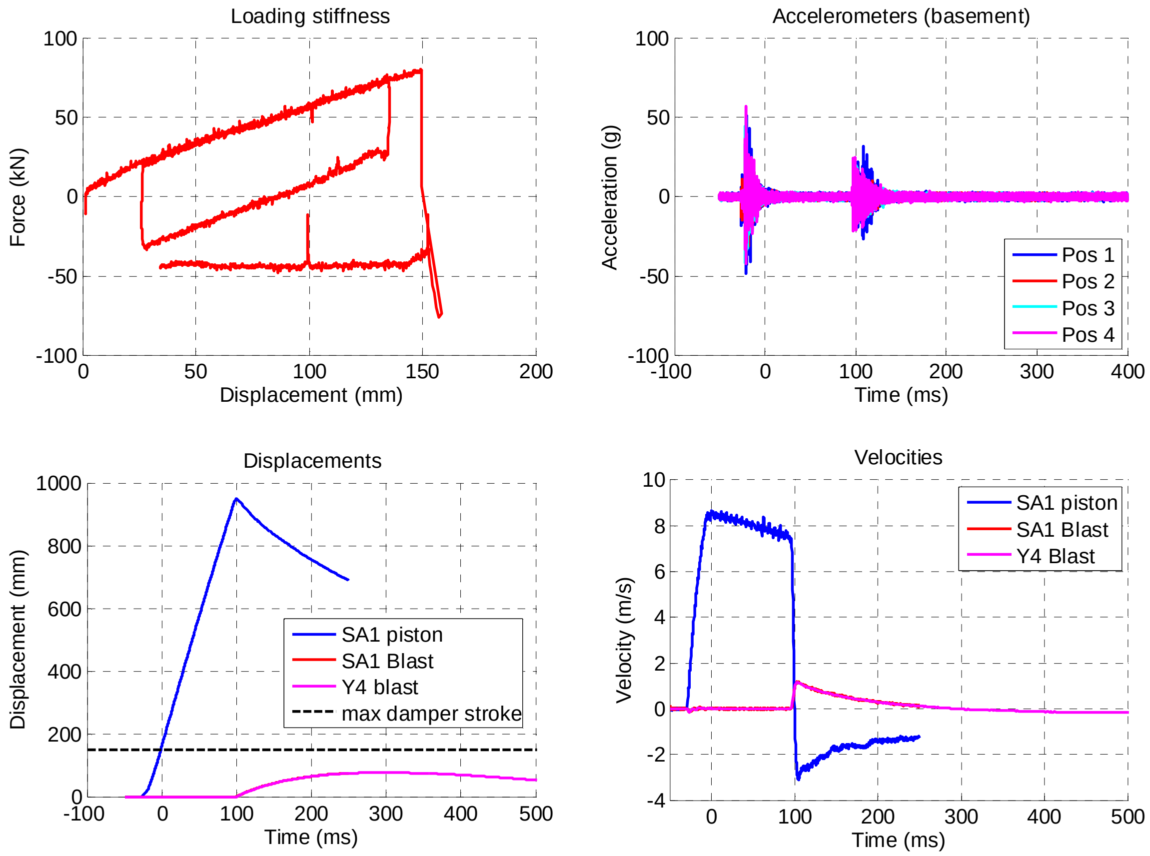

Figure 15. Experimental data

Blast 3

Blast 3 experiment has the same setup as BLAST 1 and BLAST 2 but the stored energy has been further increased using a notched fragile bolt with a diameter of 10 mm. A velocity of approximately 11.5 m/s has been reached and no substantial accelerations have been recorded on the mechanical base. In this test when the fragile broke the whole facility moved back (loaded by the reaction force) by 2 mm due to a not sufficient pre-load of the four Dywidag bars that connected the base to the floor. After this problem the check of Dywidag pre-load bars has been integrated in the test procedure.

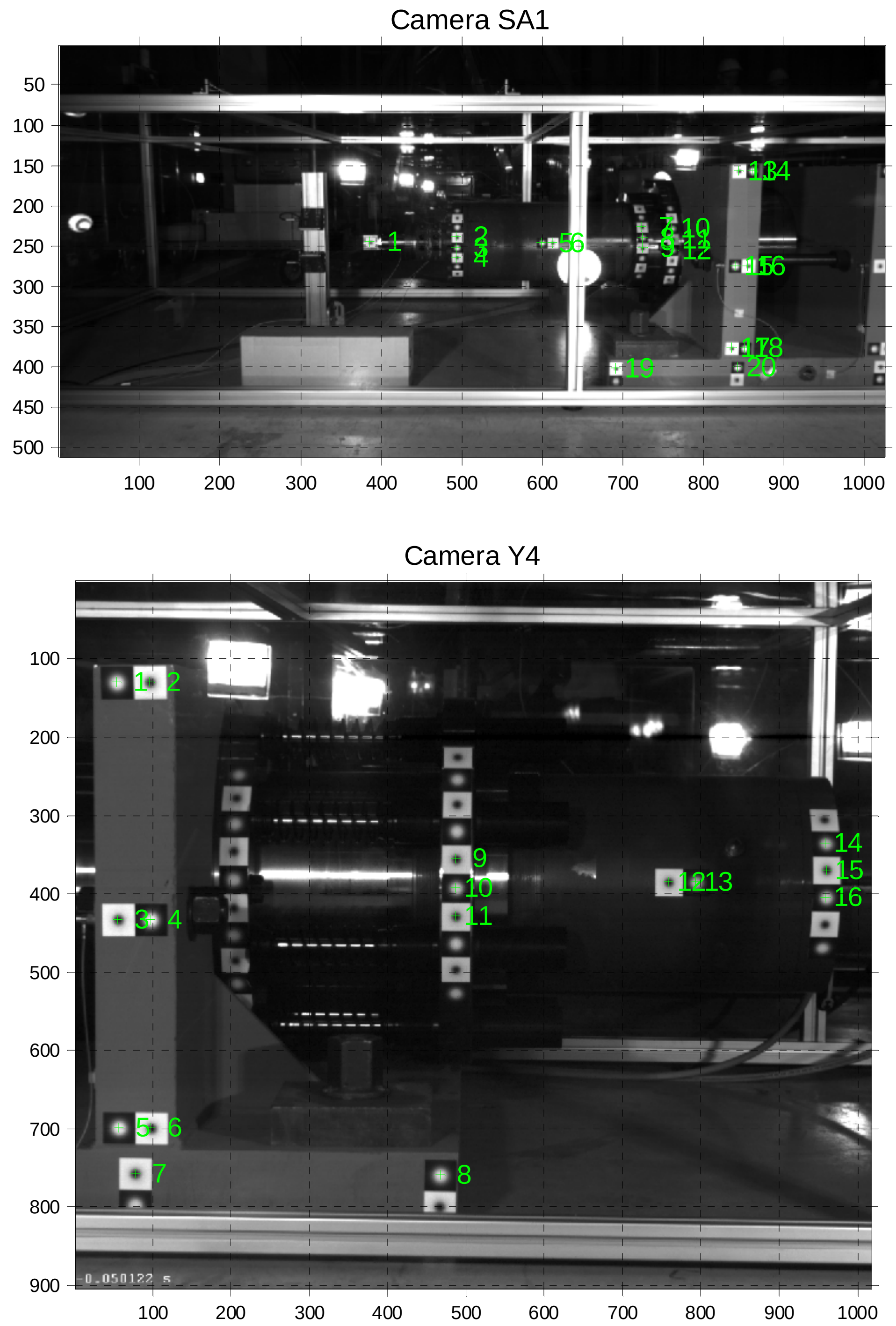

Figure 16. Camera acquisitions and computed targets

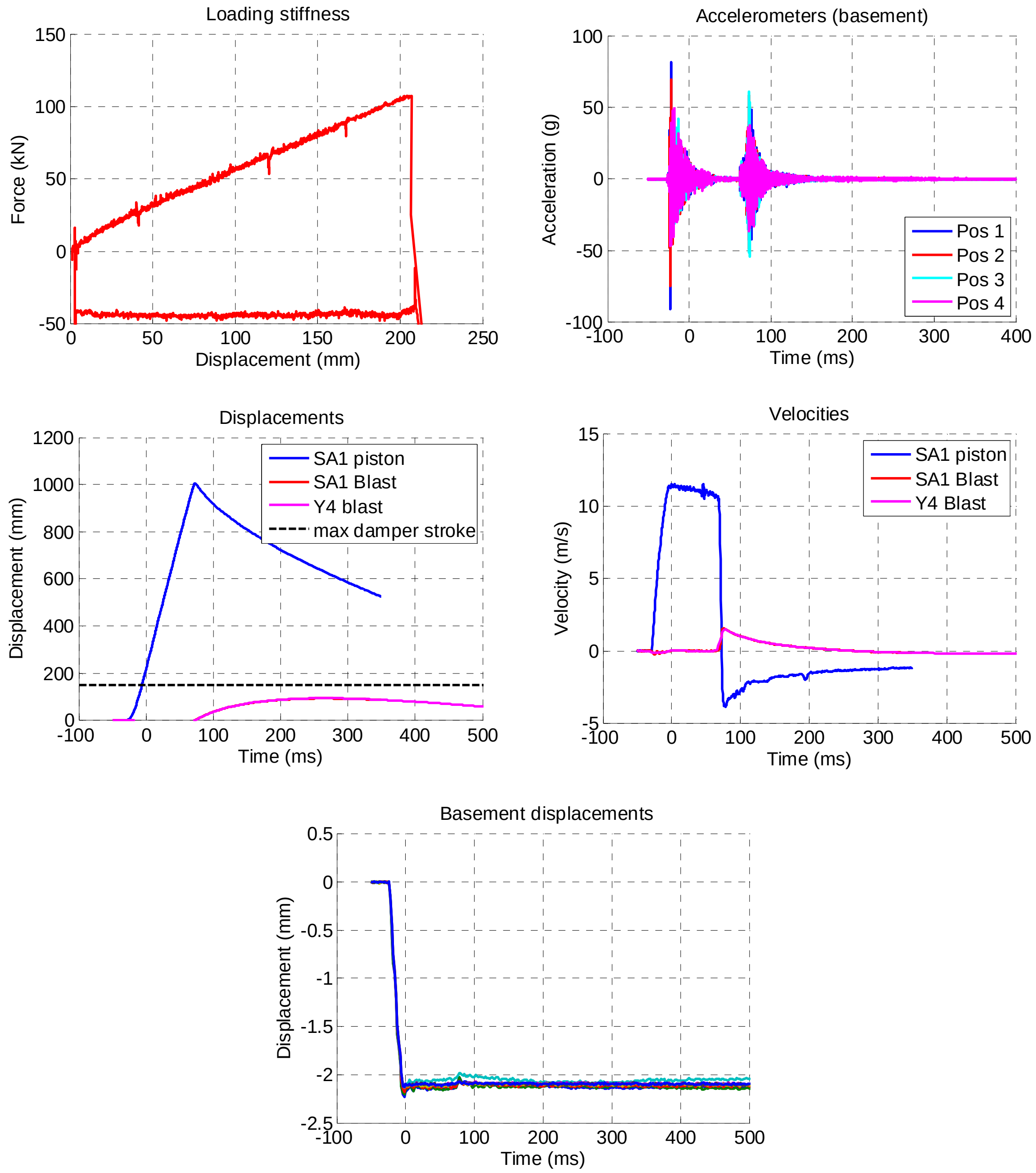

Figure 17. Experimental data

Blast 4

Blast 4 experiment involved only the oleo-dynamic pre-load system to investigate the performance of a new controller generation (ethercat technology) developed in the ELSA/ITU laboratory. With the new controller the pre-load phase has been totally automated. In this test the oleo-dynamic jack has been moved without any fragile bolt placed. For this reason the internal springs was not charged during the displacement of the oleo-dynamic cylinder.

