PROGRAMMABLE DECELERATION DEVICES FOR AUTOMOTIVE TESTING

Hansjoerg Schinke,
MESSRING Automotive Service GmbH
Robert Weber, Ulrich Fuehrer
MESSRING Systembau MSG GmbH
Germany
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ABSTRACT

This paper provides an overview and analysis of a programmable deceleration device for crash pulse simulation systems. Briefly the differences between acceleration or deceleration sleds for simulation are outlined. Working principle and technical data of the device are explained. By means of test results qualities like reproducibility, repeatability, and the ability to simulate crash-pulses are presented.

INTRODUCTION

In today's car design for passive safety sled test play a more and more important role. Since programmable systems for crash pulse simulation were introduced into the marked, they proved to be a helpful tool in component testing, computer model validation, and restraint system optimization, etc.

CRASH PULSE SIMULATION

<u>Acceleration vs. Deceleration Devices</u> - Impact simulation systems can be divided into two categories. The first group simulates the impact actively by accelerating a resting sled with hydraulic or pneumatic actuators. Their major advantage is that the whole system is at rest at the beginning of a test and the simulation results are excellent. Disadvantages are the high installation costs and the limitation to perform exclusively component tests on these systems.

The second category are the so-called deceleration devices. With these systems the sled moves initially with impact speed. To simulate the impact the sled intrudes a brake system. The mounted components on the sled experience a specific deceleration by controlling the brake force. Due to their compact design these systems can be mounted on full scale crash tracks, typically onto the face of the impact block. However the rear end of the track can be used either. Consequently, the major advantage of a system like this is that the same track can be used for car crashes and for sled tests as well. The simulation results obtained from either system are comparable.

Deceleration devices like the bending bar brake, spring bar brake, PU-tube brake, or the system introduced in this paper, the HYDRO-BRAKE system, belong to the later group.

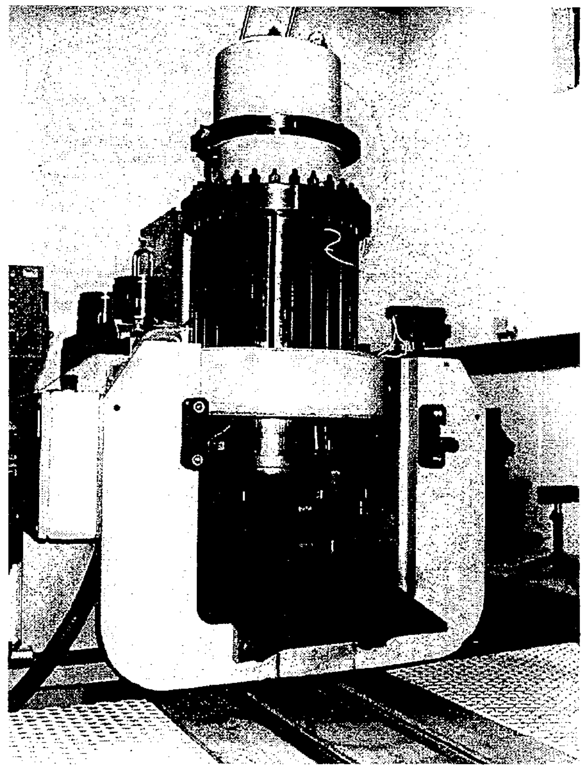

Figure 1. HYDRO-BRAKE System viewed from the front.

HYDRO-BRAKE System

The HYDO-BRAKE system (see Figure 1) which is introduced in this paper is among the deceleration devices. It is capable of simulating crash pulses

- with peaks up to 70 G ,
- sled masses up to 2,000 kg,
- pulse slopes up to ±4 G/ms,
- impact speed up to 80 km/h,
- brake distance up to 1 m (option 1.2 m),
- and repeatability better than ±0.5 G.

With an overall length of 1.7×1.2 m (width×height) and a total weight of 1,500 kg the HYDRO-BRAKE system is a fairly compact system and easy to handle.

Working Principle - In Figure 2 the HYDRO-BRAKE system is schematically shown.

