Car Crash Simulators Continue to Make Progress

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A car crash simulator is a test device that can accurately reproduce the acceleration generated in a vehicle cabin at the time of a car crash. They are used in the research and development of passive safety devices such as seats and seatbelts, air bags and headrests, doors, car interiors, etc.

This article describes the achievements made so far and future efforts for the car crash simulator that Mitsubishi Heavy Industries Mechatronics Systems, Ltd. manufactures and sells.

1. Features and major specifications

Our simulator is a test device that adopts an electro-hydraulic servo system. The test is performed based on the principle that as shown in **Figure 1**, a carriage on which a test body is mounted is struck in the direction opposite to the collision direction by the piston of the servo actuator to generate collision acceleration, which is the mainstream test method at present. The servo actuator uses the accumulated oil of an accumulator as a power source and is controlled with a servo valve to make the acceleration on the carriage agree with the target acceleration. The main specifications of this system are shown in **Table 1**.

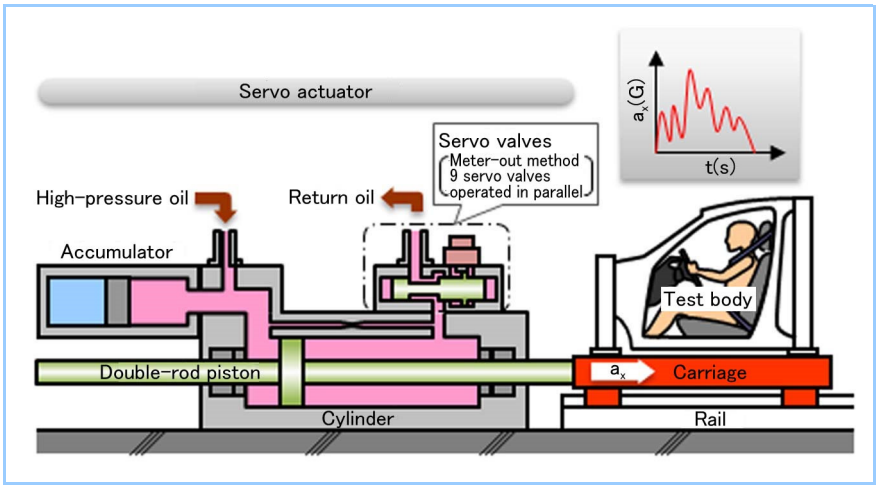

Figure 1 System overview

Table 1 Example of main specifications

Item	Specification value	Remark
Mass of test body	2,000 kg at maximum	
Firing acceleration	80 G at maximum	With a test body of 1,500 kg
Firing velocity	90 km/h at maximum	＝25 m/s
Control displacement	1,700 mm at maximum	＝Piston stroke
Control time	0.3 s at maximum	
Response frequency	150 Hz at maximum	

The greatest feature of our servo actuator is that it adopts the meter-out method with servo valves located on the hydraulic oil discharging side. This enables a high pressure start in the cylinder, and the natural frequency of the hydraulic excitation system is increased, allowing the high-fidelity reproduction of the waveform of collision acceleration to precisely match the high-frequency component.

Nine servo valves are operated in parallel, and the number of servo valves to be operated is changed according to the magnitude of test acceleration, whereby a crash test can be made with a wide range of acceleration, ranging from a frontal collision with a high acceleration to a rear-end collision with a low acceleration.

In addition, a double-rods piston is adopted to prevent the movement of the piston before firing, increasing the accuracy of the timing for piston movement to start. This is an important requirement in operation timing adjustment tests of air bags or seatbelts.

2. Efforts for improvement of basic performance

Since MHI put its first simulator on the market in 1997, we have made efforts to improve the basic performance. The major targets of basic performance required for the reproduction of car crash phenomenon with a higher fidelity are greater power (acceleration, velocity), larger displacement, and higher response. The process of progress in these items is shown in **Table 2**.

