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Impact Analysis of Vehicle Door Structure by Using FEA Tools.

By

Prof. Mahesh P. Chopade * Prof. Mahesh. R.Mishra ** Dr.Vinod S.Gorantiwar***

*** Head of Department, Mechanical Engineering, Shri Sai College of Engg.& Tech. Bhadrawati, Chandrapur, Maharashtra,India**

maheshrchops@gmail.com

**Assistant Professor, Mechanical Engineering, Shri Sai College of Engg.& Tech.Bhadrawati, Chandrapur, Maharashtra,India. mmaheshrmishra@gmail.com

*** Principal,Shri Sai College of Engg.& Tech.Bhadrawati, Chandrapur, Maharashtra, India. vinodgorantiwar@gmail.com

Abstract

Impact performance of side-door impact beam of selected design made of omega cross-section for a sedan car has been presented. Parameters influencing crashworthiness of the component have been used for the comparision of various beam cross-sections .

Five alternative cross-sections, both open and closed, of beams were first compared for their crashworthiness using a model of a simply supported beam impacted by a sphere. Based on this assessment the most promising cross-section was used in the side impact simulation of a sedan. Section made of steel was assessed.

Use of omega cross-section was found to be advantageous as it adequately satisfied the crashworthiness criteria with reduction in amount of intrusion and increase in energy absorption capacity at the front door .

Keywords: Vehicle door, Impact Beam

I. Introduction

Based on the most harmful road accidents, side impact accounts for 25% of fatalities for passenger car and 15% of fatalities for light truck crashes all over globe. The frequency of occurrence of side impact event is around 20% [l].

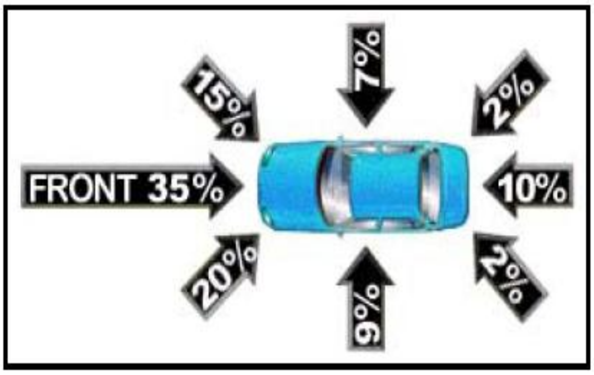


Fig 1. Frequency of occurrence of side impact event [2]

Since the use of dynamic Federal safety standards in side impact protection began in recent years, occupant protection in side impact crashes has received increasing interest. This interest comes from both the consumers and the automotive industry. In comparison with frontal collisions, the space between the occupants and the intruding element in side crashes is extremely small and the side impact occurs much more rapidly as specified by NHTSA. Consequently, occupant protection in side crashes presents a challenge to engineers, designing a vehicle for safety.

Due to the increasing requirements for passive safety of vehicles, car manufacturers are continuously developing improved solutions for crash resistance. Vehicle manufacturers have made great leaps in terms of side impact protection over the last 10 years. Protection has been steadily increasing as technology has allowed. At the same time, the safety requirements must also meet the other design criteria, such as low costs and the body weight reduction. Door reinforcement is one of the important factors in side impact. The beam inside the door is the only anti intrusion device used for passive safety during the side impact. Other reinforcements are located in the floor, under the door, to absorb the impact energy. Therefore, door beam being one of the critical parts of the door during side impact should have a proper design. The best way to reduce the weight and improve the energy absorption of the door beam is to employ composite materials because fiber reinforced composite materials have high specific strength and high impact energy absorption characteristics [6]. They can be mass produced by employing automated manufacturing equipments to meet the production rate and cost. Achieving crashworthiness is an iterative process. Therefore, conducting tests at component and sub-structure level is not always viable, as tests cost more and consume more time. Use of computer simulations enables the construction of models that have sufficient detail to provide accurate results in the shortest possible timescales.

Objectives and Methodology

The objectives of this project work were as follows:

1. Find out the structural dynamic response prediction capability of vehicle door by simulation model in a free-free configuration to find the natural frequency and mode shapes.

