

# **INNOVATIVE BONNET ACTIVE ACTUATOR (B2A) FOR PEDESTRIAN PROTECTION**

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## **ABSTRACT**

Since few years, appearance of front vehicles has changed progressively to become friendly towards pedestrians and to meet new regulatory and Euro NCAP queries.

In 2009, Pedestrian Protection received an additional weight with the second phase of the European regulation “Phase 2” and the new scheme of EuroNCAP rating. Requirements on head impact injuries mitigation have been reinforced and compel cars designers to make advised choices between passive and active solutions.

Car designers implement passive solutions with significant changes of the structure to provide a clearance between the bonnet and hard surfaces underneath, allowing free deformations of the bonnet and head energy absorption during the impact.

In parallel, more and more solutions named active hinge systems (or bonnet deployment mechanism) are selected with the aim to lift the bonnet in few milliseconds when a pedestrian knocks the bumper, and to create the saving space under the bonnet surface.

The choice of such active hinge systems is lead by relevant benefits because they allow for:

- car designers, greater freedom for the style;
- carmakers, to meet CO2 rate limitation by improving aerodynamic characteristics;
- consumers, to reduce gasoline consumption.

In January 2011, Euro NCAP working group on pedestrian protection has officially published a method for testing “pop-up” bonnets. As a consequence, active hinge systems can be from now assessed with an official and comprehensive document.

The Bonnet Active Actuator (B2A) designed by SNPE Matériaux Energétiques (SME) is a smart pyrotechnic piston lifter specially designed to operate Active Hinge Systems and to help

carmakers to increase the pedestrian score and so to get a satisfying Euro NCAP rating.

The Bonnet Active Actuator (B2A) has been tested in various cars environment and is ready for applications in cars programs.

## **AIM OF STUDY**

This paper gives an overview of the features and a description of the B2A. It includes the following:

- Background,
- Active Bonnet System review,
- B2A physical content and functions,
- Components testing and simulation,
- Conclusion

## **BACKGROUND**

Directive 2003/102/EC (2) allowed for the EU wide introduction of safety legislation aimed at the protection of pedestrian and other vulnerable road users. Vehicles were required to pass a number of performance tests in two phases in 2005 and 2010. The second phase has been approved in 2009 and came into force with the EC N° 78/2009 regulation (3).

The content of these regulations is based on individual component tests: a Legform test assesses the protection afforded to the lower leg by the bumper, an Upper Legform assesses the leading edge of the bonnet and child and adult Headforms are used to assess the bonnet top area.

The protection of vulnerable road users is also a critical concern for Euro NCAP since 1997. Euro NCAP released a separate star rating for pedestrian valid until 2009 and assesses vehicles with similar sub-systems tests. From 2009, pedestrian score has become integral part of the overall rating scheme with the aim to raise significantly the pedestrian safety area of assessment and to challenge vehicles manufacturers to find solutions for Pedestrian Protection improvement.

In January 2011, the Euro NCAP working group on pedestrian protection has officially published a new method for testing deployable bonnet systems through the updated pedestrian testing protocol version 5.2.1 – January 2011 (1).

In this paper, Euro NCAP requires that pedestrian protection is not compromised by the results of the deformation of the bonnet on impact due to the load of the body. So at the point of head impact, it is essential that the bonnet deflection in the deployed position is controlled and so doesn't exceed the total available clearance between deployed bonnet and engine hard points.

As a consequence, Active Hinge Systems must be able to:

- sustain pedestrians with controlled collapses of bonnets and not bottom out throughout head impact duration,
- retract and absorb energy of head impact in a reverse controlled motion,

Furthermore, Active Hinge Systems must be able to sustain the bonnet few hundreds milliseconds after T fire - 300 ms are generally requested by cars manufacturers - and to keep its head shock absorption capacity during all this period.

## ACTIVE BONNET SYSTEM REVIEW

### Main features

Bonnet Active Actuator (B2A) is designed to be adapted easily to various hinge kinematics, bonnet strengths, geometries and mass, and cars manufacturer's queries related to functions and performances to fulfil before, during and after pyro-triggering.

Bonnet Active Actuators (B2A) control the movement of the bonnet and the effort during the 3 functioning phases requested by Active Hinge Systems.