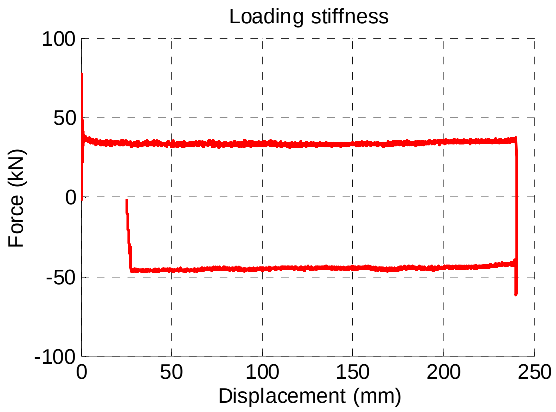

Figure 18. Experimental data

Blast 5

Blast 5 experiment involved the complete setup, shown in figure 7-9, concerning the acceleration of a mass against a rigid wall. To absorb part of the impacting energy an aluminum tube has been placed between the two impacting plates as shock absorber. As in the preview tests only the propulsion energy stored in the springs has been used. To check the performances of the rail structure the stored energy has been limited using a low strength fragile bolt of 5 mm diameter. Unfortunately, due to unexpected connection problems the acquisition of SA1 Photron camera failed during the experiment. Also the load cells applied between the impact plate and the aluminum mass did not work correctly because of an unexpected movement of the impact plates.

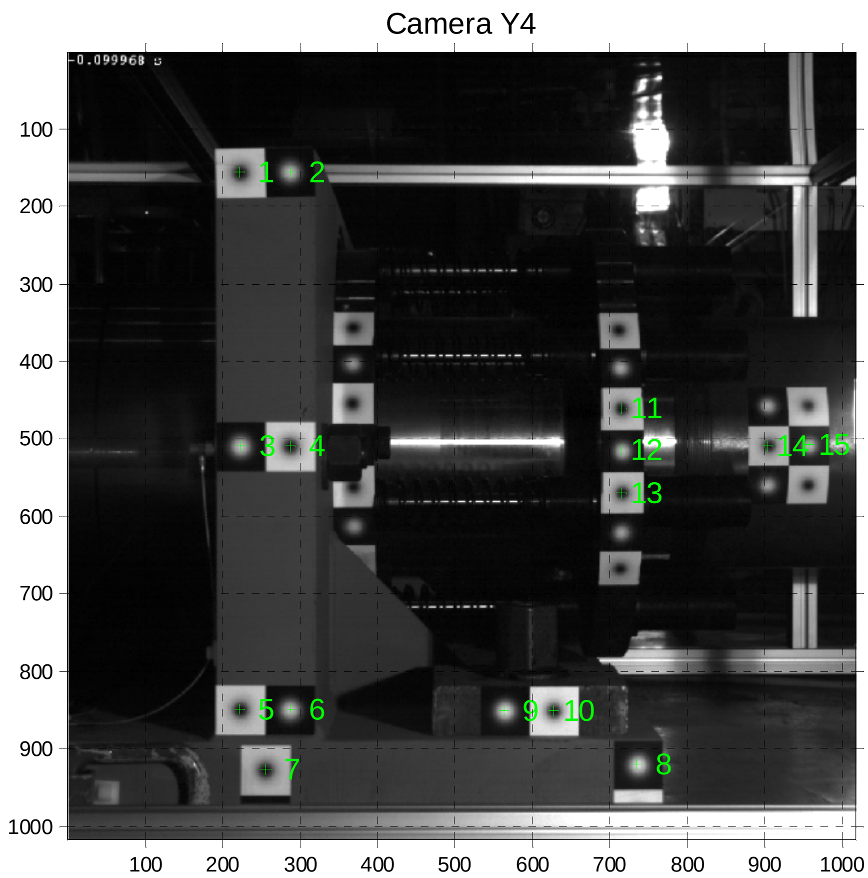

Figure 19. Camera acquisitions and computed targets.

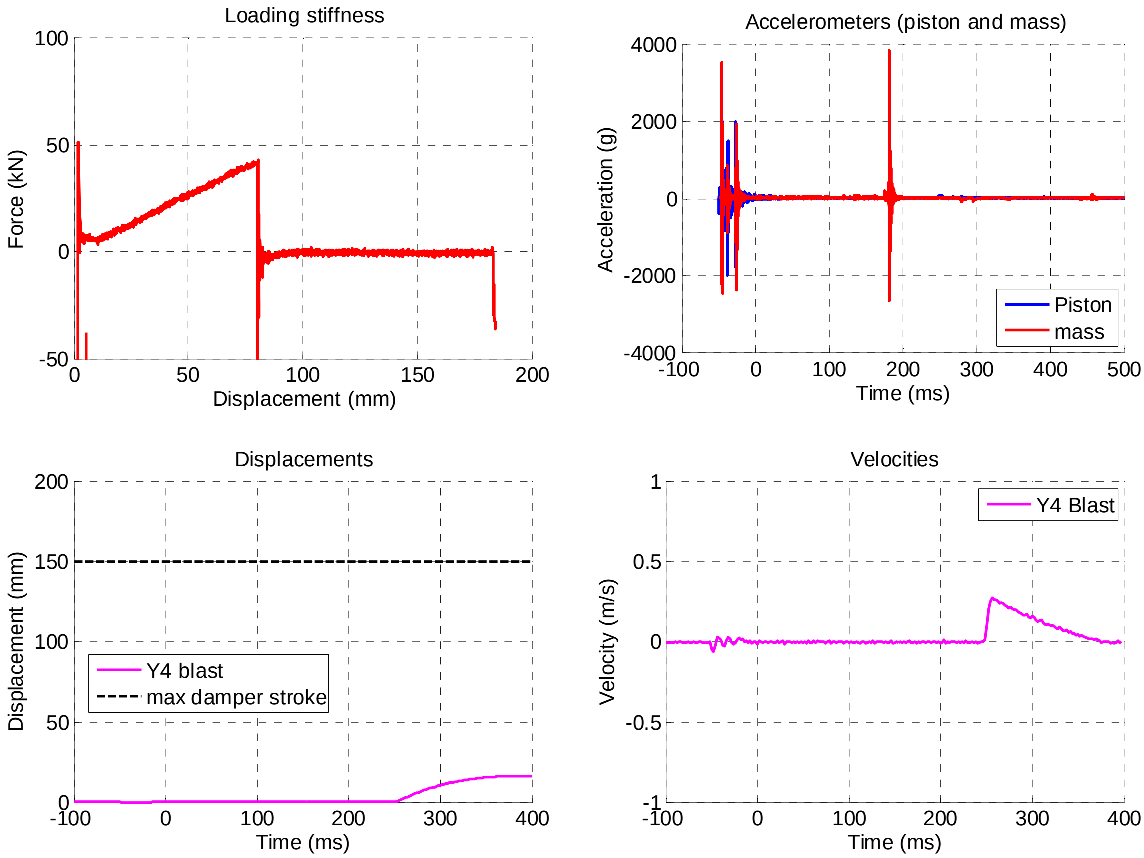

Figure 20. Experimental data

Blast 6

Blast 6 experiment involved the complete setup, as the previous test, but a fragile notched bolt with a diameter of 8 mm had been used to increase the energy stored and therefore the impact velocity. An impact velocity of about 11 m/s has been reached and the maximum peak force applied by the mass was 130 kN (13 Tons). As can be seen in figure 22 the two load cells were symmetrically loaded. The force computed by integrating the mass acceleration has a time shift due to the measurement position (on the other side with respect the load cells).

