Development of Side Door Intrusion Beam of Passenger Car For Maximum Bending Load

Yogesh K. Nichit[1], Prof. Arun. K. Battu [2]
[1, 2] Dept of Mechanical Engineering
[1, 2] D. Y. Patil College of Engineering, Akurdi, Pune-44 Savitribai Phule Pune University (SPPU), INDIA

Abstract- *Now a Days, to reduce the fuel consumption more fuel efficient vehicles are introduced. It's the main challenge automotive industries are facing. Without compromising Safety, they are changing structure of vehicle to reduce the vehicle weight. In early stage of design, Finite Element Analysis (FEA) is used to determine appropriate cross-section profile for the side door intrusion beam. Side door intrusion beam are used to absorb energy during accident and to protect the passenger during crash. Side door intrusion plays a major part in complete assembly of the door. FEA models have been developed with different cross-section to do three point bending test. Iterations are taken using LS-DYNA. Improved parameters are determined on the basis of maximum bending load capacity. The Bending force required for different sections are evaluated and compared. Optimum design of 'side intrusion beam' which is best performing for intrusion is determined.*

Keywords- Side Impact, Design optimization, Side-door Intrusion beam, Various Cross-sections, Finite element analysis, Impact energy absorption.

I. INTRODUCTION

Road accidents are one of the major causes of death in India. In today's automobile development sector, car safety is the major issue. Accidents which are causing Injuries that can be controlled significantly if sufficient attention is given to accident and injury avoidance strategies. Because of this issue, Vehicle manufacturers are now using various passive safety devices and feature for their vehicles, including energy absorbing steering columns, airbags, side door beams etc. Mostly, side impact accidents are the second leading cause of death and injury in the road accidents after front impact crashes. Unlike a front collision, side-impact collisions are mostly dangerous; that is, the space between an occupant and the side of the vehicle is negligible. There are engine, bumpers and so on to help to absorb the energy of the impact in a front impact. Hence, Passenger has very little safety when a vehicle is hit on its side. To develop a safe and effective passive safety devices are necessary for reducing occupant injuries in a side-on crash.

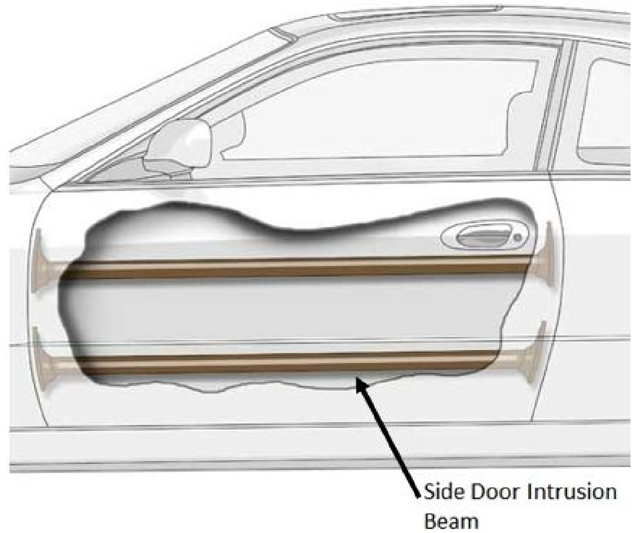

Fig. 1: 'Side Door Beam' In Vehicle Front Door

The current vehicle standard requires each door to resist crash forces that are applied by solid block. The manufacturers generally required to meet the requirement of the side door strength by reinforcing the doors with door intrusion beams. The core function of the side intrusion beam is to provide the high level of safety to the occupant.

Federal Motor Vehicle Safety Standard (FMVSS 214) 1:

Side Impact Protection was modified in 1990 under the Federal Motor Vehicle Safety Standard (FMVSS) 214 to assure the occupant protection in a crash test that simulates a severe perpendicular impact. Since the Side Impact caused 33 percent of serious injuries in 1993 to passenger car occupants, it was established to new passenger car models during the year 1994 to 1997. It is amid the most critical and promising safety regulation distributed by the National Highway Traffic Safety Administration (NHTSA).