- They open quickly and simultaneously the 2 hinges located at each corner of the rear part of the bonnet with a controlled linear lift motion.
- They absorb pedestrian impact on the bonnet by a reverse controlled linear motion.
- They relax their efforts after few seconds and so allow bonnet re-closing manually in case a false deployments.

Bonnet Active Actuator (B2A) is a cost effective and highly reliable solution. It allows to meet the new Euro NCAP tests method and increase the score with its particular features and functionalities:

- easy adjustment for various models of hinges and kinematics;
- hinge unlocking and bonnet deployment time;
- bonnet support waiting for pedestrian impact until few hundred milliseconds after T fire;
- bonnet deflection control under body loading and head shock absorption particularly on hinges areas;
- bonnet reclosing without effort in case of false deployment.

### Active Bonnet System overview

This section describes the basic structure and mechanisms of Active Bonnet System. So as it is illustrated in Figure 1., Active Bonnet System consists of the following components:

1. Bumper sensors. They are installed behind the front bumper fascia. They give information about the fact that an impact is occurring and also on the stiffness of the impacting object which can be pedestrian legs or anything else: pole, ball...
2. Electronic Control Unit (ECU): It is located inside the cabin of the car and judges the necessity to lift the bonnet after receiving and analysing bumper sensors signals and vehicle speed.
3. Active Hinge Systems (Hinge + B2A): As it is illustrated in Figure 2., they raise simultaneously the rear portion of the bonnet as soon as they receive the triggering signal send by ECU.

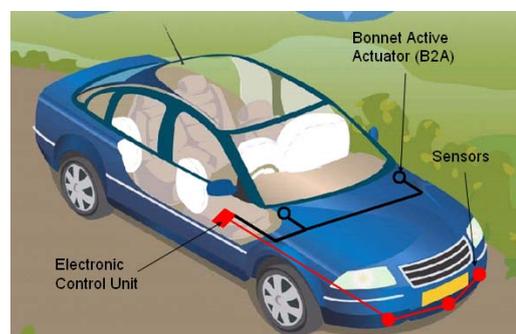
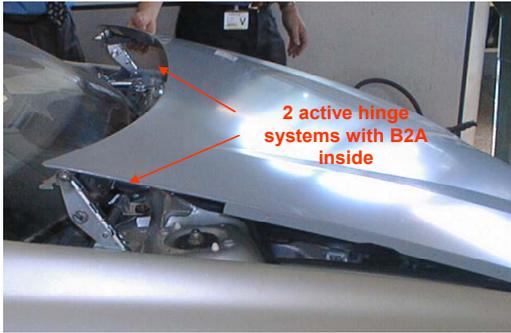


Figure 1. Active Bonnet System



**Figure 2. Bonnet and Active Hinge Systems in elevated position**  
(ready for head impact absorption)

### Active Hinge System

Active Hinge System consists of 2 components:

#### 1. Bonnet Active Actuator (B2A)

The pyro-actuator proposed and designed by SME is named Bonnet Active Actuator (B2A). It is constituted with a Micro Gas Generator (MGG) and a piston located in a tube as shown in Figure 3..

The piston move out under pyro-gas pressure when the MGG is triggered.



**Figure 3. Bonnet Active Actuator (B2A) designed by SME**

#### 2. New hinges designs

Hinges are specifically designed to ensure an unusual function which is the lifting of the rear portion of the bonnet under a pushing force at approximately 100 mm high.

During normal operations, bonnets are currently open and close by upward and downward movements of their front parts which are controlled by hinges pivots.

When Active Hinge Systems are triggered, latching systems located currently at the vehicles front end become fixed pivots and as a result control the rotating movements of bonnets rear portions (Figure 2.).

New hinges designs gather the following components (Figures 4. & 5.):

- pivots for normal bonnets closing and opening operations,
- upper and a lower members for fixation on cars bodies and bonnets,
- locking devices to keep hinges mobile members folded for normal bonnets operations (shear pin, rivet or hook),
- intermediate ties arms and pivots to provide particular hinge kinematics and specific bonnets trajectory.

Figures 4. and 5. illustrate hinges designs examples with typical characteristics gathered in table 1. below.