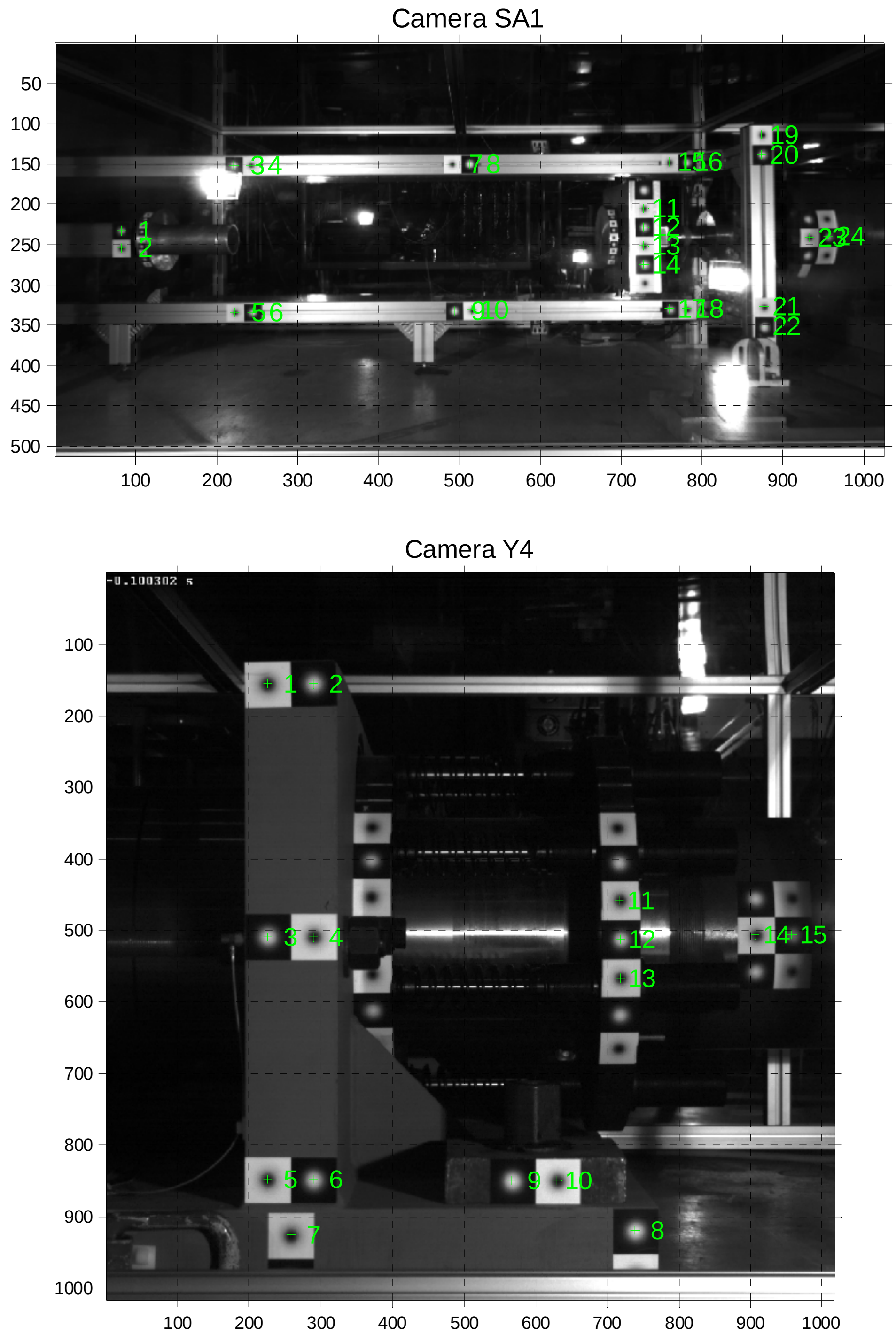

Figure 21. Camera acquisitions and computed targets

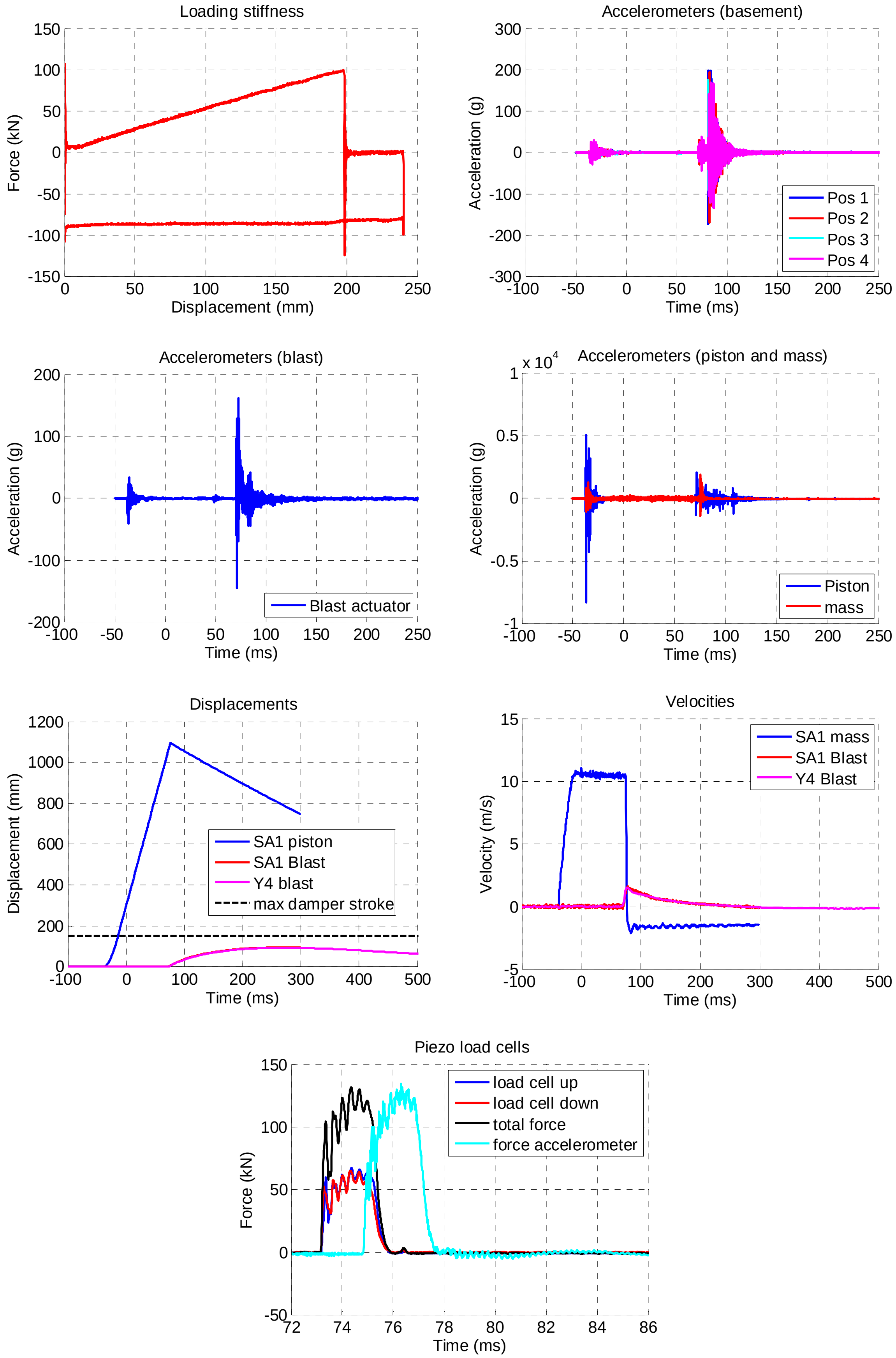

Figure 22. Experimental data

Blast 7

Blast 7 experiment maintained the same experimental setup as Blast 6 (a fragile notched bolt with a diameter of 8 mm has been used). The only variation concerned the increase of the impact mass to about 40 kg by attaching to the aluminum block 6 additional compact masses of lead. This feature implied a considerable increase in the impacting energy of the moving mass. An impact velocity of about 10.5 m/s has been reached and the maximum peak force applied by the mass was 140 kN (14 Tons).