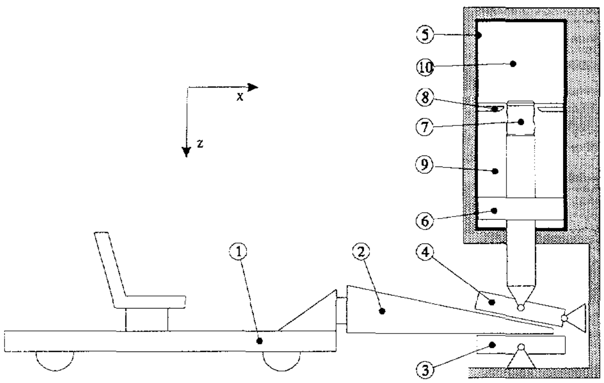

Figure 2. Operating principle of the HYDRO-BRAKE. Shown is the test sled with the impact wedge, brake pads, hydaulic unit mounted.

The brake system comprises of two main parts. First the hydraulic system second the two brake pads (3) and (4). The lower one is stationary mounted the upper one is connected with the same angle as the impact wedge (2) to the hydraulic piston (6) which is housed in cylinder (5). At the lower end of the piston the upper brake pad is mounted and at the upper end a metering pin (7). Together with this pin a mask separates (8) two volumes (9) and (10). Initially volume (9) is filled with oil and volume (10) with air.

The impact wedge (2) connected to sled (1) intrudes with impact speed the brake system. At time t=0 the impact wedge sits tightly between the two brake pads. Due to its angle the penetrating wedge is forcing the upper pad to move in Z-direction. As the wedge is moving, the piston presses oil through the gap between the metering pin and the mask. The gap size and the piston velocity in -Z-direction at any time t determines the pressure in volume (9) as the oil flows from volume (9) to (10). Depending on the contour of the metering pin it reveals a once more once less sized gap as it moves through the mask. Hence, the pressure in volume (9) changes as the metering pin reveals the gap. Due to the direct coupling of deceleration of the sled and the position of the metering pin in the mask one has a tool to determine the pressure at each instant during the deceleration process. Together with the area of the piston the pressure determines the deceleration force and consequently the time-deceleration history.

For a wanted time-deceleration curve an especially written software tool is calculating the shape of the metering pin. In order to do this the software requests the test's boundary conditions like time-deceleration curve and the sled's total mass. Subsequently the software generates the metering pin's diameter as a function of the position on the z-axis.

One feature that makes this system work so well is the orientation of the piston in Z-direction instead in X-direction like it is usually done in competitive systems. Since the wedge (2) is working like a gearbox the piston only travels $1/7^{th}$ of the distance the sled is moving. Consequently a fraction of the oil is merely needed to be controlled. One would expect an increase in forces coming along with the spared distance. This is not the case since a large amount of energy is absorbed between the brake pads and the impact wedge. In fact with this trick the force in Z-direction is of the same value as the impact force in X-direction. Briefly: with this orientation of the cylinder the cylinder diameter can be kept contestant but be built seven times shorter as operating the cylinder in X-direction.

TEST RESULTS

Some questions regarding the capabilities of the HYDRO-BRAKE system will be discussed below.

Reproducibility - When simulating a crash pulse on a sled test facility it is of particular interest how precisely a predefined deceleration curve can be re-produced by the system. This property is called reproducibility. In Figure 3 this is illustrated for the HYDRO-BRAKE system.

Repeatability - An important characteristic of a system that reproduces predefined time-deceleration curves well is the capability of repeating already conducted test at a later time reliably. Figure 4 shows the resulting test curves from 10 subsequent tests. Figure 4 shows the excellent repeatability. Since the HYDRO-BRAKE is controlled by a invariant mechanical system (metering pin) there are no parameters that can be altered by the user or operation. Simply changing the metering pins guarantees the same test conditions from earlier conducted tests.

Reproducing crash pulses - A third point of discussion is the quality how crash pulses from a real car crash can be simulated. One crucial value is the rise or fall time of the deceleration. The shown predefined curve in Figure 5 was calculated with the intention to test the system response. It can be seen that the system can not keep up with the sudden drop and rise in the acceleration curve. The maximum/minimum slope possible for the HYDRO-BRAKE are 4 G/ms. This has to be kept in mind when defining the simulation curve. Hence, the high frequencies of a crash pulse can not be simulated with this system. But an averaged curve of the time-deceleration can still match the time-velocity curve very well.