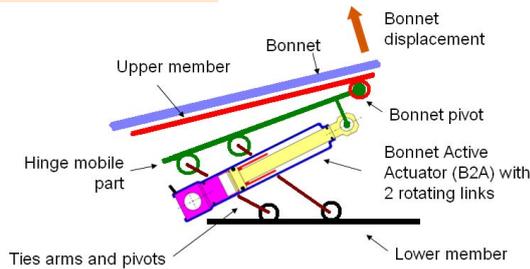
	Figures 4 & 4bis	Figure 5
Hinge type	-Link hinge design type	-Free Pushing Force hinge design
B2A mounting	-B2A linked to the bonnet with a hinge mobile part	-No link between B2A and bonnet
Upraising controlled movement	-B2A pushing force applied horizontally (or almost) on the intermediate mobile part of the hinge. -Bonnet pivot vertical trajectory controlled with 2 intermediate ties arms	-B2A pushing force applied vertically on the bonnet.
Gear ratio between B2A and hinge strokes	3 (as an example)	1
Locking device		Shear pin

**Table 1. Hinges designs characteristics**

In both cases, hinges kinematics can be modified by the lengths and positions of intermediate ties arms.

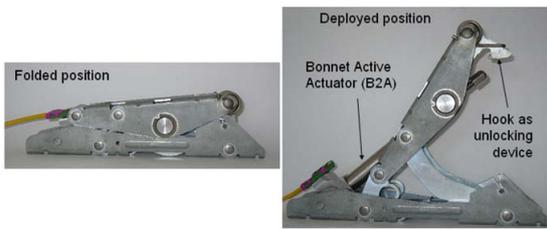
During normal bonnets opening or closing, the locking devices (ex: shear pin, rivet or hook) keep hinges mobile parts in folded position, allowing only hinges upper member and bonnets to rotate around bonnets pivots.

**Hinge gear ratio 3**



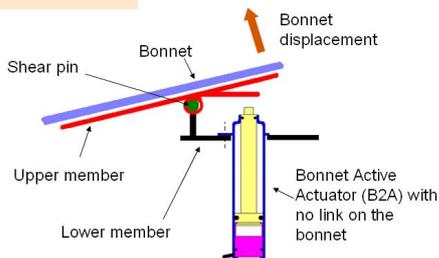
**Figure 4. Link hinge design type**  
B2A end piston is linked to the hinge upper member

**Hinge gear ratio 3**



**Figure 4bis: Link hinge design type**  
Prototype implementing a hook to unlock the hinge mobile parts

**Hinge gear ratio 1**



**Figure 5. Free Pushing Force hinge design type**  
Piston is not linked to the hinge upper member

When B2A is triggered, its piston pushes the locking device until it breaks (shear pin or rivet) or opens (hook) allowing hinge upper member to move upward.

The piston deploys under pyro-gas pressure and extends the hinge. As the result, bonnet rear portion raises and provides the saving clearance under the bonnet surface.

**Setting the times for the Bonnet Active Actuator operating phases**

This section describes B2A operating phases, thresholds and durations for each of them.

Phase 1: Bonnet deployment

Active Bonnet System must provide assurance that bonnet always deploys before head impact and remains in elevated position when it happens.

Tests and simulations are carried out to evaluate typical head contact times in car to pedestrian collisions at a speed of 40 km/h. With AM50 dummy, it occurs at approximately 150 ms. The shorter is the height of the dummy, the shorter is the head contact time, so with the C6Y dummy, the contact time is estimated at 60 ms and the maximum value is given for 250 ms according to specific studies (4).

As a result and illustrated in Figure 6., the time for the bonnet deployment after T fire must be lower than the shortest head contact time and so is usually specified within 30 ms.

Phase 2: Bonnet support

After bonnet deployment, B2A must sustain a sufficient and constant effort (pyro-pressure) until pedestrian impact on bonnet, to ensure a deflection control under body loading and head shock absorption.

The time limit of this sustained force after T fire is usually specified at 300 ms Regarding the longest head contact times define above.

Phase 3: Bonnet reset ability

The sensing system could trigger a deployment even if no pedestrian is involved. In that case, B2A sustained force must be relaxed and cancelled after the 300 ms threshold, allowing a manual bonnet re-closing (few daN are generally requested).

