ISSN 2395-1621

Optimization study of a vehicle bumper subsystem with the phenomenon of crash

#1Niketa.S.Kankariya, #2Dr. F.B. Sayyad

1nikitakankariya01@gmail.com
2fbsayyad@gmail.com

#12Mechanical design engineering, Pune University
Genba Sopanrao Moze College of Engineering, Pune, India.

ABSTRACT

Need for a compact and lighter vehicle has become need of the hour. Over the years designers have been continuously finding ways to reduce the overall bumper weight, for it can help in improving performance, weight of car and eventually fuel efficiency. The safety factor of a vehicle mostly depends on the behavior of frontal automotive structures during crash. A good design of car bumper must have optimized weight and must provide safety to passengers. With increasing competition in the marketplace, the OEM's and suppliers main challenge is to come up with time-efficient design solutions. Many times there is conflicting performance and cost requirements, this puts additional challenge with R&D units to come up with a number of alternative design solutions in less time and cost compared to existing designs. These best solutions are best achieved in a CAE environment using some of the modern CAD and FEM tools. Such tools are capable of effecting quick changes in the design within virtual environment. Therefore the design of an automotive vehicle must be in such a way that during collision some portion of its structure will act as an energy absorbing zone to absorb the kinetic energy released during impact in a predictable manner, while the passenger compartment retains it rigidity, as much as possible to reduce intrusion into areas occupied by vehicle occupant & crash testing plays a important role in this aspect.

***Keywords*—Bumper, Crash, effective plastic strain, finite element analysis.**

ARTICLE INFO

Article History

Received :18th November 2015

Received in revised form :

19th November 2015

Accepted : 21st November , 2015

Published online :

22nd November 2015

I. INTRODUCTION

BUMPER beams are one of the important structures in passenger cars. For which we need to have careful design and manufacturing in order to ensure good impact behavior. The new bumper design must be flexible enough to reduce the passenger and occupant injury and stay intact in low-speed impact besides being stiff enough to dissipate the kinetic energy in high speed impact. The bumper beam is the key structure for absorbing the energy of collisions. Today's plastic auto bumpers and fascia systems are aesthetically pleasing, while offering advantages to both designers and drivers. The majority of modern plastic car bumper system fascias are made of thermoplastic olefins (TPOs), polycarbonates, polyester, polypropylene, polyurethanes, polyamides, or blends of these with, for instance, glass fibres, for strength and structural rigidity. The use of plastic in auto bumpers and fascias gives designers a tremendous amount of freedom when it comes to styling a prototype vehicle, or improving an existing model. Plastic can be styled for both aesthetic and functional reasons in many ways without greatly affecting the cost of production. Plastic bumpers contain reinforcements that allow them to be as impact-resistant as metals while being less expensive to replace than their metal equivalents. Plastic car bumpers generally expand at the same rate as metal bumpers under normal driving temperatures and do not usually require special fixtures to keep them in place.

I. LITERATURE REVIEW

Mohapatra S [1] discussed that automotive development cycles are getting shorter by the day. With increasing competition in the marketplace, the OEM's and suppliers main challenge is to come up with time-efficient design solutions. Researchers are trying to improve many of existing designs using novel approaches. Many times there is conflicting performance and cost requirements. This puts additional challenge for Research and Development units to come up with a number of alternative design solutions in less time and cost compared to existing designs. These best solutions are best achieved in a CAE environment using some of the modern CAD and FEM tools. Such tools are capable of effecting quick changes in the design within virtual environment. The researches have been done on the study to develop a numerical analytical model of collinear low-speed bumper-to-bumper crashes, the model treats the car body as rigid structure and the bumper beam as a deformable structure attached to the vehicle. The model is also used to compare that how the structural characteristics of the vehicles' bumpers and the closing speed affect the crash pulse and to demonstrate a technique to estimate the maximum severity of a low-speed crash that has already occurred[2]. The experiments were done on the engineering thermoplastics which are used with good results in applications such as knee bolsters, structural instrument panels, head-impact-protection pillars, automotive bumpers, and body panels, where structural integrity, crashworthiness, and energy absorption capacity are key requirements [3]. With the global trend of energy saving and automobile light weight [4，5]researches for bumper beam focus on its light weight on the basis of better crash and pedestrian protection performances at home and abroad [6-9]. There are many kinds of methods for bumper beam light weight design currently as follows：a. using light weight materials with low density and high strength， such as high strength steel，aluminum alloy，magnesium alloy and composite materials，etc. [10]；b. optimization design for less parts and better quality ， such as shape optimization ， topography optimization and thickness optimization，etc. [11]；c. using advanced forming process， such as hot stamping，roll forming，etc. [12].