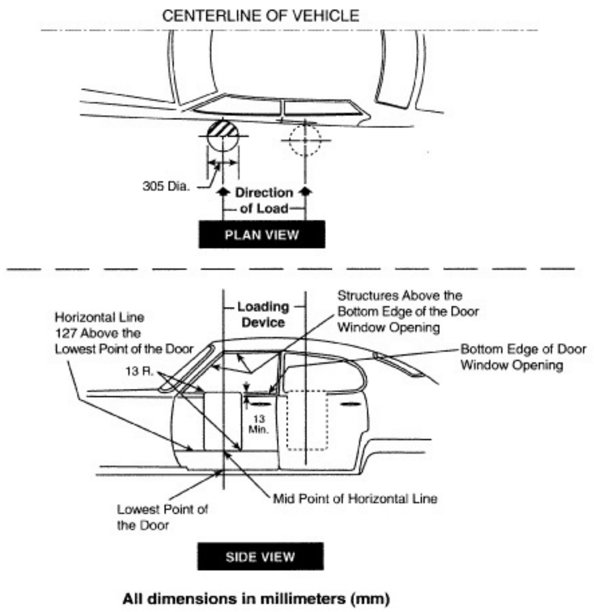

Fig. 2: FMVSS 214 Test Configuration

The present FMVSS 214 is the result of many years of research to manufacture the passenger vehicle less vulnerable to Side Impacts, and mainly to reduce casualty to the inside occupant during the vehicle hit by another vehicle near door area, which is primary responsible for the majority of side-impact losses. In this test procedure the crash is similar to the one used in Federal Motor Vehicle Safety Standard (FMVSS 214) but the wheels on the moving deformable barrier (MDB) are line up with the longitudinal axis of the car (zero degrees) to allow 90 degree impact with the velocity of 50 Kmph (31 mph).

II. OBJECTIVE

This research is started to change the current side impact beam with the better development and using a different cross-sections with same material as well as different material on the other hand in order to reduce the total weight of the vehicle without minimizing the safety of the passenger. In this investigation In accordance with the basic principles of crashworthiness which states that the intrusion of the striking vehicle should be minimum and the deformation ability of the deforming structure should be low. The usage of the different cross-section for side impact beams on the car door has been proposed and its effectiveness in reducing intrusion has been evaluated.

III. METHODOLOGY

This research begins with the development of the side intrusion beam, then comparing the new steel beam cross-section with a current steel beam cross-section for total deformation. Existing beam is tested first for maximum bending force. Then numerical testing is carried out to find out maximum bending force for comparison of different cross-section. The material property of the old beam is changed from steel to aluminium. Effectiveness of the current steel beam, different cross-section steel beam and aluminium material beam is found out by finding the intrusion at the center of the beam by implementing them into the finite element model of 3 point bending test.

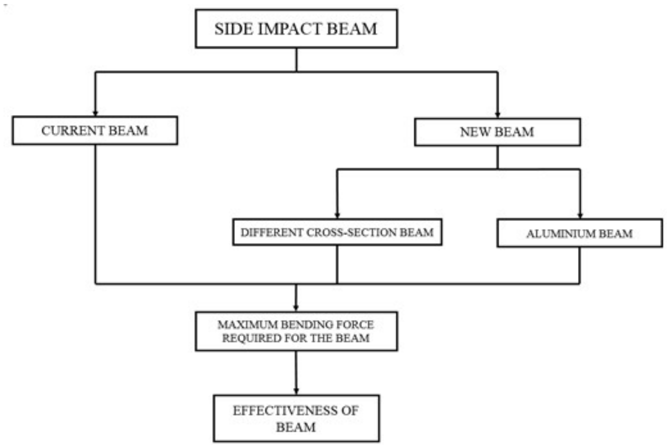

Fig. 3: Methodology

A. Existing Beam Testing Overview

Side impact beam are taken from existing vehicle. 3 point bending test is carried out to find maximum bending force taken by beam while considering beam as simply supported.

Fig. 4: Anti-intrusion beams testing equipment; 1 – Universal testing machine; 2 - cylindrical support; 3 - punch; 4 - anti-intrusion beam

Side intrusion beam is tested for bending test on Universal testing machine. Rigid cylinders with a 40 mm diameter are used to support the side door intrusion beams. Also 40 mm diameter rigid cylinder is used as a punch supported with V Block.

For side door beams a constant punch speed of 0.1 mm/s and stroke of 150 mm has been chosen. A punch of the diameter of 40 mm was pressed at middle point of the beam. After total deformation machine was able to move only 45 mm due to machine limitations. Machine has a special setting to avoid punch collision with the different machine parts. Due to that reason we set machine ram movement up to 20% of the maximum bending load. For circular cross-section workpiece maximum bending force was 6.4 KN. After 3 point bending test we tested side impact beam for material test. We found out ASTM1010 as a workpiece material.