Figure 6. presents threshold and times requested for B2A operating phases with the following parameters:

- T0 First contact leg-bumper
- T sensor Time for firing signal
- T sensor\_max Largest value of T sensor
- T fire Time for firing

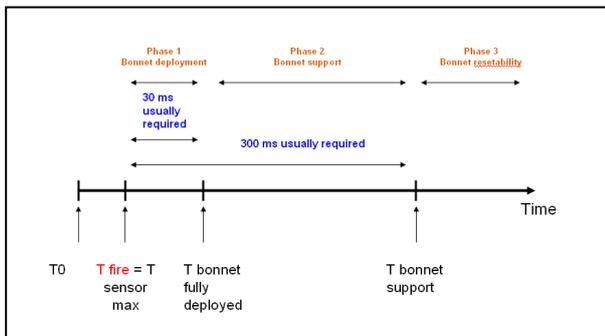


Figure 6. Times of B2A operating phases

## B2A PHYSICAL CONTENT AND FUNCTIONS

### B2A physical content

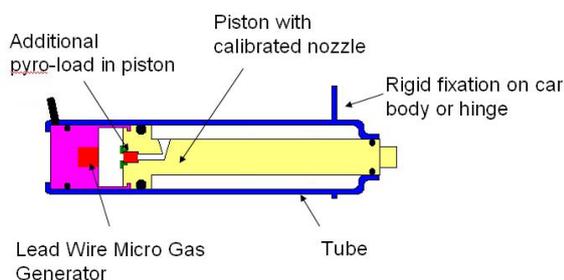


Figure 7. B2A general design

As shown in figure 7., B2A consists of:

- MGG (Micro Gas Generator),
- Additional pyro-load (in piston),
- Piston in tube with calibrated nozzle for pyro-pressure control,
- Casing/tube.

B2A is a fully tight actuator able of resisting the humidity and severe atmospheres which we find in engines compartments.

## B2A functions

B2A design allows an easy sizing to achieve customers performances requirements illustrated in Figure 8. below.

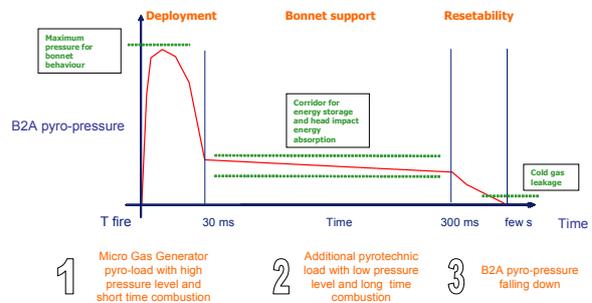


Figure 8. B2A operation phases vs pyro-gas effort (pressure)

### Phase 1: Bonnet deployment - Controlled pyro-pressure and time with MGG pyro-load

B2A provides a controlled piston motion and effort upon receipt of an electric signal. This movement is started by the MGG ignition.

B2A piston extension occurs in a short time (within 30 milliseconds as requested by customers) under a quick pyro-pressure increase provided by the combustion of the MGG pyro-load. That creates a force which elevates the bonnet at the deployed position.

Combustion chamber pressures and resulting extension speeds can be sized and adapted to customers requirements without any modification of the B2A design.

The bonnet vertical trajectory is to be multiplied with the gear ratio of the hinge in order to define the stroke of the piston.

B2A design is able to fulfil a minimum stroke of around 10 mm to a maximum stroke of at least 120 mm depending on hinge kinematics and gear ratio (Figures 4. & 5.).

Phase 2: Bonnet support - Controlled energy storage for head impact absorption with the secondary pyro-load

When B2A is fully extended, it is able to store energy. The force level for this “work function” is achieved after the deployment phase and must remain constant until 300 ms after the T fire. The topic is to control the bonnet deflection under the body loading and to absorb the head shock which can occur during all this time.

The pressure of the additional pyro-load (Figures 7. & 8.) takes over the MGG pyro-pressure to provide longest time combustion at a lower level (Figure 11). Its combustion time is roughly multiply by 10 regarding MGG pyro-load combustion time. (30 ms for deployment to 300 ms for bonnet sustain).

This B2A force level is also easily tuneable. The value is define by the quantity and the composition of the additional pyro-load.