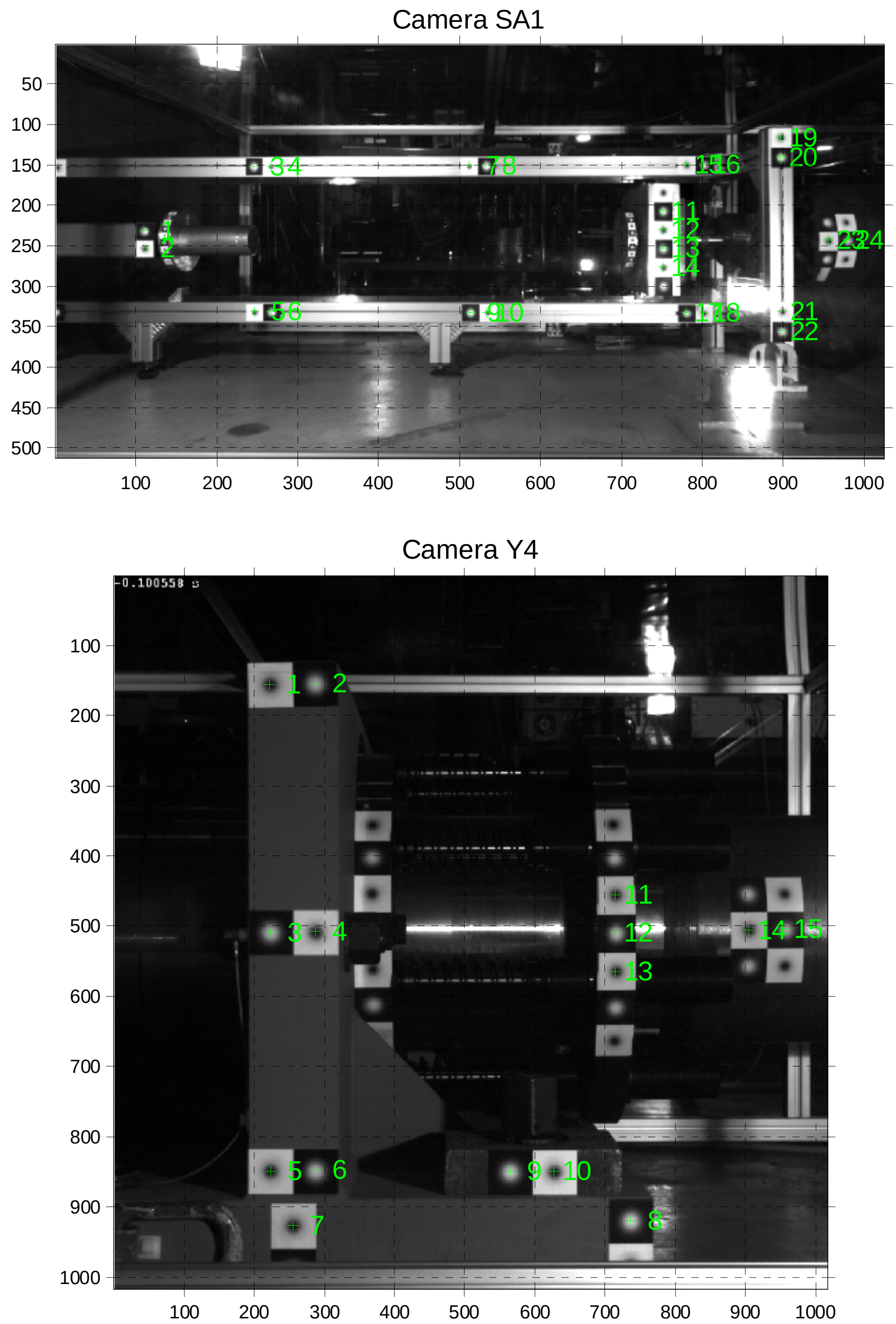

Figure 23. Camera acquisitions and computed targets

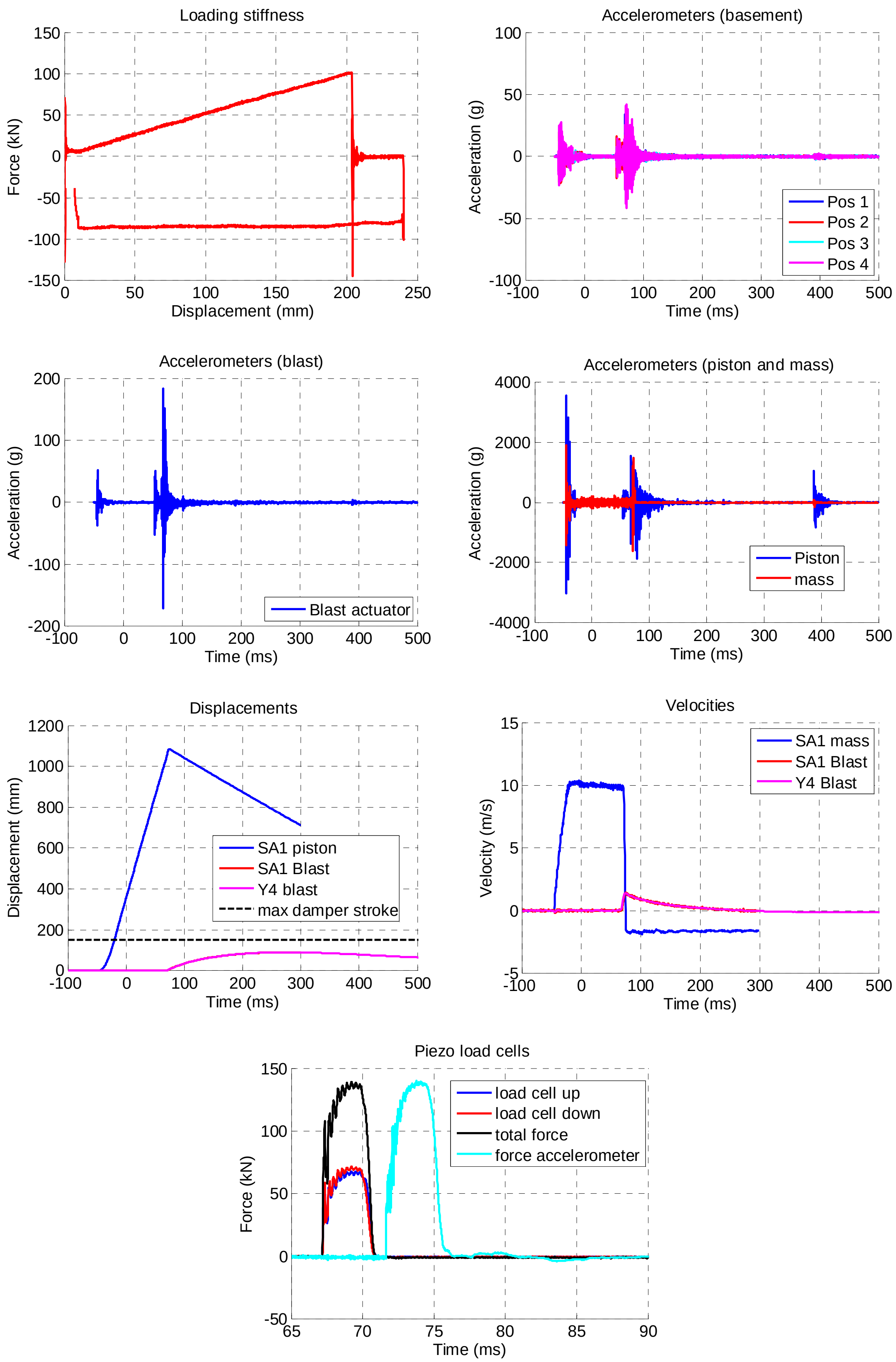

Figure 24. Experimental data

Blast 8

Blast 8 experiment maintained the same experimental setup as Blast 6-7 tests . To further increase the mass impact velocity pressurized nitrogen (10 bar) has been charged in the active gas chamber of the blast actuator and a fragile notched bolt with a diameter of 10 mm has been used. The impacting mass was always about 40 kg and the energy stored in the actuator was doubled, compared with the previous experiment. An impact velocity of about 19 m/s has been reached, but the load cells did not properly worked because of electrical problems.