2. Find the natural frequency and mode shapes for fixed-free condition.
3. Simulate the impact analysis of door structure by impacting a deformable barrier or rigid body impact and find the energy absorb by different door components.
4. Numerical simulation (baseline solution) of an automobile side impact to assess the crashworthiness of the automobile door fitted with metallic door beam
5. Analysing the door beams of various designs and selecting the better cross-section for door beam
6. Placing the selected beam with steel as material and solving
7. Replacing the existing metallic door beam with selected omga door beam to assess the changes in impact performance

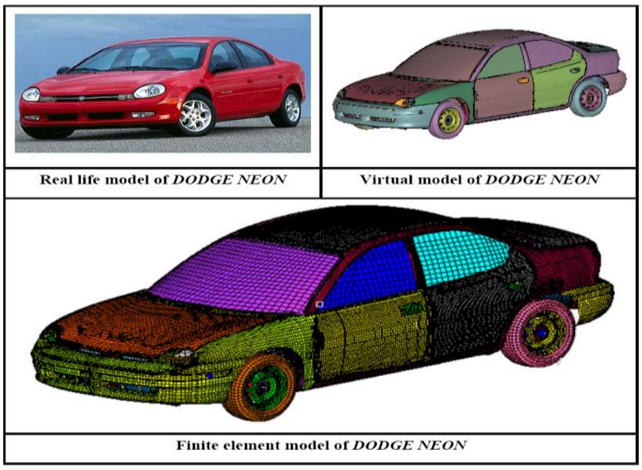
Methodology and approach adopted to solve the problem and achieve the aim of the project are as follows:

1. By using HYPERMESH software the refinement & preprocessing of the FE model of car door assembly for the modal analysis
2. Carring out the modal analysis of the door assembly by using ANSYS in free-free & fixed-free conditions to find out natural frequencies & various mode shapes.
3. Working on the finite element model of a car door using HYPERMESH to bring the car door in a state suitable for the modal & crash analysis (Model cleanup)
4. Baseline solution: Solving the car door model with the existing metallic door beam of circular cross-section
5. Analysing beams of different designs by impact simulation and selecting the best cross-section for beam
6. Placing the selected beam into the door structure such that it is compatible within the available space in the door, without affecting the other parts present in the door
7. Modeling the selected beam with steel material and solving
8. Comparision of results for door fitted with existing & changed cross-section beam
9. Design alternative for side-door impact beams.

MODEL CONSTRUCTION & SOLUTION

A. VEHICLE UNDER STUDY

The finite element model of 2002 DODGE NEON four door sedan was used.



Real life model of *DODGE NEON* | Virtual model of *DODGE NEON*

Finite element model of *DODGE NEON*

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Fig. 2: Vehicle under study

B. FEM Model:

The FEM model of Car Door Assembly is generated in ALTAIR HPERMESH 3D software. The CAD model in IGES format is imported to Hypermesh 3D software. The CAD model is meshed using Automesh with an element size of 15.The figure below shows FEA model of Car Door Assembly:

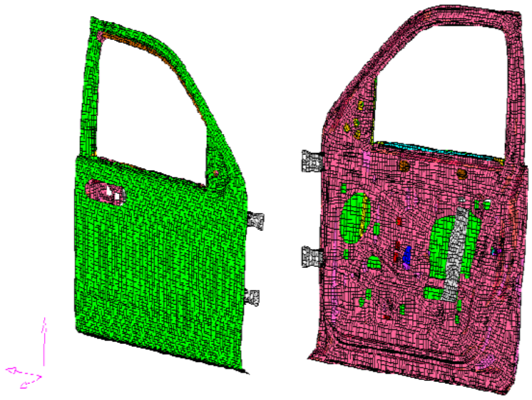

Fig. 3 : FE Model of Car Door Structure

C. Bolt Connections

Each bolt is modeled with a so called star of RBE2 elements that connects the nodes at the periphery of the holes through which the bolt runs on the physical door.