Table 2 Process of progress of basic performance

Basic performance	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	～	2015	2016-
Mass of test body	700kg →			1,300kg →		1,500kg →					2,000kg →						
Firing acceleration	40G →			75G →								80G →					90G (Under development)
Firing velocity	65km/h →			83km/h →			90km/h →										
Control displacement	1,000mm →			1,300mm →		1,500mm	1,700mm →										2,200mm (Being manufactured)
Control time	0.12s →			0.15s →		0.3s →											0.6s (Being manufactured)
Response frequency	80Hz →			100Hz →		150Hz →											160Hz (Being manufactured)
Our deliveries	● First model			●	●	●	●		●●		●	●●●		●●	●●		● (Being manufactured)

Meter-out method adopted

3. Efforts for development of test options

As vehicle technologies and technical knowledge have improved, new collision safety tests have been introduced. **Table 3** shows the safety standards and the history of the introduction of new car assessment testing in Japan.

Table 3 Collision safety standards and the history of the introduction of new car assessment testing (example in Japan)

Test item		1994	1995	～	1998	1999	2000	2001	～	2006	2007	2008	2009	～	2014	2015	2016
Collision safety	Full-wrap frontal collision	●	→														
			○	→													
	Offset frontal collision						●	→			●	→					
							○	→									
	Side collision				●	→											
						○	→										
	Rear-end collision neck injury protection												●	→			
	Child car seat							●	→		●	→					
								○	→								
Active safety	Collision damage reducing brake													(Against vehicle)	●	→	

(Collision safety standards introduced ●→, New car assessment introduced ○→)

To correspond with such trends in testing, we have worked on developing various test options. The representative test options are shown in **Table 4**, and the development history and delivery results for the test options are shown in **Table 5**. We have developed the test options anticipating global testing trends and put them on the market. Among these test options, the pitching is notable, which allows vehicle motions in three degrees of freedom, that is, movements in the back-and-forth and up-and-down directions and vertical rotation, with the addition of four vertical servo actuators. Thus, a frontal collision test can be reproduced with a higher fidelity.

Table 4 Representative test options

Test option	Description	Remarks
Pitching	Purpose: To improve the accuracy of frontal collision tests Content: Reproducing vehicle movements in the up-and-down direction and vertical rotation at the time of a frontal collision	Addition of four vertical actuators and special carriage
Toe board intrusion	Purpose: To improve the accuracy of frontal collision tests Content: Reproducing the phenomenon of toe board intrusion into the cabin	Two degrees of freedom motions of parallel movement and inclining
Side collision	Purpose: To reproduce a side collision test Content: Making doors collide with passenger dummies while door's accelerating and decelerating	Addition of carriage and jigs for side collision test
Rear-end collision	Purpose: To improve the accuracy of rear-end crash neck injury protection performance tests Content: Improving the accuracy of low-acceleration waveforms by variable control of the number of servo valves	Standard equipment

Table 5 Development history and deliveries for the representative test options

Test option	1997	～	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	～	2016～
Pitching						●		●			●●				● (Being manufactured)
Toe board intrusion												●			
Side collision	●		●	●				●	●		●	●			●
Rear-end collision			●		Hereafter, equipped as standard. →										

4. New efforts

The global trends in automobile collision safety technologies that we pay attention to are solutions to small overlap crash tests, the spread of the use of collision damage reducing brakes, and self-driving car. In connection with these trends, we consider that the development targets shown in **Table 6** will be required for our simulator in the future.

We will continue to make aggressive efforts toward the realization of the new development targets in the future.

Table 6 Future development targets

Trend in collision safety technology	Development target	Description
Small overlap test	Yawing device	Reproducing the horizontal rotational movement of the vehicle in a small overlap crash test
Collision damage reducing brake	Prebrake-capable actuator	An actuator that can simultaneously reproduce the behaviors of a collision damage reducing brake and collision acceleration
Self-driving compact car	Actuator for compact car	An actuator that can be operated for collision waveforms typical in compact cars which are expected to spread as self-driving cars, electric cars, etc.