A Standards for bumper

In most jurisdictions, bumpers are legally required on all vehicles. The height and placement of bumpers may be legally specified as well, to ensure that when vehicles of different heights are in an accident, the smaller vehicle will not slide under the larger vehicle.

India

India is the 10th largest producer of automobiles in the world. The country's attention to vehicle safety requirements has progressed significantly since the year 2000. More than 35 million vehicles are registered in India. In 1989, the Central Motor Vehicle Rules (CMVR) became effective and the rules are greatly enforced today. Under Rule 126 of the CMVR, manufacturers of motor vehicles must allow a separate agency to test prototypes of new vehicle designs for safety requirements. It is necessary for all vehicles in India to have basic safety features, such as seat belts, rear-view mirrors and laminated safety glass for windshields. Also, all vehicles in use must pass a pollution test every six months.

B Types of bumpers

- Plastic bumper
- Boby kit bumper
- Carbon fibre bumper
- Steel bumper

Plastic Bumper

Most modern **cars** use a reinforced thermoplastic bumper, as they are cheap to manufacture, easy to fit and absorb more energy during a crash. A majority of car bumpers are custom made for a specific model, so if you are looking to replace a cracked bumper with a similar one, you would have to buy from a specialist dealer. However, many companies now offer alternative designs in thermoplastic, with a range of fittings designed for different models.

Boby Kit Bumper

Modified cars often now have a full body kit rather than just a front and rear bumper. These kits act as a skirt around the entire body of the car and improve performance by reducing the amount of air flowing underneath the car and so reducing drag. Due to each car's specifications, these have to be specially purchased and can be made from thermoplastic, like a standard bumper, or even out of carbon fiber.

Carbon Fiber Bumper

Carbon fiber body work is normally the thing of super-cars, but many car companies, and specialist modifiers, are starting to use it for replacement body part on everyday cars. This is because it is very light and is safe during a crash. It is, however, a lot more expensive than normal thermoplastic.

Steel Bumper

Originally plated steel was used for the entire body of a car, including the bumper. This material worked well, as it was very strong in a crash, but it was very heavy and dented performance. As car engine design has improved, steel bumpers have pretty much disappeared for anything except classic cars. Replacing one involves a lot of searching for scrap cars or having one specially made.

C Materials used in bumper

At one time, most car bumpers were made of steel. Then, most were made of chrome or a chrome-plated material. Today, car bumpers can be made from anything from chrome-plated material to a variety of different rubber materials or plastics. This makes detailing car bumpers somewhat more complicated, as bumpers made from different materials require very different detailing treatments. For the purposes of this article, we will assume that your car bumper is chrome-plated. Detailing a chromeplated bumper requires a bit of patience and a light sanding touch, but it is certainly something that even the most casual car owner can accomplish in a day or less. The primary enemy of chrome-plated bumpers is oxidation (rust). The longer you allow rust spots to remain on your bumper, the more difficult the detailing process is going to be. Bumpers on most new cars are color-coordinated plastic "wrappers," moulded sleekly around the front and back ends of the vehicles. They may please the eye, but whether these bumpers protect the vehicle they surround from damage in low-speed impacts is another matter.

II. Finite Element Analysis

The modeling of two types of automotive bumpers namely basic bumper made of steel and bumper with Acrylonitrile butadiene styrene (ABS) material was modeled. The models were exported to ANSYS in .igs format for further analysis.

Bumper consists of four portions, namely front panel, side panel, bracket, supporting bracket.

TABLE 1. Bumper Part list

Sr No.	Part name
1	Front panel
2	Side panel
3	Bracket
4	Supporting bracket

Loading and Boundary Condition:

To carry out impact analysis of bumper system within framework of FEA, this is low speed impact(4kmph) and as per standards bumper should withstand it. Appropriate contacts have been defined at appropriate locations between different parts. Fig. 1 shows loading and boundary conditions. Boundary conditions are reference for problem solving in analysis. This deals with constraining (fixing) the model, application of loads, giving proper contacts etc. Here we are provided with the constrained conditions, mass of vehicle which is about 887 kg and velocity of impact which is 10m/sec. bolt connections are given by beams and proper constraints are applied. The constrained model appears as shown in figure 1. The velocity is given to the impactor through contacts defined between bumper and impactor. The mass of vehicle here is considered during impact conditions. Contacts are defined via elements as shown in figure 1.