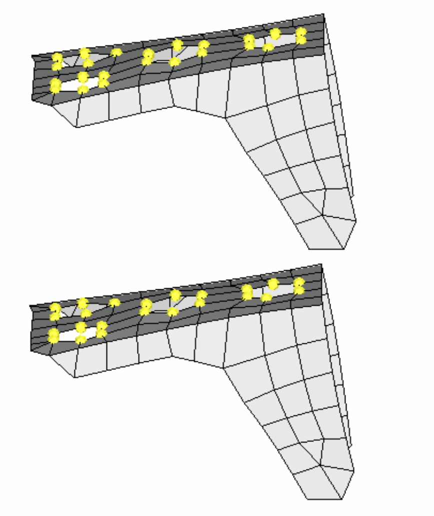

Fig 4: Bolt connections

D. GEOMETRIC MODELING OF DOOR BEAMS

After getting the dimensions of the door, the door beams with most commonly used cross-sections were modelled. The modelled door beams were classified into two groups depending on their cross sections: Open and closed cross sections.

Open cross sections were:

1. C-section
2. I-section
3. Omega section

Closed cross sections were:
1. Rectangular section
2. Stepped rectangular section

The geometric models of the door beams are shown below.

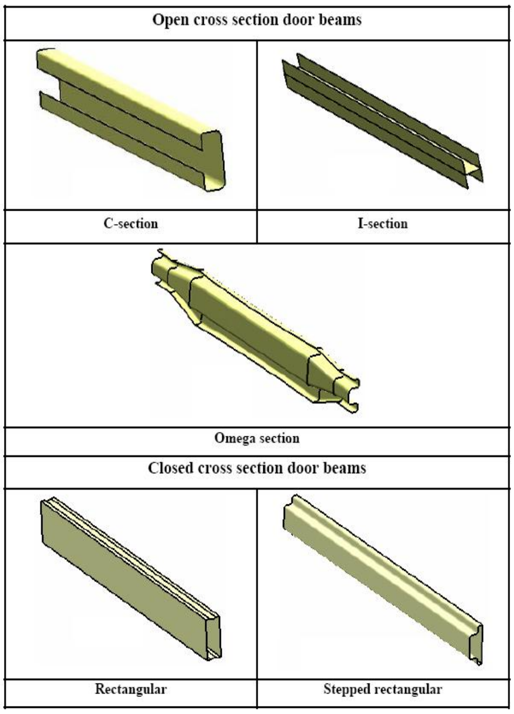

Fig. 5: CAD models of door beam

E. MODIFICATIONS MADE IN DOOR GEOMETRY

The extracted door surface was cleaned up. The door beam plates were modified to make the new door beam compatible within the same available door space in such a way, that the new position of the door beam does not get too close or too far from the door outer panel which might affect its energy absorbtion.

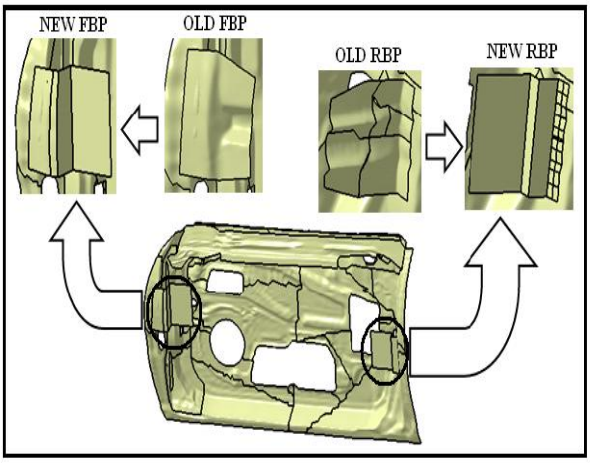

Fig. 6. Modifications made in door assembly

F. FINITE ELEMENT MODELING OF DOOR BEAMS

All the door beams were modelled using shell element. The size of shell elements was selected such that the bending behaviour of the beam is captured to the highest possible level.

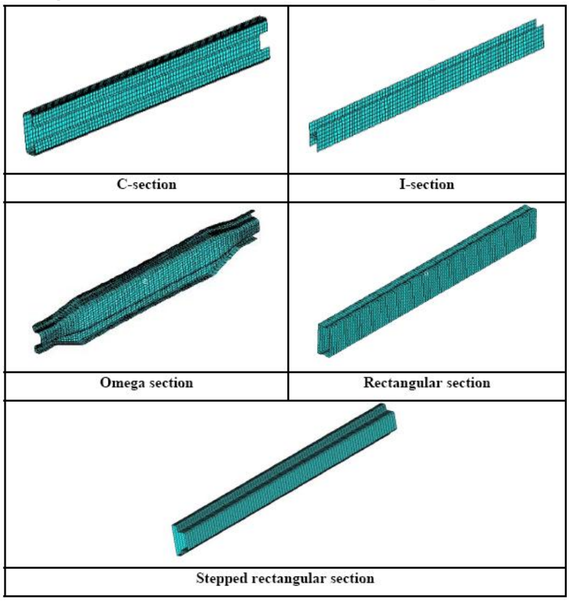

Fig. 7: FE models of door beam

G. SIDE IMPACT SIMULATION SET-UP

The side impact simulation was conducted for two different configurations of door beam model. They are listed below:

1 Configuration 1. : Baseline model, i.e. steel door beam of circular cross section

2. Configuration 2 : Model with steel door beam of omega cross section (selected cross section)

1. Configuration 1

This configuration was the base line model and it consisted of a door beam of circular cross section and steel properties. The properties used for this beam are given below:

- Material model used for beam MAT_LINEAR_PIECEWISE_PLASTICITY (MAT_24)
- Material type – High strength carbon steel
- Yield strength of beam = 650 N/mm2
- Thickness of the beam = 2.7 mm
- Mass of beam = 1.895 kg

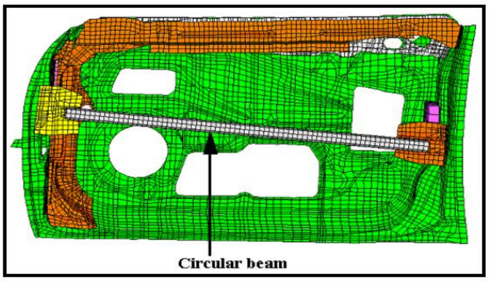

Fig 8. Circular metallic door beam

2. Configuration 2

In this configuration, there was change in cross-section of beam. The beam with circular cross-section was replaced by the cross-section selected through the beam impact simulation i.e. Omega cross-section. The properties of the omega beam were same as for the circular beam in the configuration 1. Only thickness of the beam was reduced from 2.7 mm to 1.3mm so that the mass of the beam remains constant i.e. 1.895 kg.

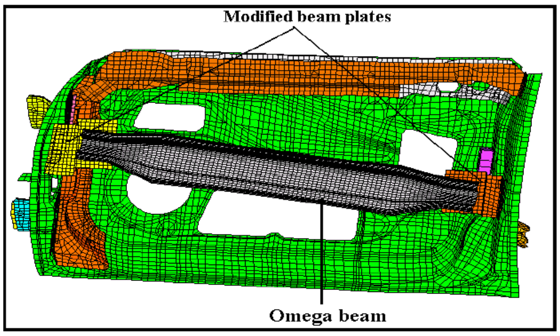

Fig. 9. Omega beam fitted in the front door

H. Final simulation set-up

The impact point in the test is set to be 940 mm towards front from the mid of the wheelbase (W) irrespective of the car model as per FMVSS 214. The barrier model is also set such that at the time of impact the impact point is 940 mm from the mid of the wheelbase of the car. The impact barrier of mass 1367 kg is propelled onto the car at a velocity of 54 kmph (15 m/s). The wheels of the barrier were inclined at an angle of 27° with its longitudinal axis as shown in figure 4.8. This inclination of the wheels about the longitudinal axis of car is called ‘Crab angle’. [11] The simulation tool used is LS-DYNA.

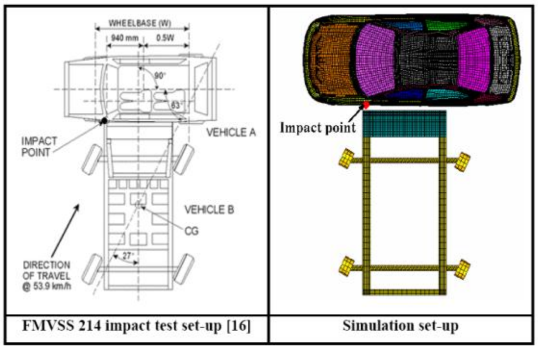

Fig. 10. Simulation set-up

I. SOLVER USED

The Lagrange solver was used for solving the crash simulation. In the Lagrangian approach, the grid points or nodes are fixed to the structure and move with the structure.
The mesh can deform, but must not deform too drastically or element volume may go negative causing the simulation to stop. [Best practices for crash modeling and simulation, 2002].