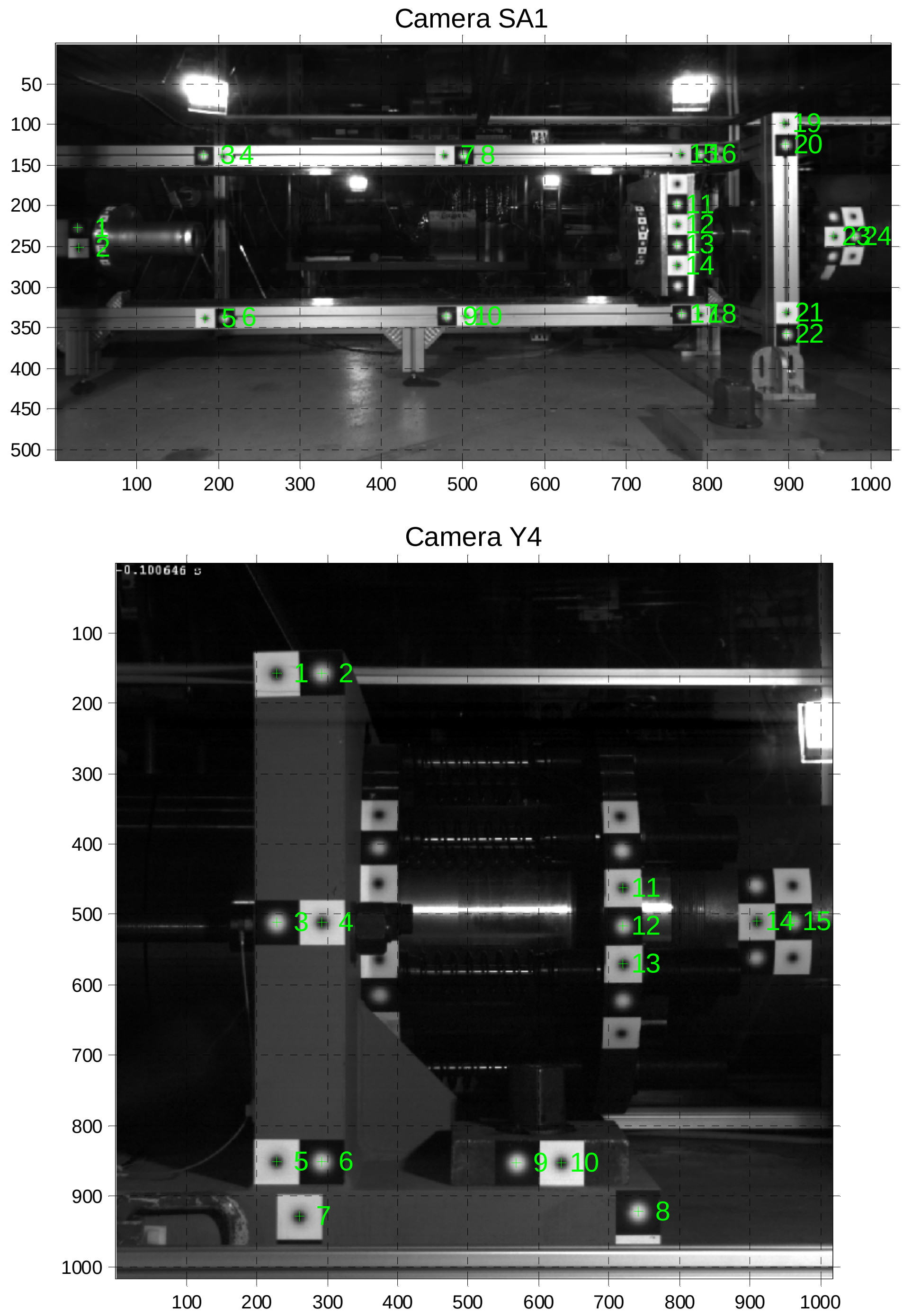

Figure 25. Camera acquisitions and computed targets

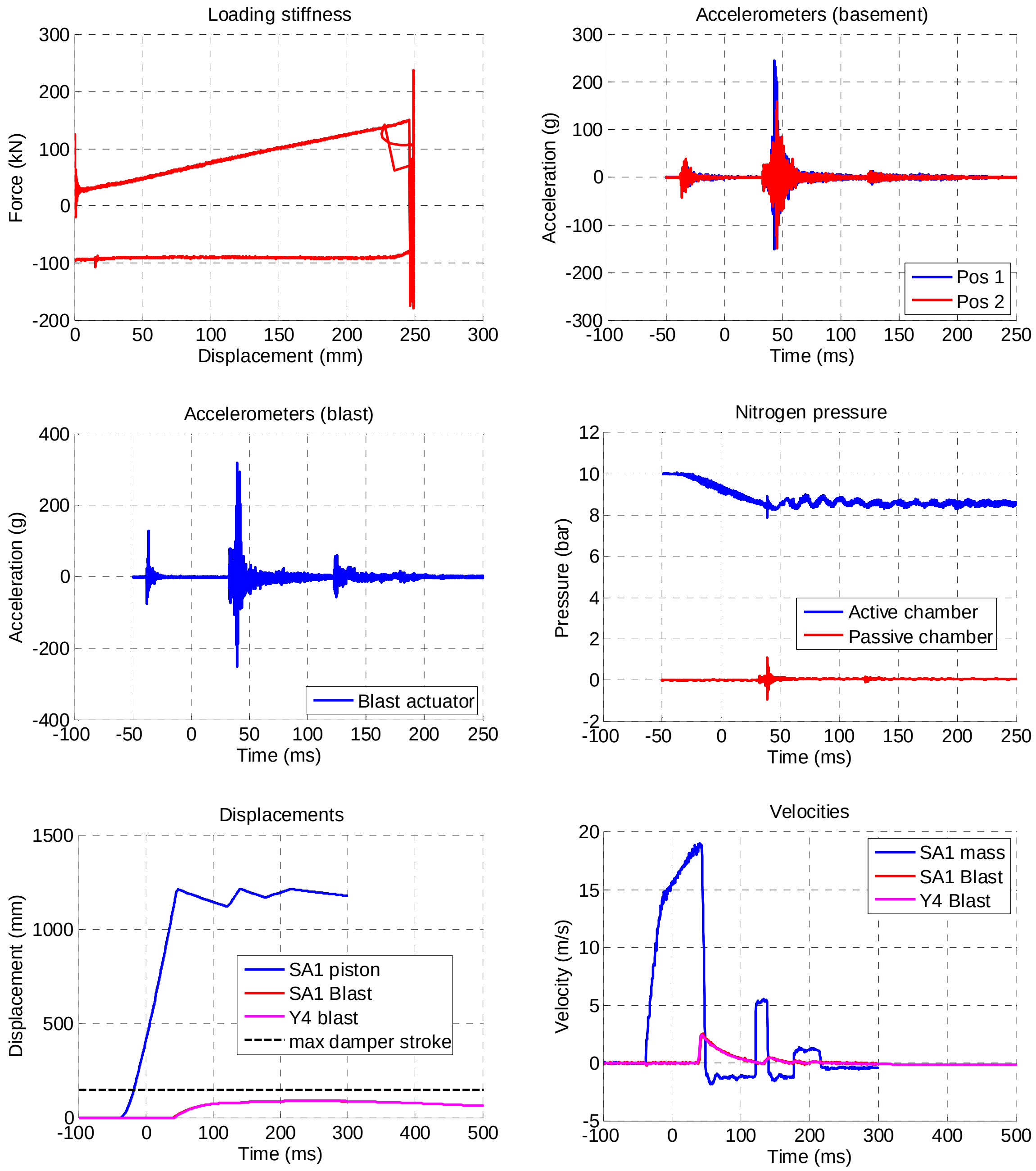

Figure 26. Experimental data

Blast 9

Blast 9 experiment was a repetition of Blast 8 test with an increased nitrogen pressure (15 bar) and a fragile notched bolt with a diameter of 10 mm. An impact velocity of about 21.5 m/s has been reached and the maximum peak force applied by the mass (about 40 kg) was 180 kN (18 Tons). The design velocity of 20 m/s has been reached with a safe level of nitrogen pressure. The accelerometer on the mass was damaged due to an unexpected lateral rebound of the actuator piston.

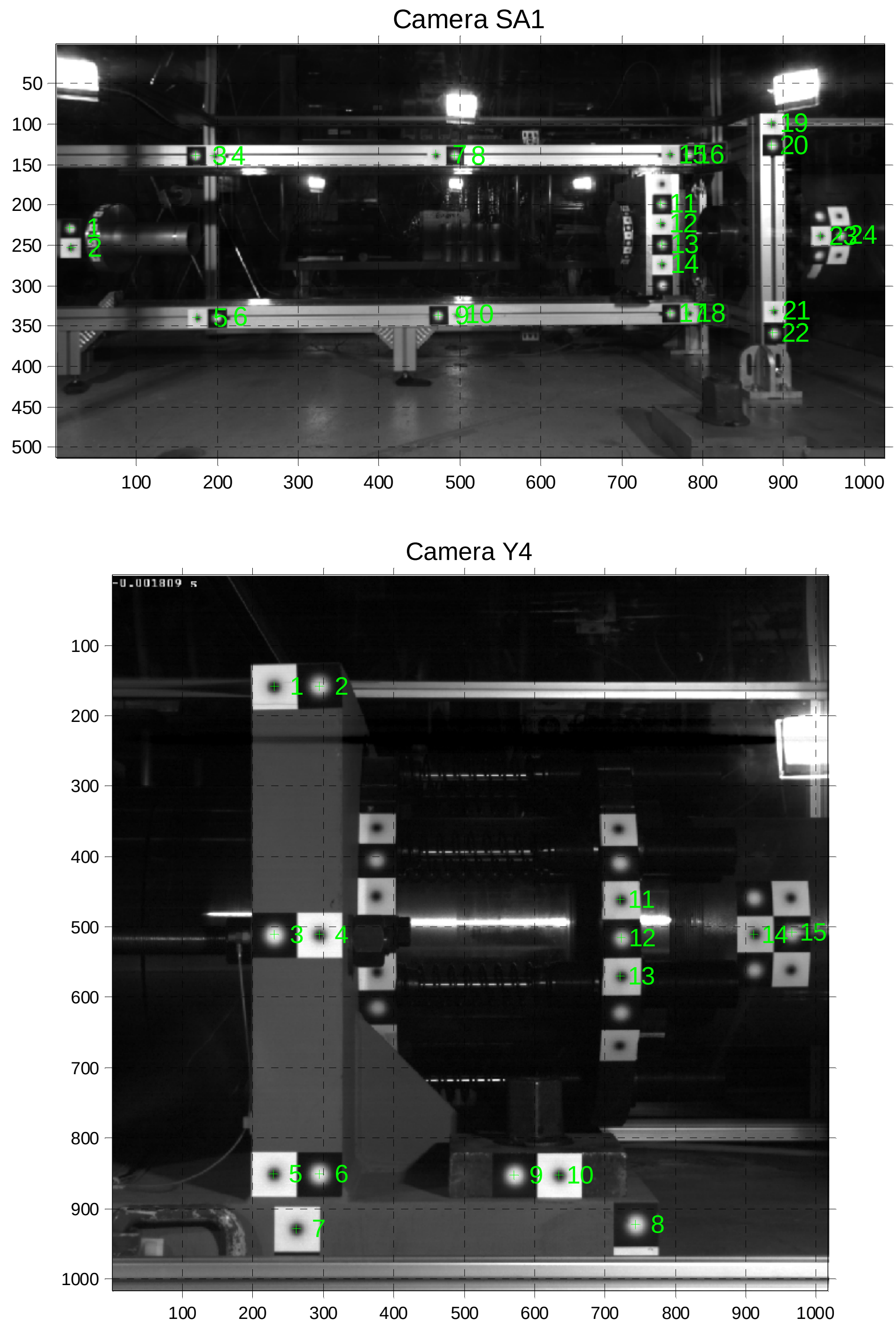

Figure 27. Camera acquisitions and computed targets

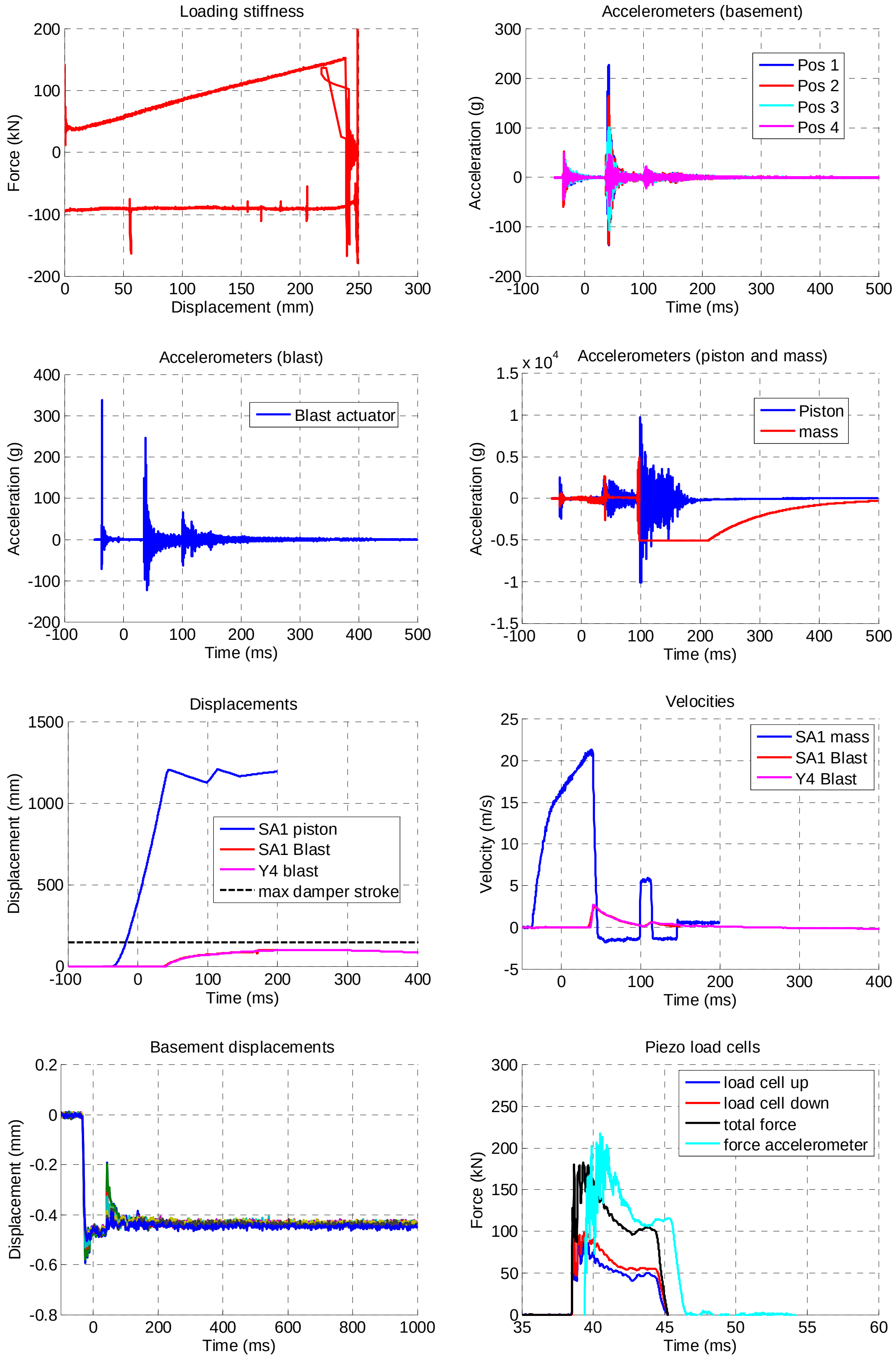

Figure 28. Experimental data

Blast 10

Blast 10 experiment involved the shape and size evaluation of the impulse generated by the impact of the mass against a rigid wall. In this test no shock absorber were placed between the two impacting plates. To partially "smooth" the impulse generated by the impact, an elastic polymeric foam was glued to the moving plate. To reduce the impact forces a small fragile bolt has been used. However, the load cells charge amplifiers saturated at a level of 200 kN. Anyway, the maximum applied force has been computed by integrating the mass deceleration record.