$€_c = 0.31$

Material Properties:

Mechanical properties of steel are given in table 2.A nonlinear elastic–plastic material model was used to describe the material behavior of bumper in the dynamic analyses. The true stress–strain curve of the soft steel and hard steel is plotted in figure 2. True stress–strain material data are required for input into the finite element model

Table 2 Material Properties of steel Bumper

Modulus of Elasticity (N/mm2)	Poisson's Ratio	Yield Strength (N/mm2)	Ultimate Strength (N/mm2)	Fracture Strain
210000	0.3	350	650	0.21

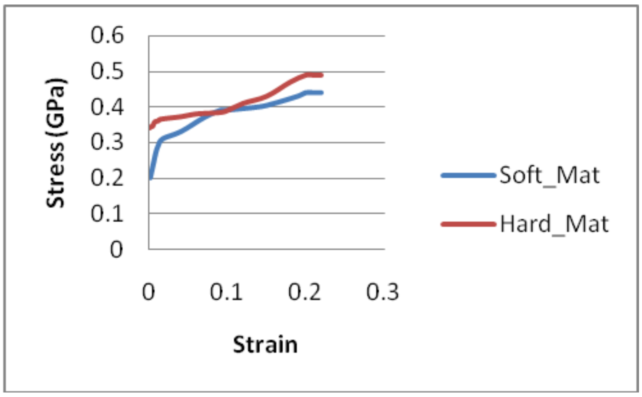

Figure 2. True Stress-Strain curve

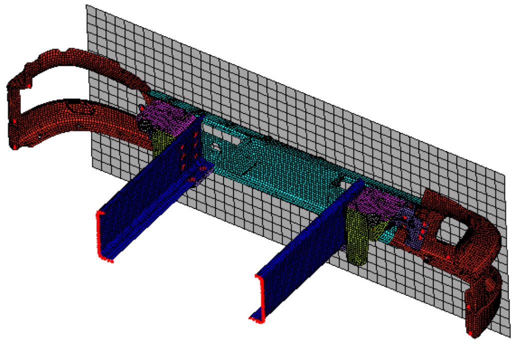

Figure 1. Constrained Bumper Model

The failure criterion to assess the bumper impact characteristics for the FEA simulation is on the basis of a fracture strain criterion. Such a criterion considers the failure of bumper when the calculated equivalent plastic strain exceeds the critical plastic strain of the material.

$$\bar{\varepsilon}_p = \frac{\sqrt{2}}{3}\sqrt{(\varepsilon_{p1}-\varepsilon_{p2})^2+(\varepsilon_{p2}-\varepsilon_{p3})^2+(\varepsilon_{p3}-\varepsilon_{p1})^2} \qquad (1)$$

Where, subscripts (1, 2, 3) indicate the three axes corresponding to the three principal directions. The critical plastic strain is assumed to be the percent elongation, that is, the fracture strain. The critical value is

III. Results and Discussion for Steel Bumper.

Bumper Front Panel

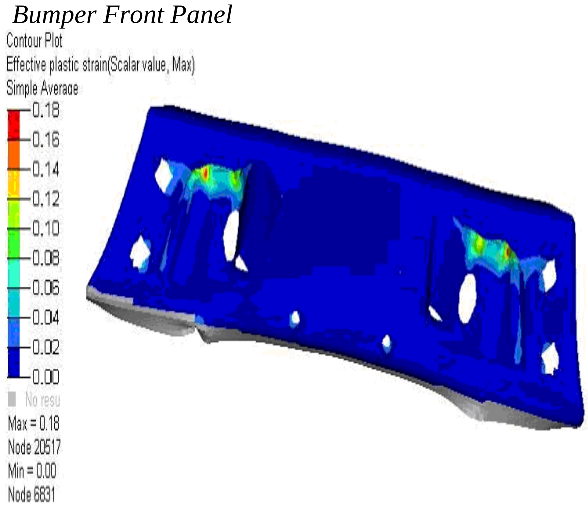

Figure3. Contour plot of effective plastic strain values for Bumper Front panel

From figure 3 the maximum plastic strain value for bumper front panel is 0.18 which is less than permissible limit hence the design for Bumper frontal panel is safe.