System Handling and Maintenance - Since one metering pin corresponds to only one combination of time-deceleration curve and total sled mass it is usually calculated for higher sled masses than needed. To avoid tooling a new pin, additional masses are added to the sled if once the mounted components are lighter than the ones used before.

Once a test is conducted the impact wedge needs to be pulled out of the HYDRO-BRAKE. For this the upper brake pad is to be lifted pneumatically, the brake opens and the sled can be pulled back. To prepare the brake for a new test the upper brake pad is lowered and the brake is then ready for a new test. The time between two tests so can be less than 2 minutes.

To simulate a new crash pulse by means of the HYDRO-BRAKE the metering pin needs to be changed. For this the lid of volume (10) is lifted, the metering pin removed, and the new one installed. After closing the lid the system is ready for a new test. The time needed to prepare the system for a new crash pulse then is about 10 minutes.

The HYDRO-BRAKE requires very low maintenance since there is ware between the impact wedge and the brake pads only. By selecting appropriate friction partners the ware can be limited. After 250 tests the HYDRO-BRAKE system did not show any significant ware neither at the impact wedge nor at the brake pads.

FUTURE DEVELOPMENT

One crucial limitation of this system to achieve universal operation certainly is its limited brake distance of 1 m. One possibility to extend this is the reduction of the wedge angle. Consequently the hydraulic pressure will increase and a lower deceleration peak is being simulated. To maintain the performance of the system the wedge angle could be kept constant and the hydraulic system and impact wedge had to be lengthened.

Since the oil flow through the gap is fairly low for this system MESSRING is working on a closed loop control system. By using servo hydraulic valves to control the oil flow versa time in the system it is expected to cut down time in approaching new time-deceleration curves. In addition a better high-frequency response of the system is expected.

In Figure 4 it can be seen that there is an initial peak in the beginning of the test curve. This results from the inertia of the upper brake pad, the piston and the metering pin when accelerating them to $1/7^{th}$ of the impact speed. To prevent this a mechanical system is introduced to accelerate these parts prior the start of simulation.

CONCLUSION

Since a full scale crash test facility can be retrofitted with the HYDRO-BRAKE system the investment costs are significant lower compared to acceleration devices. Through its low preparation time by using automated test preparation and very few maintenance costs it is to be considered as a very cost effective system for crash-pulse simulation and especially for quality assurance testing. It is simple in use and therefore a safe and reliable system. In addition the HYDRO-BRAKE system excels through excellent repeatability.

A disadvantage of this system is the limited high-frequency response. Due to tooling times for the metering pin the time passes by to generate a complete new time-deceleration curve for this system is longer than using servo hydraulic acceleration systems. By introducing servo hydraulic valves to the deceleration device the system performance might be enhanced dramatically. Considering the time-deceleration mass dependency of the hydraulic system it might behave sensitive to changes in impact speed or the total mass of the sled than the metering pin is calculated for.

REFERENCES

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Economic Commission for Europe, Geneva 1990