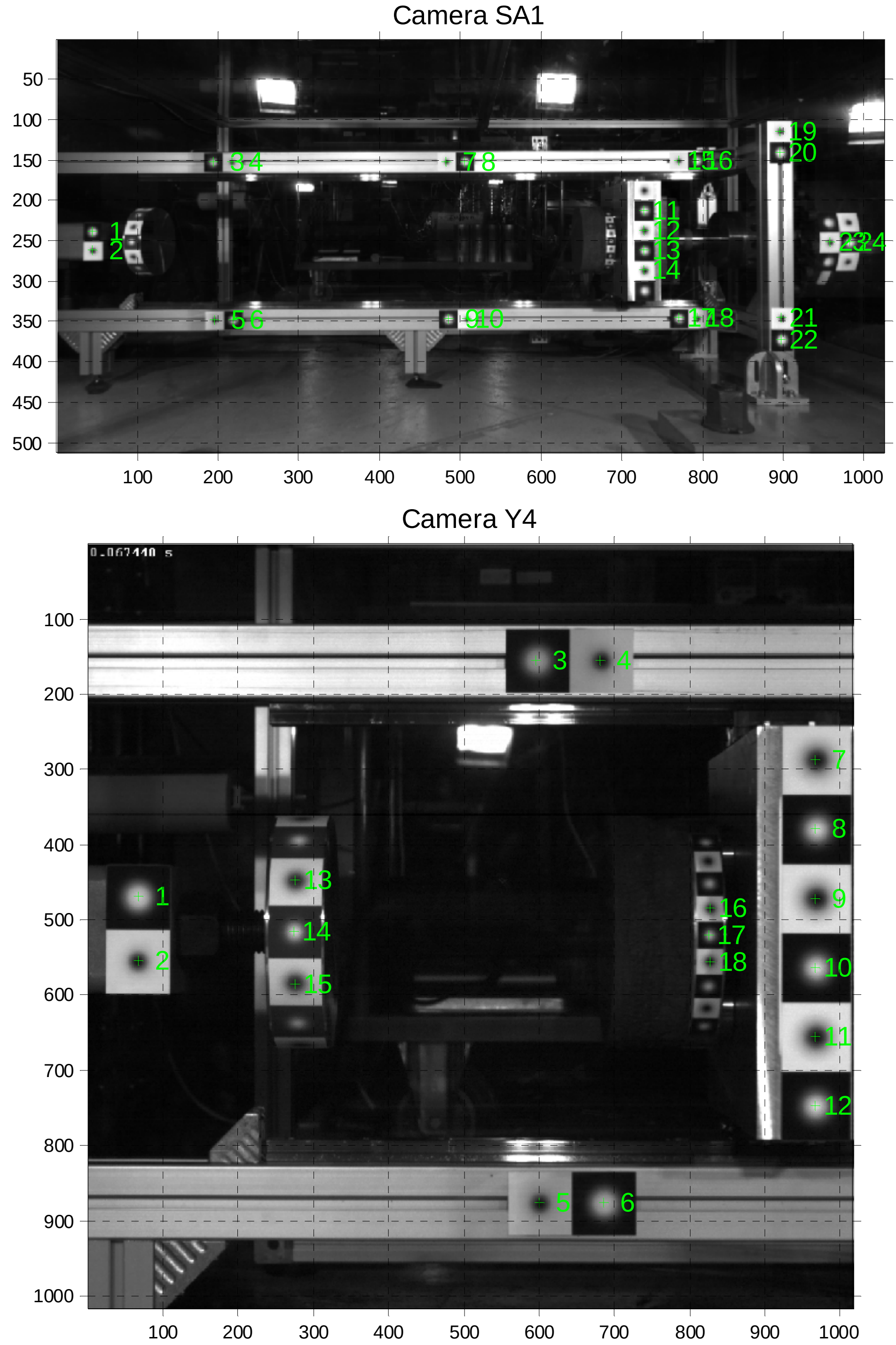

Figure 29. Camera acquisitions and computed targets

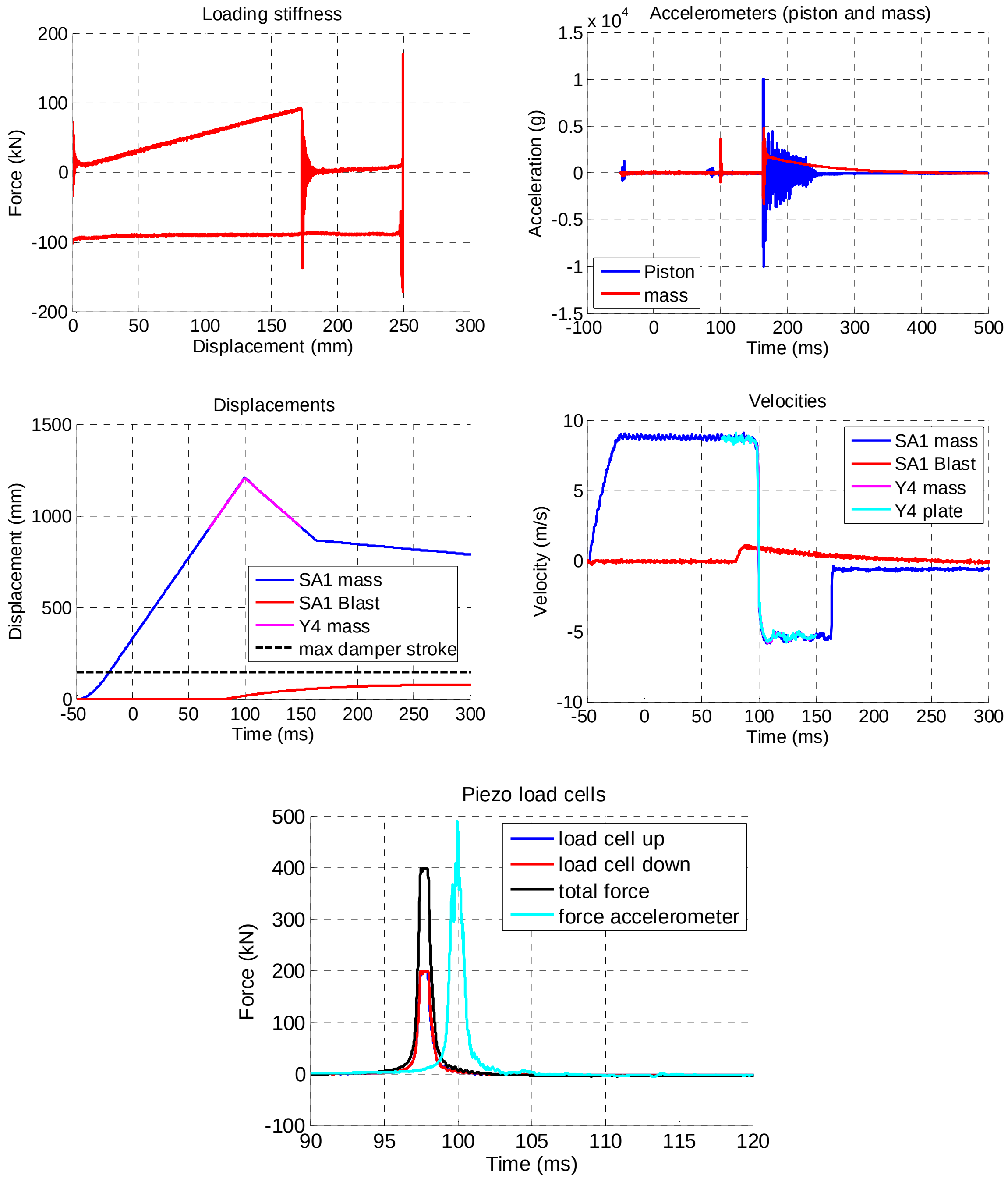

Figure 30. Experimental data

Blast 11

Blast 11 experiment was a repetition of Blast 10 test with an increased saturation limit for the load cells (500kN). Although the fragile bolt broke prematurely, at a pre-load half the value of the previous experiments, the impulse generate had a shape comparable very close with a blast impulse.