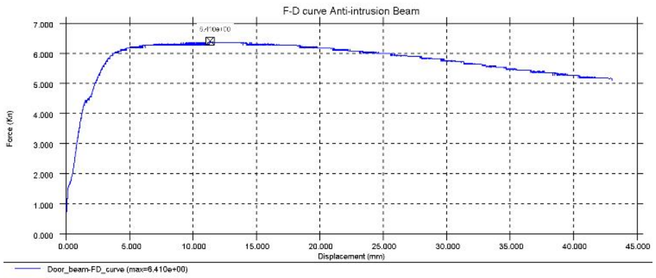

Fig. 5: F-D Curve: Anti-Intrusion Beam

B. Simulation Setup Overview

Side impact beam is modelled with 4-noded quadrilateral elements. The same set up is used in FEA simulation to determine the anti-intrusion behaviour of the side door beam:

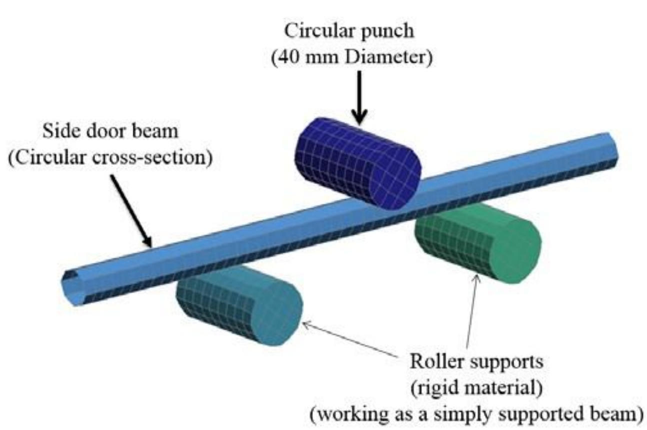

Fig. 6: FEA Setup to Determine Characteristics of Side Door Beam

1) The side door beam is supported on 2 rigid cylinder supports of 40 mm diameter. They are constrained in 5 degrees of freedom. They can roll about their own axis.
2) The side door beam is considered as simply supported beam.
3) A punch of diameter 40 mm was used, which intrudes into the intrusion beam. It is fully constrained in other 5 degrees of freedom.
4) Surface to Surface Contact was defined for below conditions:
   a) ‘Punch’ to ‘Side door beam’
   b) ‘Cylinder supports’ to ‘Side door beam’
5) Side intrusion beam kept 80 mm outside from both supporting cylinders.
6) For all cross-section 450 mm length is kept constant due to space availability.

TABLE I MATERIAL PARAMETERS FOR FEA

Material Name: AISI 1010	
Young’s Modulus, GPa	205
Poisson’s ratio	0.28
Density, kg/m3	7860
Yield Strength, MPa	886

Cad models ware imported from Creo in IGES format. Meshing was done in hypermesh. Bending test was conducted in LS-DYNA with following loading condition.

C. Cross-Sections Used For Optimizing Beam

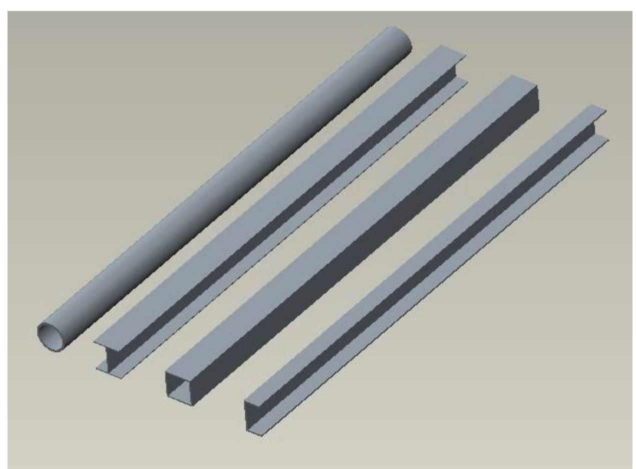

Figure 7: Cross Section Details of Side door beam

D. Cross-section details

Different cross-sections of the side door beam are considered (Circular, I beam, square tube, C beam) are shown in figure 6. One test is carried out for circular cross-section with aluminium material. Due to poor results aluminium material is skipped.