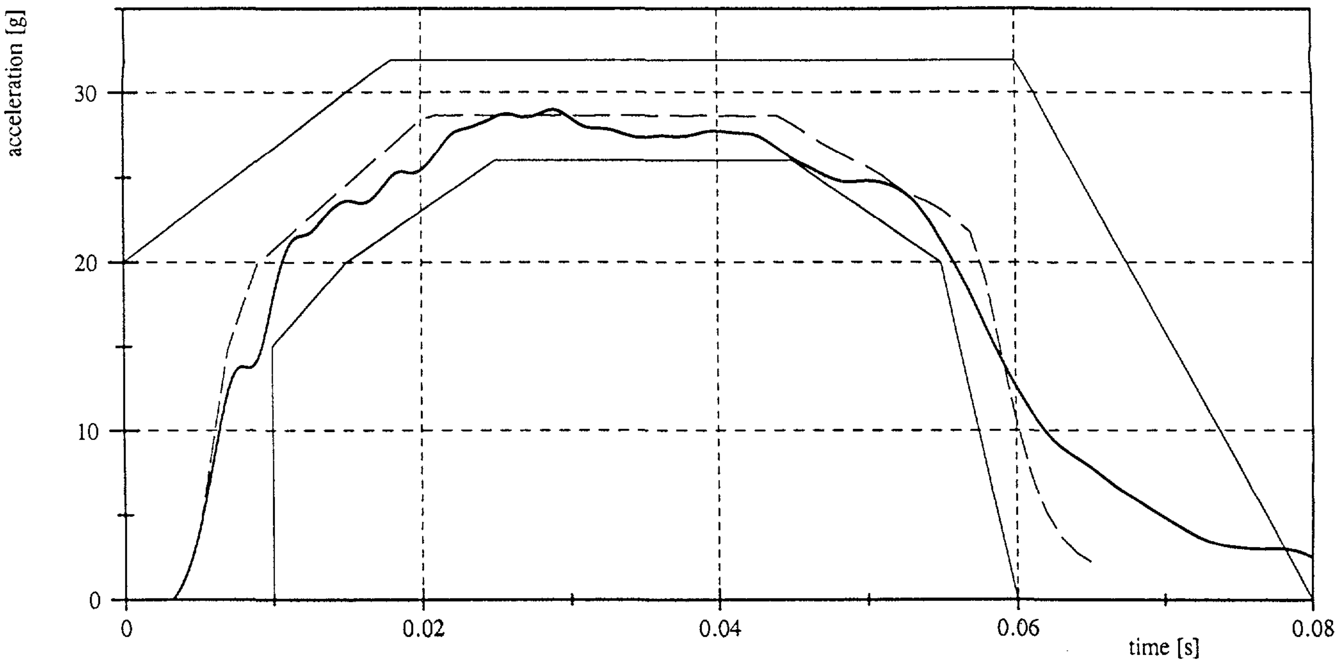

Figure 3. Reproducibility of an ECE-R16 pulse with the HYDRO-BRAKE system. Also included in the figure the minimum and maximum corridors. The dashed line is the wanted, the solid line the simulated curve.