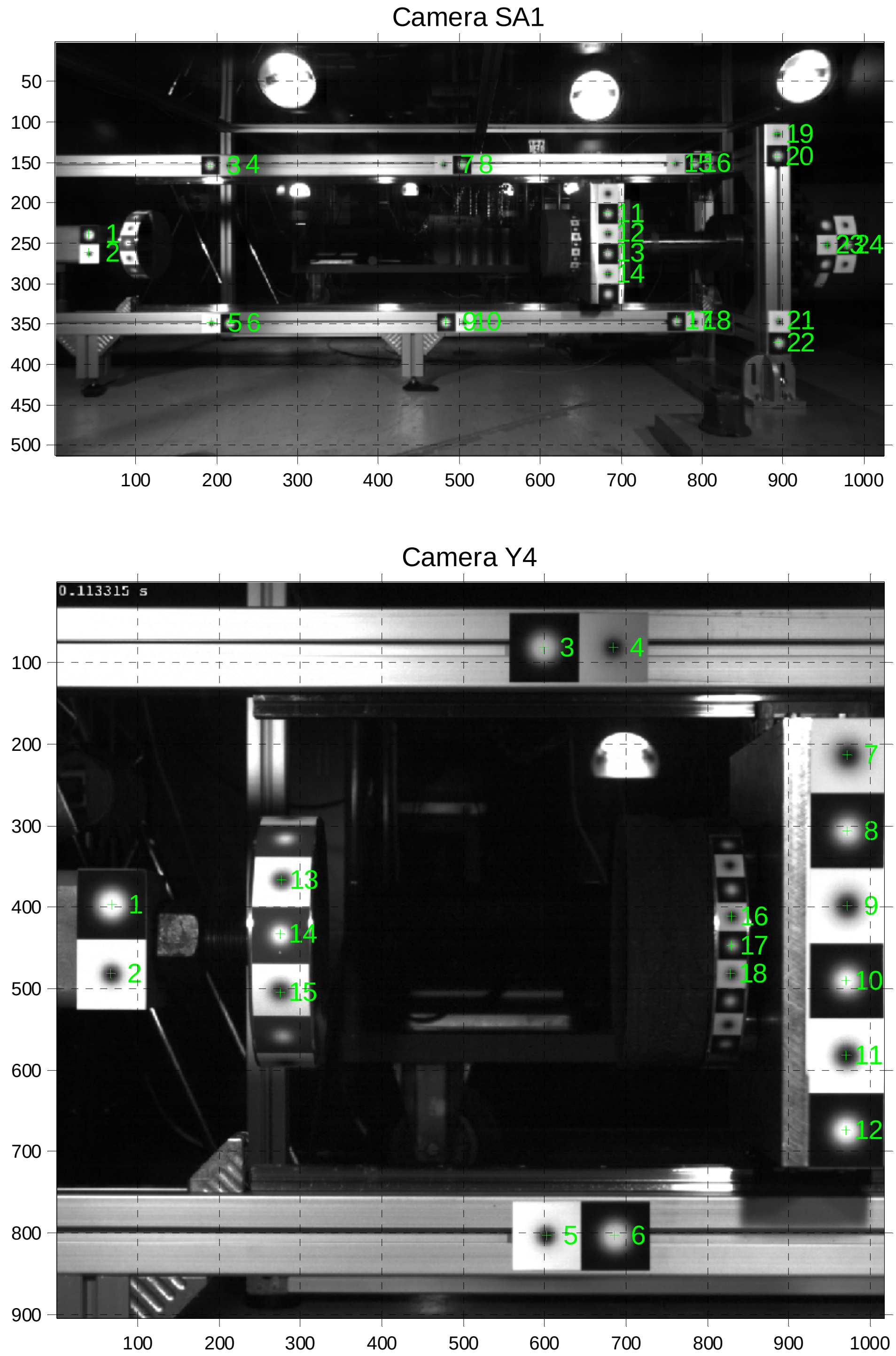

Figure 31. Camera acquisitions and computed targets

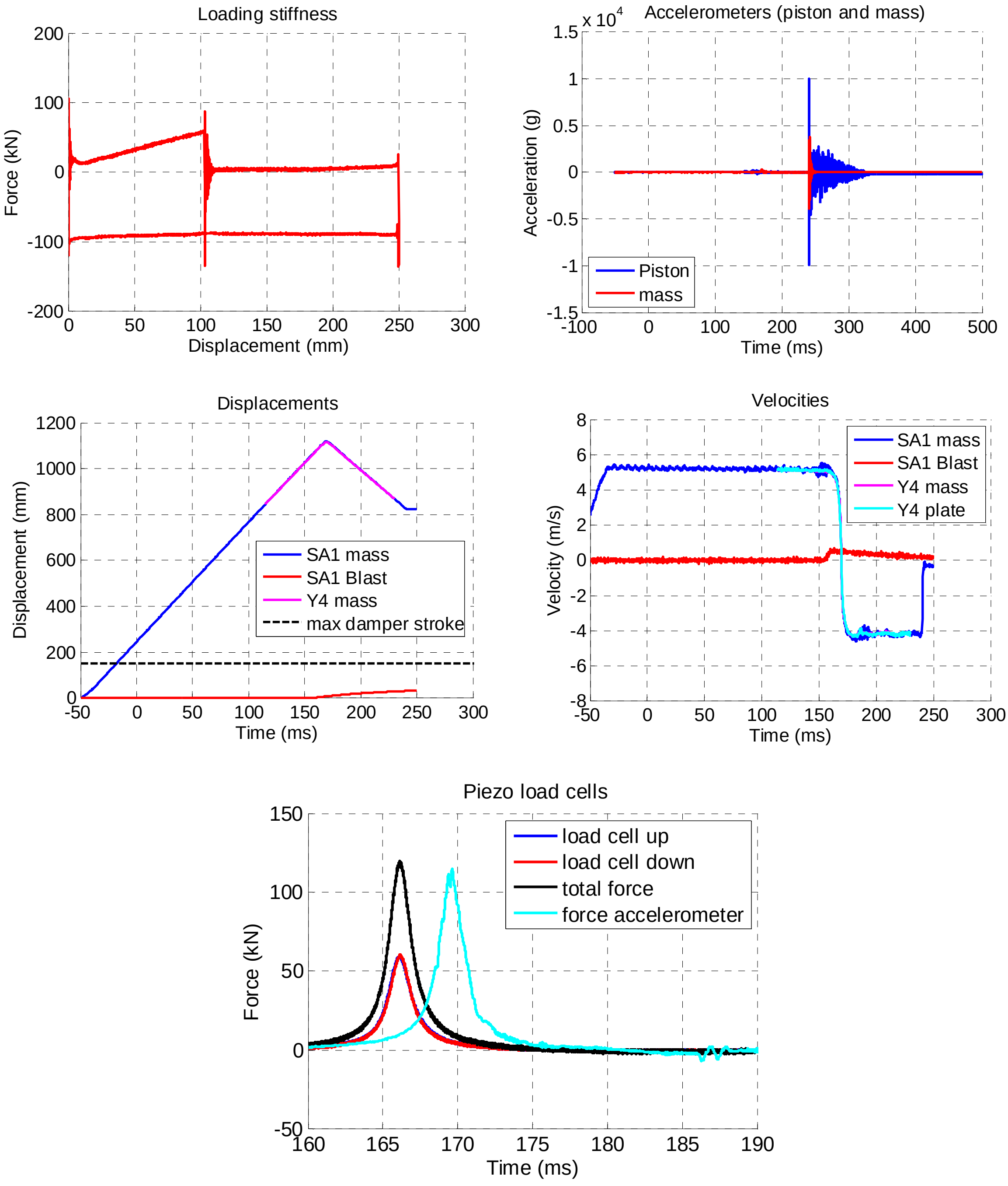

Figure 32. Experimental data

5. Comparisons and conclusions

This section presents some calculations, modelling and comments concerning the performance assessment test of the blast actuator and some considerations about further tests and developments.

With reference to the pre-load oleo-dynamic system and the notched fragile bolt it is possible to predict with a satisfactory accuracy the pre-load (i.e. the fracture load of the bolt) applied to the springs and nitrogen chamber. In fact interpolating the available experimental data the curve proposed in figure 33 shows the pre-load force as function of the diameter of the notched fragile bolt. The interpolation has been made assuming the same material strength for the fragile bolts adopted.

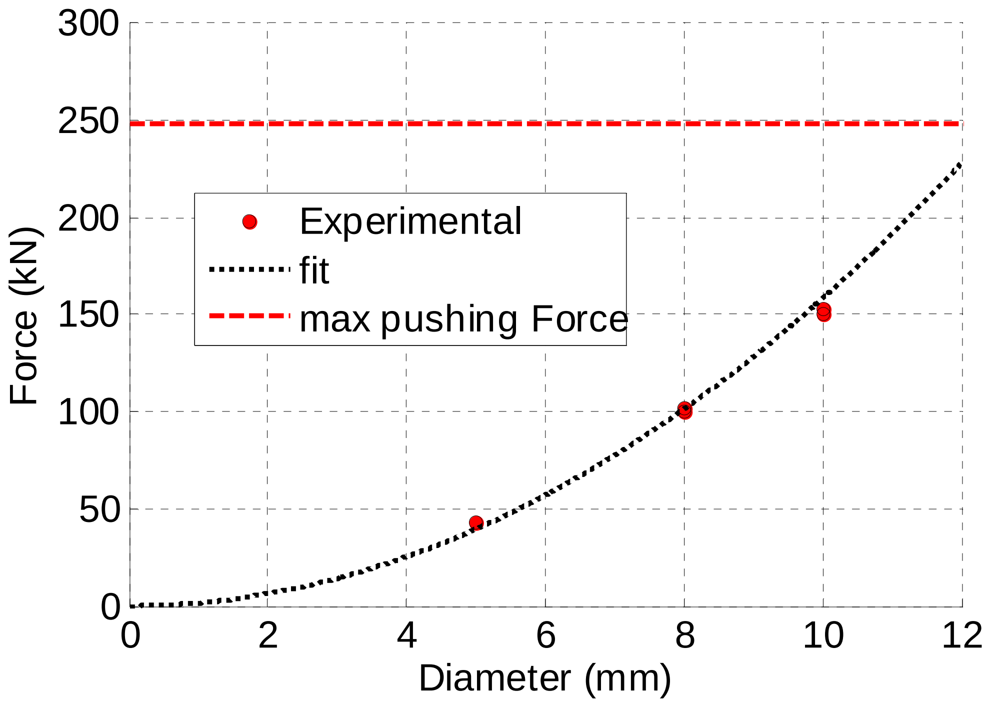

Figure 33. Pre-load force vs. notched fragile bolt diameter

To check the performance of the blast actuator it is possible to calculate in a simplified way the theoretical velocity of an accelerated mass using an energetic approach. Considering only the experiments with the spring propulsion the energy stored in the spring-system can be described with the relation:

$$E_{stored} = \frac{1}{2}kx^2 \quad (1)$$

where k is the stiffness of the springs and x the pre-load stroke.
Assuming that all stored energy is fully converted to kinetic energy, the velocity of the accelerated mass can be computed with the relation:

$$V_{mass} = \left(\frac{2E_{stored}}{m}\right)^{0.5} \quad (2)$$

where m is the total accelerated mass.

Using these two relations it is possible to evaluate the performance of blast actuator in terms of velocity with the spring propulsion, as shown in figure 34a. For all experiments performed, equation (2) slightly over-estimates experimental data. Introducing an efficiency parameter that takes into account experimental losses (mainly friction between seal and cylinder), the test data can be properly fitted (figure 34b). Only the first test performed seems to fall out of the trend, probably due to unpredictable friction phenomena and a very low level of stored energy.