TABLE II MATERIAL THICKNESS FOR DIFFERENT CROSS-SECTIONS

Sr. No.	Cross-section of the Beam	Thickness
1	Circular	2.1
2	I section	1.1
3	Square tube	1.3
4	C channel	1.6

IV. RESULTS AND DISCUSSIONS

Effectiveness of vehicle structures, stiffness or energy absorbability is defined by two methods: applying approximate methods and larger assurance factors, and accurate numerical methods and minimized factors. The energetic method is improper in this case, so it's applied broader to various slow cars and structures, the Self weight is not real to them. The second method authorities to decrease structures weight considerably with obtaining performance safety required, but needs accurate evaluation of all possible structural particularities. Simplified design arrangements were used in initial project stages, with the valuation of specific working conditions of vehicle side structure.

In simulation by FEM of such complicated assemblies like vehicle doors, mostly some model simplifications may be understood, with the isolation of specific elements and maintaining extreme situations, at once rushing time for the solution without any effect on solution accuracy. In this case some calculation schemes were applied for the same structure, subject to working situations imitated by the structure. In this stage of analysis the results of trial and computational research of side door intrusion beams were compared.

A. Stress Concentration for all cross sections

Stress Concentration is the major factor for parts which designed to absorb energy during impact. Parts which can sustain more stress during bending can perform well in impact test.

1) Von Mises Stress Plot, Circular Beam:

Von Mises stress of side door impact beam with 'Circular' cross section are shown in figure 8.

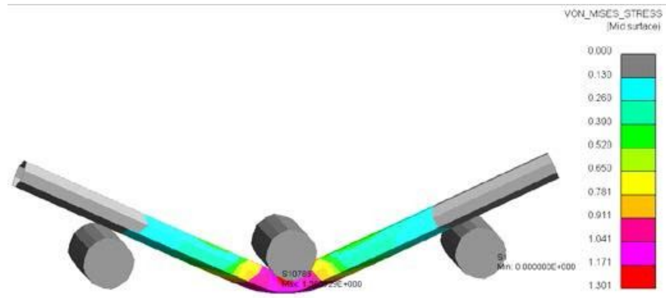

Fig. 8: Von Mises stress (1301 MPa), Circular Beam

2) Von Mises Stress Plot, I Section Beam:

Von Mises stress of side door impact beam with 'I' cross section are shown in figure 9.

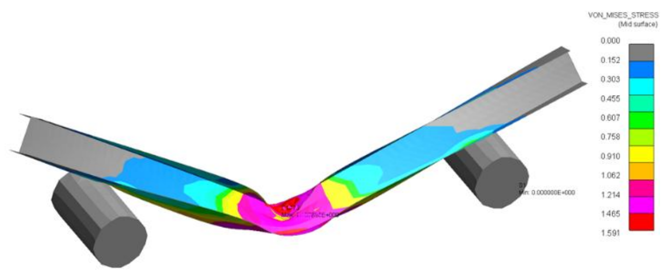

Fig. 9: Von Mises stress (1591 MPa), I Shape Beam

3) Von Mises Stress Plot, Square Beam:

Von Mises stress of side door impact beam with 'Square' cross section are shown in figure 10.

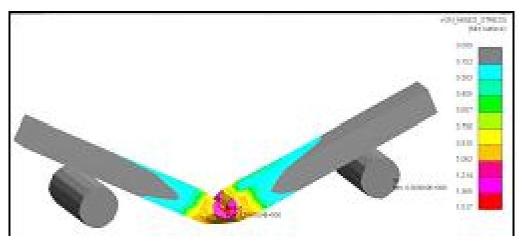

Fig. 10: Von Mises stress (1517 MPa), Square Beam

4) Von Mises Stress Plot, C channel Beam:

Von Mises stress of side door impact beam with 'C' cross section are shown in figure 11.