Bumper Side panel-:

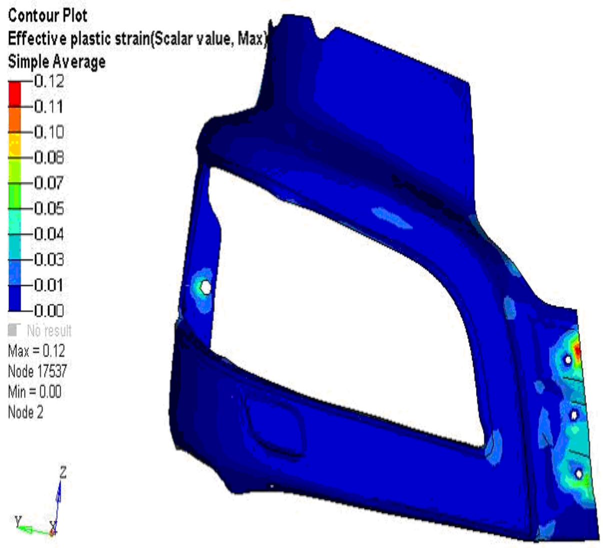

Figure 4. Contour plot of effective plastic strain values for Bumper Side panel

From figure 4 the maximum plastic strain value for bumper Side panel is 0.12 which is less than permissible limit hence the design for Bumper side panel is safe.

Bumper Bracket-:

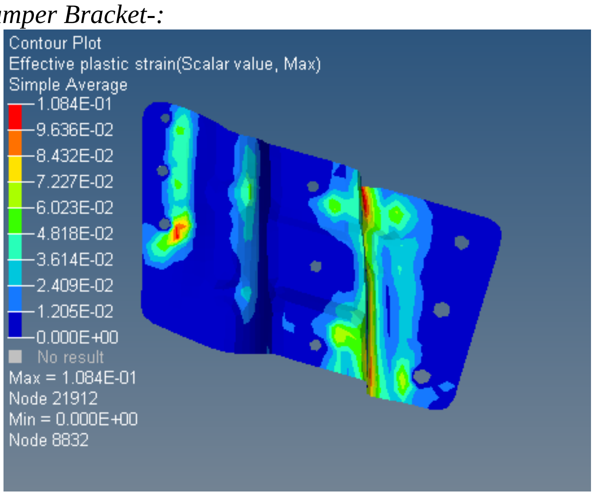

Figure 5. Contour plot of effective plastic strain values for Bumper Bracket

From figure 5 the maximum plastic strain value for bumper bracket is 0.25 which is equal to permissible limit hence the design for Bumper side panel is safe.

Bumper supporting Bracket-:

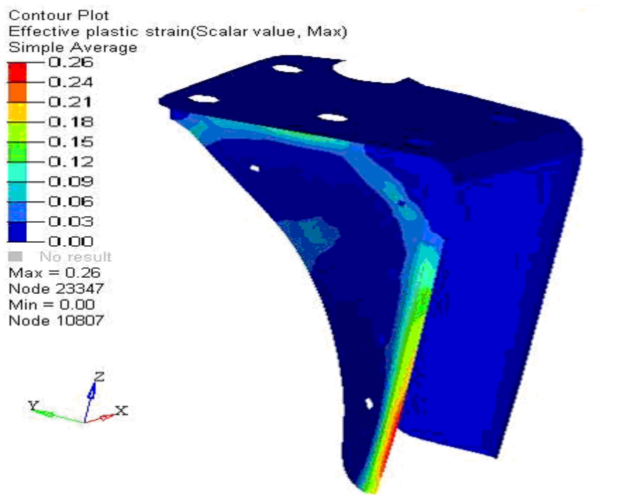

Figure 6. Contour plot of effective plastic strain values for supporting Bracket

From figure 6 the maximum plastic strain value for bumper supporting Bracket is 0.26 which is less than 0.33 permissible limits hence the design for Bumper supporting Bracket is safe.

Bumper made of ABS material.

ABS-acrylonitrile-butadiene-styrene is a durable thermoplastic, resistant to weather and some chemicals, popular to vacuum formed components. It is rigid plastic with rubber like characteristics, which gives it good impact resistance.