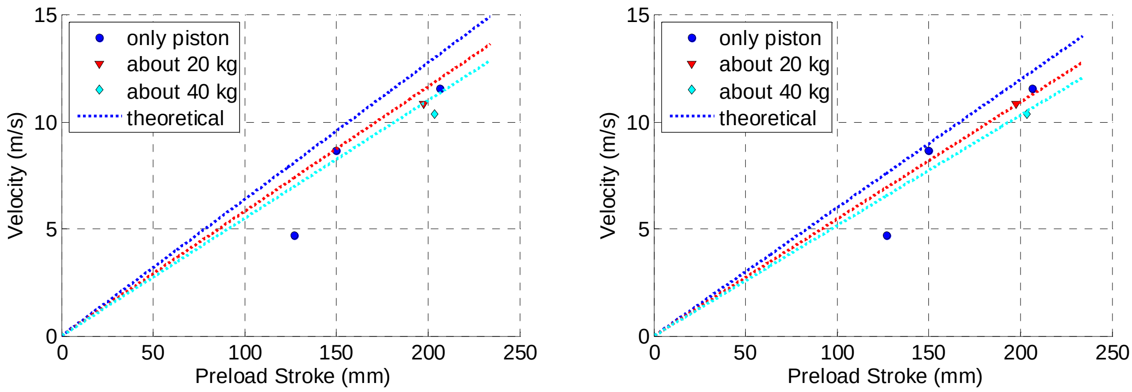

Figure 34. Velocity vs. pre-load stroke a) without and b) with efficiency parameter

The same approach can be adopted to evaluate the tests performed with mixed spring and nitrogen propulsion. The energy stored in the springs is still described by relation (1) while the energy accumulated in the nitrogen chamber can be evaluated considering the work of an adiabatic gas expansion in the form:

$$E_{stored} = \int_{V_{initial}}^{V_{final}} p \, dv = \int_{V_{initial}}^{V_{final}} \frac{p_{initial}(V_{initial})^k}{(V)^k} \, dv \qquad (3)$$

where $V_{initial}$ and V_{final} are respectively the nitrogen chamber volume at the beginning of the experiment and at the end of gas expansion, p the nitrogen pressure and k the adiabatic exponent. In this way it is possible to evaluate the mass velocity using relations (1), (2), (3) for several combinations of nitrogen pressures and accelerated masses, as shown in figure 35.

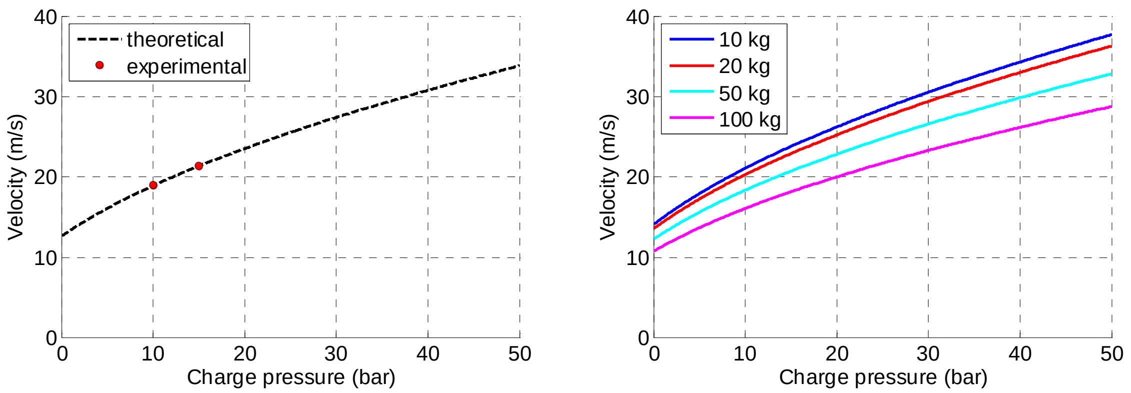

Figure 35. Velocity vs. nitrogen pressure: a) experimental tests fit and b) trends with different masses

With the same efficiency parameter introduced before, experimental data can be properly fitted also in this case and useful estimates of impact mass velocity can be obtained.

As mentioned in the section 1, the objective of this project is to reproduce, in a testing laboratory, the pressure impulse generated by an explosion without using explosives. Assessed the blast actuator performance in terms of accelerated masses and velocities, another import feature relates to the momentum and the kinetic energy (stored into the accelerated mass) and their conversion into a pressure impulse. In fact the pressure impulse onto a structure generated by an explosion has a particular shape that must be reproduced in order to achieve the same effects on the structure.

To reach this goal it is possible to experimentally control three main parameters: the impacting mass, the impact velocity and the geometry/mechanical properties of the material placed between the impacting mass and the structure. This latter is generally a plastic foamed material.

The last two experiments presented in this report concern exactly the study of the impulse profile obtained using a layer of elastic foam with a thickness of 60 mm. To evaluate in this respect the performance of the blast actuator other data available in the technical literature have been sought.

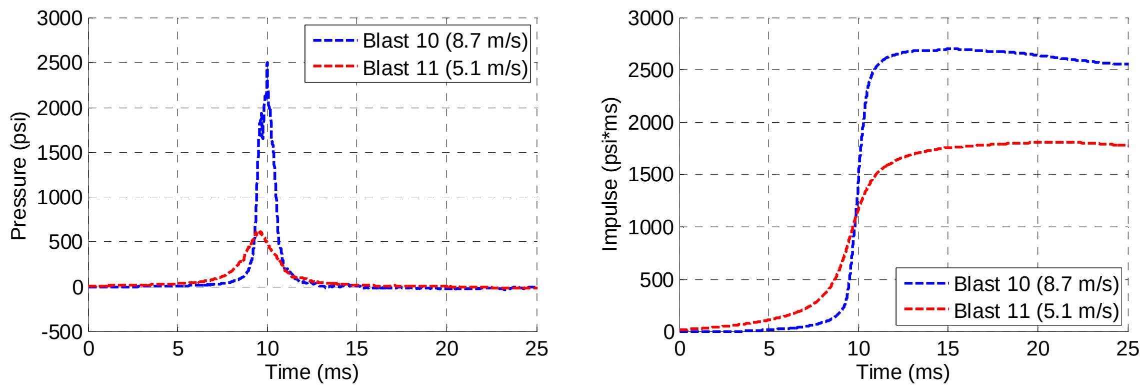

Figure 36. a) Equivalent pressure vs. time and b) trend of specific equivalent impulse

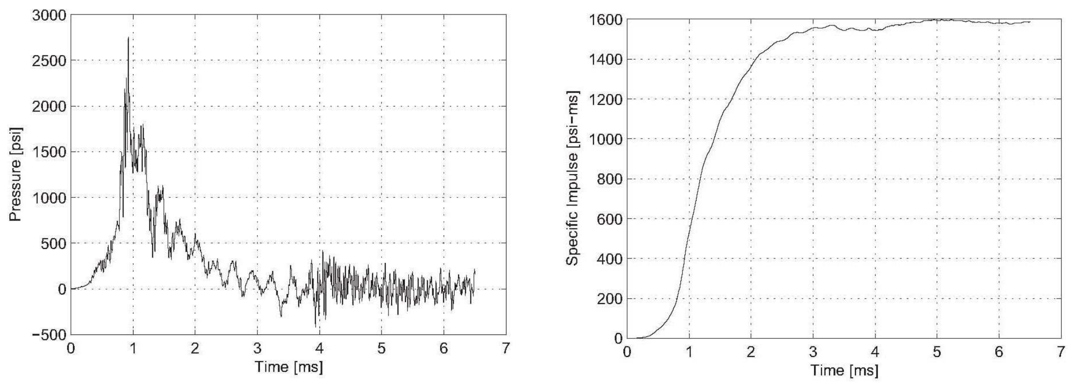

Figure 37. a) Equivalent pressure vs. time and b) trend of specific equivalent impulse (Rodriguez-Nikl 2006)

Figure 36 shows experimental results of the Blast 10 and Blast 11 tests in terms of equivalent pressure (figure 36a) and equivalent specific impulse (figure 36b). English units have been used for comparison purposes. Figure 37 presents relevant experimental data from tests on a structural component conducted at the San Diego Blast Simulator Facility (Rodriguez-Nikl, "Experimental simulations of explosive loading on structural components: reinforced concrete columns with advanced composite jackets", UC San Diego Electronic Theses and Dissertations, 2006).

It is observed that the order of magnitude of the values of the peak pressure and impulse generated by the impacting mass are perfectly compatible and, as expected, the impact velocity has a strong influence on these two quantities. It can thus be concluded with confidence that the developed blast actuator is capable of reproducing through impact the required pressure levels. A further experimental investigation will be essential to calibrate the pressure history applied by the mass in order to perform a large scale test on structural components and reproduce reliably the desired blast pressure loading profiles.

Annex A: Test procedure

1. **Check the pre-stress of Dywidag bar of BLAST base and other equipment plates**

2. **Place the fragile bolt and the safety box**

3. **Check the connection of emergency cable for pumping station shutdown**

4. **Switch on the POWER SUPPLIES of i) charge amplifiers, ii) lamps, iii) high-speed cameras iv) servo-hydraulic system.**

5. **Transient recorder PC: Launch acquisition software for transient recorder and high speed cameras**

6. **Transient recorder PC: Load transient recorder and high speed cameras configuration files for the tests**

7. **Transient recorder PC: check the triggering of digital acquisition systems**

8. **Servo Controller: Launch controller software**

9. **Servo Controller: Load acquisition and generator files and start PID (F3)**

10. **Pumping station: start the circulation pump (no pressure) to allow the oil to get warm.**

11. **Pumping station: Start the low pressure. Verify to have 30÷80 bar.**

12. **Servo Controller: Consider to make F6 to set Tempo to zero**

13. **Servo Controller: F1 open ON-OFF valve.**

14. **Pumping station: Pass to high pressure, verify that the pressure is 150 bar.**

15. **Control test PC: Connect transient recorder PC via Remote Desktop.**

16. **switch on lamps**

17. **<u>Control test PC:</u> press “shading”, record, trigger in on SA1 software**

18. **<u>Control test PC:</u> press “record” on Y4 software and arm the two acquisition boards of transient recorder**

19. **<u>Servo Controller:</u> start the ramp generator**

20. **<u>Blast Actuator Test</u>**

21. **<u>Switch off lamps</u>**

22. **<u>Transient recorder PC</u>: save transient recorder and high-speed camera acquisition**

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Abstract
The Blast Simulator project involves the development of an apparatus able to reproduce the effects of a blast pressure wave on large scale structural components (such as columns, walls, etc.) with the objective to improve their strength in these severe loading situations. This technical report presents the setting up and the performance assessment of the prototype blast actuator developed at the JRC. The first preliminary tests performed have been described and evaluated. Satisfactory results have been obtained with respect to impacting masses and velocities and with the finally obtained pressure values.

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