Phase 3: Bonnet reset ability – Bonnet closing if no pedestrian impact occurs, with pyro-pressure release

After a deployment event where no pedestrian impact occurs, bonnet has to be re-closed manually without any tool. The objective is for the driver to recover the visibility and to drive the car to a service facility.

For that topic, B2A provides a calibrated gas leakage whereby customer can move back the B2A to its initial un-deployed position through a manual force applied on the bonnet (Figure 12). Customer is likely to apply a few daN force at the rear portion of the bonnet just above hinges.

**COMPONENTS TESTING AND SIMULATION**

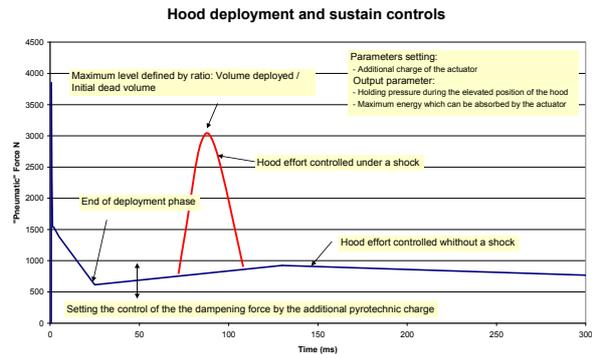
**Objectives**

Several simulations and tests has been done to check B2A operations:

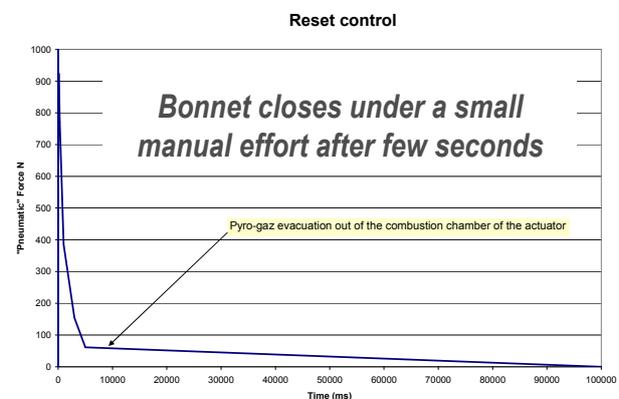
- Bonnet deployment,
- Bonnet sustain and effort control,
- Bonnet reset ability.

**Typical results**

Figures 11. & 12 illustrate the typical curves coming from these simulations and tests.



**Figure 11. Simulation and test typical results**



**Figure 12. Piston force vs time after Tfire + 300 ms for bonnet re-closing**

**Comments**

B2A allows specific tuning to meet customers requirements according to:

- Deployment time,
- Bonnet sustain effort for energy storage and time,
- Cold gas leakage to insure bonnet reset.

Tests are in accordance with simulation.

It has been so checked under impactors tests (Figure 11.) that :

- bonnets is fully lifted within 30 ms.
- Energy stored after deployment with pyro-gas allows to get good HIC values until 300 ms.

## CONCLUSION

B2A is a simple pyro-piston lifter fulfilling carmakers and hinges designs requirements.

B2A design is easily tuneable with pyro-parameters without any change of the global design and main components, so:

- Micro Gaz Generator (MGG) pyro-load for bonnet deployment,
- Additional pyro-load for bonnet sustain and energy storage until 300 ms for pedestrian loading control and head impact energy absorption,
- Piston nozzle for cold gas leakage and bonnet reset ability.

Slots of time are significantly different and allow this easy tuning related to each environment:

- Deployment phase: ~ 30 ms
- Bonnet sustain : ~ 300 ms
- Bonnet reset : few seconds

B2A sizing is achieved with pyrotechnic and mechanic numerical models and tests. B2A is available for implementation in Active Hinge Systems and serial cars manufacturing.

## REFERENCES

1. *European New Car Assessment Programme (EuroNCAP) – Pedestrian testing protocol – version 5.2.1 – January 2011..*
2. *Directive 2003/102/EC of the European Parliament and of the Council of 17 November 2003. Official Journal of the European Union L 321/15*
3. *Regulation (EC) N° 78/2009 of the European Parliament and of the Council of 14 January 2009. Official Journal of the European Union L 35/1*
4. *CLEPA European Association of Automotive suppliers - INF GR / PS /67 08.01.2004 – Pedestrian Protection Test method - Active hood/bonnet systems.*