RESULTS AND DISCUSSIONS

A. RESULTS OF SIDE IMPACT TEST

Energy balance of the systems For side impact, the forces acting on the subject vehicle are due to resistance offered to the motion of the moving barrier. The work done by these forces on the side structures of the subject vehicle causes the large deformations. The amount of this deformation is called dynamic crush of a vehicle [8]. While deforming the side structures, since the energy must be conserved, the kinetic energy of moving barrier is converted into the internal energy of subject vehicle.
From the graphs shown below, it is observed that the kinetic energy (curve A) of the entire system drops upon collision due to the sudden plunge in the velocity of the moving barrier. It is also observed that there is raise in internal energy (curve B) of the entire system, due to the energy absorbed by the deforming structural components, thus keeping the total energy (curve C) of the system constant. Energies such as sliding energy, frictional energy, changes slightly during the event and hence do not contribute to the conservation of total energy, appreciably. This describes the energy balance of the system.

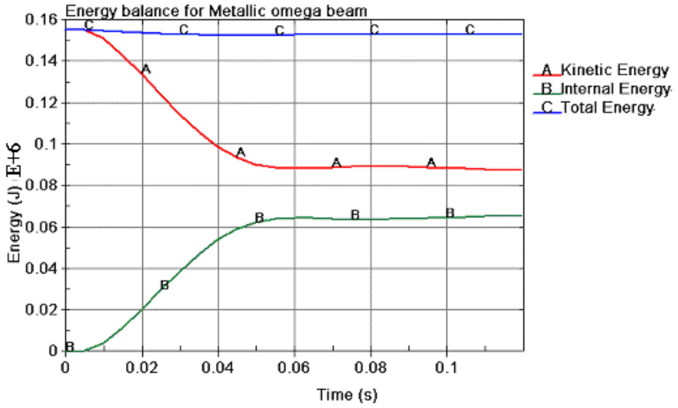

Fig. 11TIME HISTORY FOR THE SYSTEMS

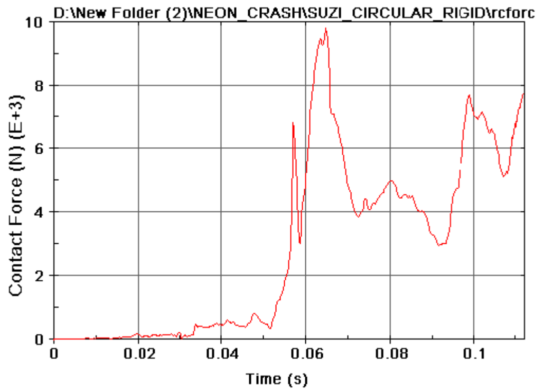

Fig. 12. Contact force time history between car with circular steel impact beam and barrier

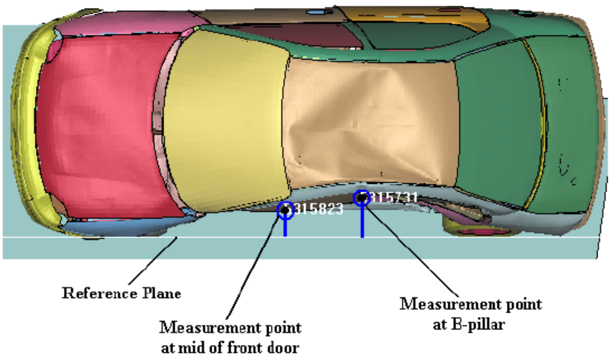

Fig. 13. Intrusion measurement in simulation

B. COMPARISION OF RESULTS

a) Intrusion at the mid of front door

The intrusion for car with steel beam of circular cross-section was the baseline value and was measured as 472.7 mm. Then after replacing the circular cross-section with the omega cross-section beam and keeping the material properties same, the intrusion was 469.7 mm i.e. there was a reduction of 3.0 mm.