Material properties of ABS

Mechanical properties of ABS are given in table 2. A nonlinear elastic–plastic material model was used to describe the material behaviour of bumper in the dynamic analyses. The true stress–strain curve of the ABS material is plotted in figure 7. True stress–strain material data are required for input into the finite element model. Figure 7 shows true stress-strain curve

TABLE 2. Material properties of ABS

Property	**Value**
Density (kg/mm^3)	**1.03E-9**
Young's modulus (GPa)	**3.1**
Poissons ratio	**3.5**

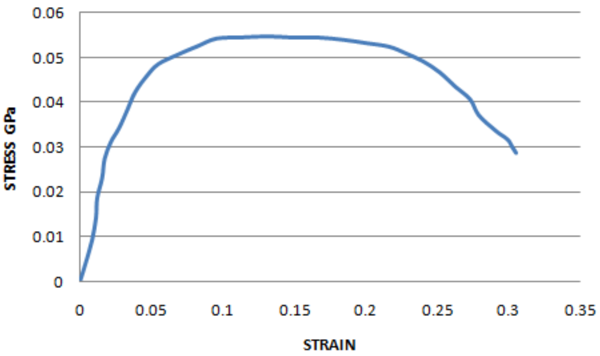

Figure 7. Stress strain curve for ABS material.

II.

Bumper Front Panel:

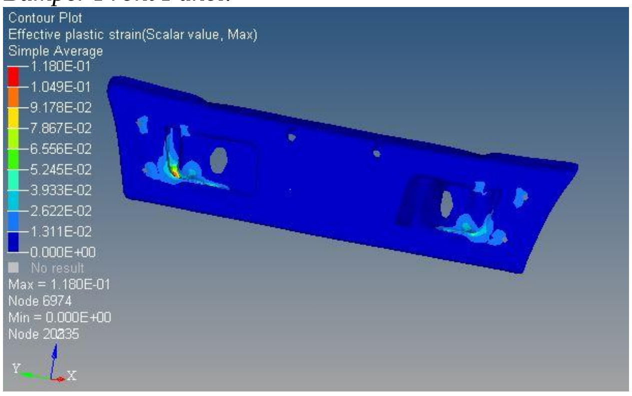

Figure 8. Contour plot of effective plastic strain values for Bumper Front panel.

From figure 8 the maximum effective plastic strain value for bumper front panel is 0.11 which is less than permissible limit hence the design for Bumper frontal panel is safe.

Bumper Side Panel:

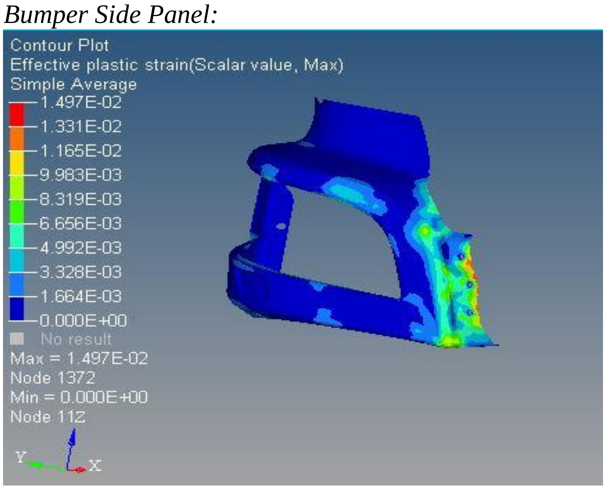

Figure 9. Contour plot of effective plastic strain values for Bumper Side panel

.

From figure 9 the maximum plastic strain value for bumper Side panel is 0.014 which is less than permissible limit hence the design for Bumper side panel is safe.

Bumper Bracket:

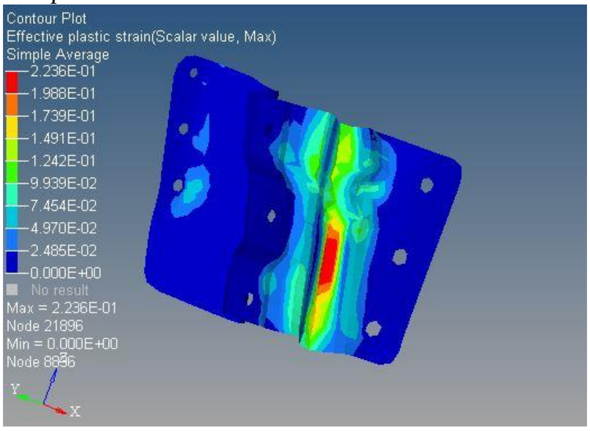

Figure 10. Contour plot of effective plastic strain values for Bumper Bracket

From figure 10 the maximum plastic strain value for bumper bracket is 0.22 which is less than permissible limit hence the design for Bumper side panel is safe.