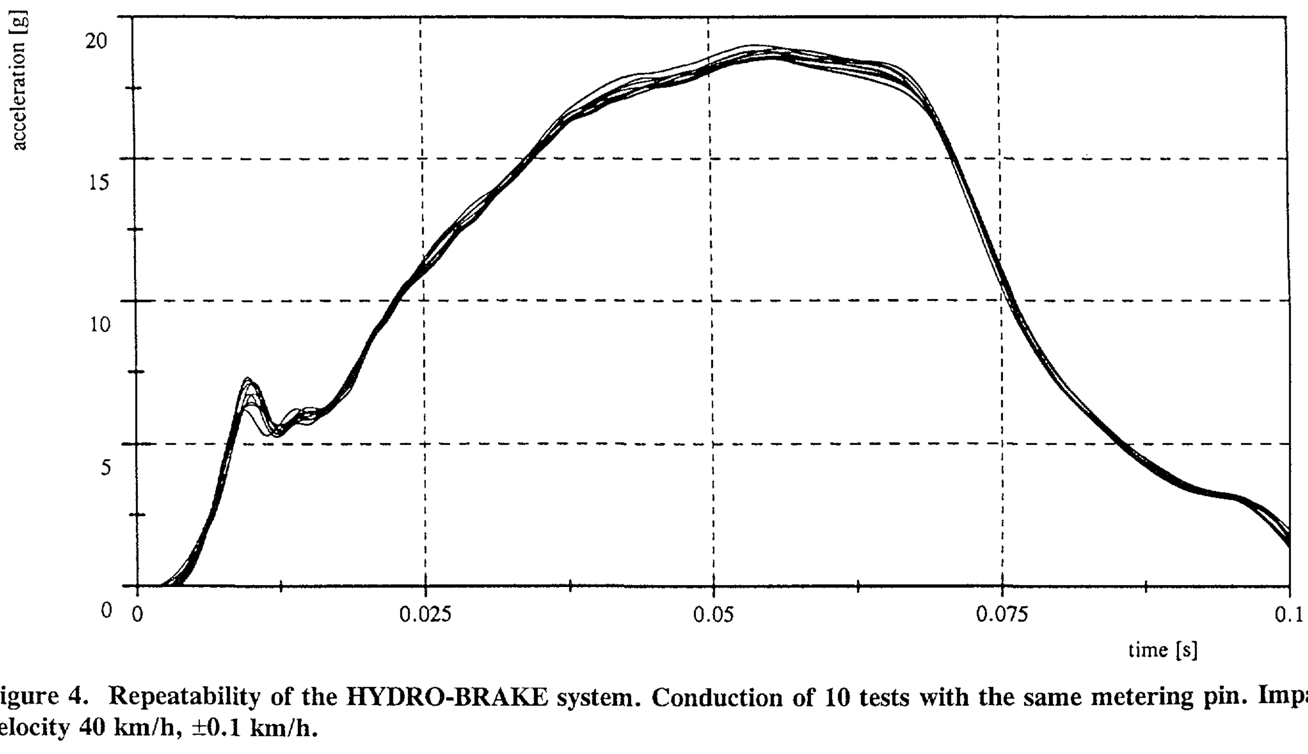

Figure 4. Repeatability of the HYDRO-BRAKE system. Conduction of 10 tests with the same metering pin. Impact velocity 40 km/h, ±0.1 km/h.

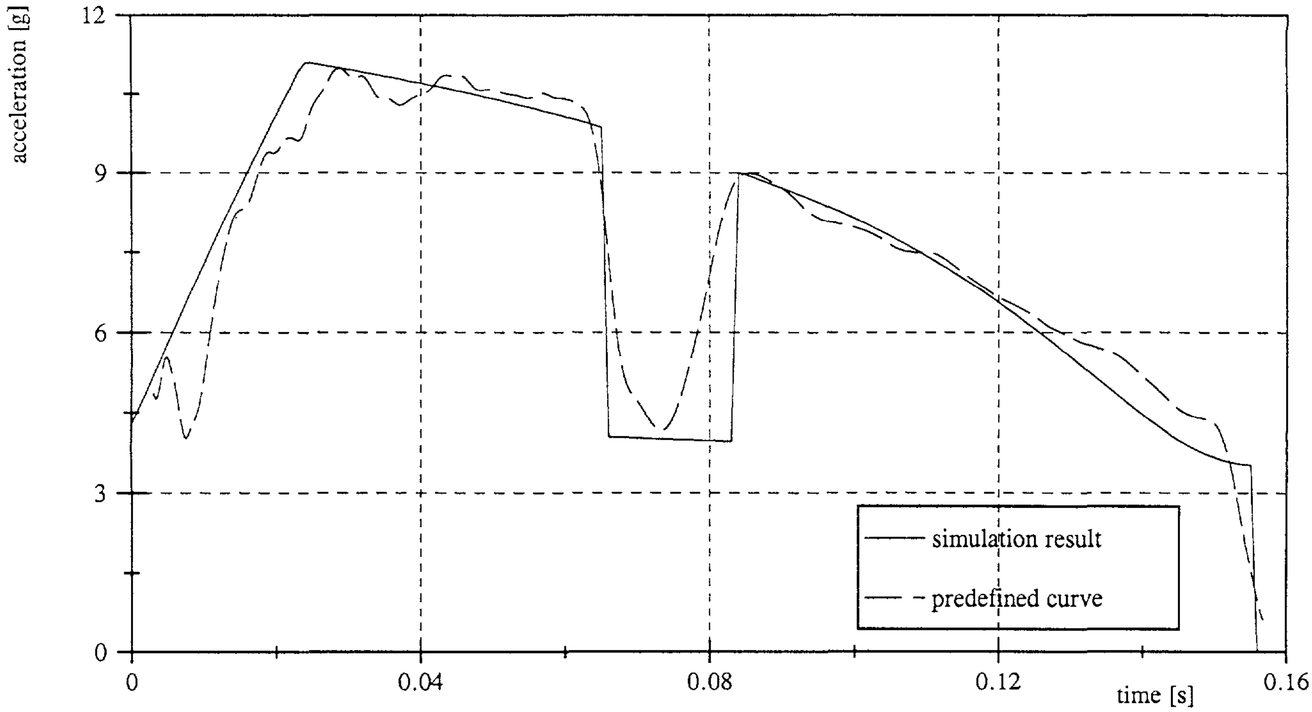

Figure 5. System response to a sudden drop and rise of acceleration