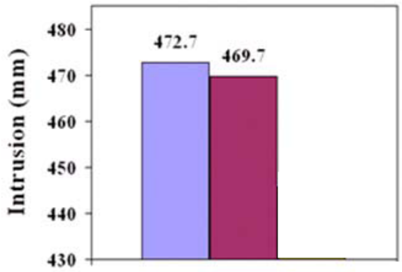

Fig. 14 Intrusion at the mid of front door

b) Intrusion velocity at the mid of front door

The intrusion velocity at the mid of front door of car with steel beam of circular cross-section was measured as 14.3 m/s. Then the intrusion velocity of the car with the omega cross-section beam and steel as material properties was reduced from 14.3 to 13.6 m/s.

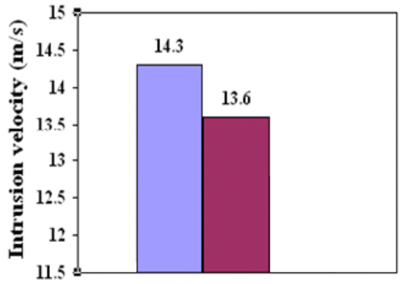

Fig. 15. Intrusion velocity at the mid of front door

c) Energy absorbed by door beams

The energy absorbed the beams alone was measured for these two beams. The steel beam with circular beam absorbed the least energy i.e. 110 J and the steel omega beam absorbed 330 J of energy.

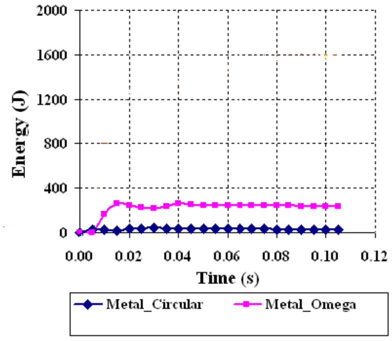

Fig. 16. Energy absorbed by the door beams

d) G-forces and Peak loads at front door

Both the G-forces and the peak loads at the front door are reduced for door beam of omega cross-section. The reduction in g-forces significant for car with door beam. Mean while the peak loads at also decreased by considerable amount for car with door beam.

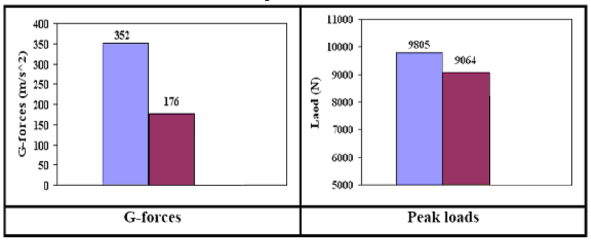

Fig. 17. G-forces and Peak loads at front door

e) Impact performance of B-pillar

The implementation of composite beam did not show any considerable change in the impact performance at the B-pillar. The amount of reduction in the intrusion and the intrusion velocity was not more. It can be seen from the graphs shown below.

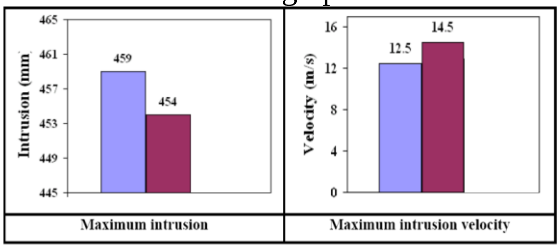

Fig. 18.Impact performance of B-pillar

Metal_Circular Metal_Omega

The effect of implementation of the omega cross-section beams improved overall impact performance at the front door, but had a little effect on the impact performance at the Bpillar.

V. CONCLUSION

The work investigated the feasibility of using the composite material for side-door impact beam of a passenger car by means of numerical simulation. The following are conclusions drawn from the work:

1. The car without side-door impact beam are not safer and do not satisfy the FMVSS 214.
2. The current existing designs of side-door impact beam are not optimal.
3. It is difficult to meet all the stringent safety standards with the existing cross-section .
4. By implementing the omega door beam, the amount of intrusion at the front door was reduced by 3 mm.
5. The G-forces acting on the door beams were reduced from 352 g to 176 g
6. Use of omega cross-section beam has increased the impact energy absorption capacity of the door beam from 110 J to 330 J.

It can be concluded that when seeking for higher strength and stiffness of the

Structure and maximum energy absorption, the use of omega cross-section beam has a clear advantage over the traditional circular beam. Based on the future prediction, the use of omega beam will increase significantly in the automotive application as significant reduction in the cost of production can be achieved by simplifying the complex manufacturing processes. Surely it will be the future inspiration in this area of research.

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