Bumper Supporting Bracket:

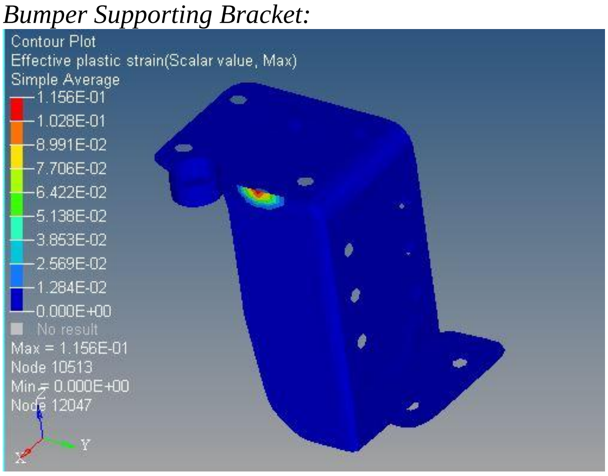

Figure 11. Contour plot of effective plastic strain values for supporting Bracket

From figure 11 the maximum plastic strain value for bumper supporting Bracket is 0.11 which is less than permissible limit hence the design for Bumper supporting Bracket is safe.

IV. CONCLUSION

In this paper, car bumper is studied for two bumpers made of steel and ABS material. The bumper is modelled using 3D modelling software. Impact analysis is done on the bumper at a speed of 36Km/hr. The analysis is done on the car bumper for different materials Steel and ABS. The density of ABS Plastic is less than that of steel, thereby the overall weight of car bumper is reduced by 24% as compared to steel. Hence, increasing the fuel efficiency. By observing the impact analysis results, the strain values are less for ABS plastic than steel.

REFERENCES

.

[1] Mohapatra S, "Rapid Design Solutions for Automotive Bumper Energy Absorbers using Morphing Technique", Altair CAE users Conference, Bangalore, India. 2005

[2]. W. R. Scott, C. Bain, S. J. Manoogian, J. M. Cormier and J. R. Funk Biodynamic Research Corporation," Simulation Model for Low-Speed Bumper-toBumper Crashes", SAE Paper 2010-01-051.
[3]. Daren Evans,TerryMorgans," Engineering Thermoplastic Energy absorbers for bumpers", SAE Paper 1999-01-1011
[4] Cantor Brian, Grant Patrick, Johnston Colin. Automotive Engineering：Lightweight, Functional and Novel Materials [M]. New York：Taylor & Francis Group, 2008.
[5] Wang Zhiwen. Probe on the development status quo of automotive lightweight technology [J]. Automobile Technology & Material, 2009(2)：1-5, 15. (in Chinese)
[6] Javad Marzbanrad，Masoud Alijanpour，Mahdi Saeid Kiasat. Design and analysis of an automotive bumper beam in low- speed frontal crashes [J]. Thin-Walled Structures，2009，47(8/9)：902-911.
[7] Kim K J，Won S T. Effect of structural variables on automotive body bumper impact beam [J]. International Journal of Automotive Technology，2008，9(6)：713-717.
[8] Park Dong- Kyou. A development of simple analysis model on bumper barrier impact and new IIHS bumper impact using the dynamically equivalent beam approach [J]. Journal of Mechanical Science and Technology，2011，25(12)：3107-3114.
[9] Park Dong-Kyou，Jang Chang-Doo. A study on the development of equivalent beam analysis model on pedestrian protection bumper impact [J]. Journal of Mechanical Science and Technology，2011，25(9)：2401-2411.
[10] Ma Mingtu，Ma Luxia. The application and advanced technology of the aluminium alloy in automotive light weight [J]. Advanced Materials Industry，2008(9)：43-50.
[11] Xu Zhongming，Xu Xiaofei，Wan Xinming，et al. Structure optimal design of aluminum alloy bumper anticollision beam [J]. Journal of Mechanical Engineering，2013，49(8)：136-142.
[12] Han Fei，Shi Lei，Xiao Hua，et al. Development and key technologies on roll-formed automobile profiles with AHSS [J]. Journal of Plasticity Engineering, 2013, 20(3)：65-69, 120.