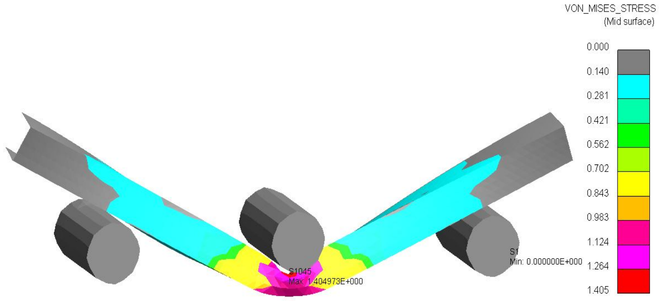

Fig. 11: Von Mises stress (1405 MPa), C Channel Beam

Though geometric differences among closed profile beams are inconsiderable, nevertheless materials mechanical properties change stiffness several times. Be- sides, it was noticed in initial FEM iterations, that nice mesh has great effect on force characteristics of closed shapes. Therefore while performing numerical experiments on closed shapes it was decided to evaluate the effect of finite elements mesh.

As observed from Figure 12, in practical bending test circular rod gives the maximum bending force required to bend is 6.4 KN. In FEA it gives the results for circular beam is 7.2 KN. This difference in values is due to material properties considered for FEA in software. We cannot consider actual material properties for FEA calculation.

For this report we have tested only change in cross-section and find out the best cross section we can use instead of old cross-section without increasing space required and minimum weight. We have tested many different sections but following cross-sections were more suitable in required space.

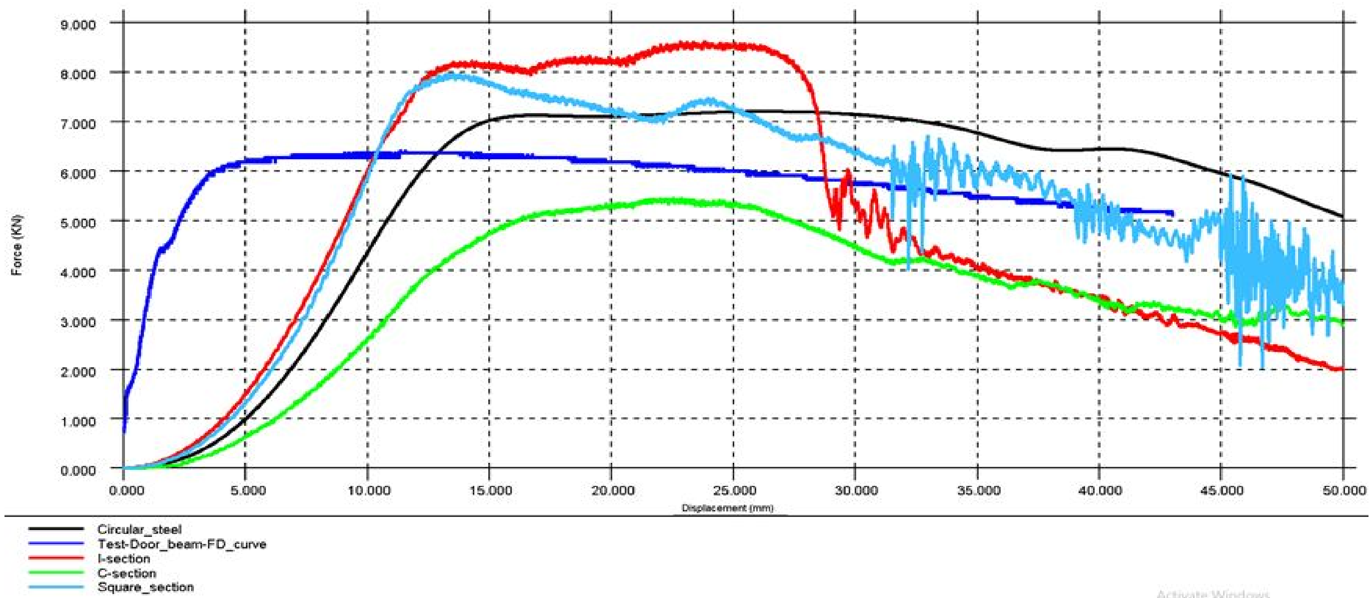

Fig. 12: Force Vs Deflection Curve

Comparison of the beams of different geometry, but with rather similar mechanical properties of materials show detailed computational models reflect experimental investigations adequately.

A beam welded in side door can move together with a door. Beam are considered as a simply supported for experiment purpose only. From the performed analysis we can say that square tube is more efficient than other cross-section. I section with two ribs will be a better option but due to welding characteristic and space available for welding is very less and welding increases its weight. So that we cannot consider it as a practical option. Also C section is failed due to lower section modulus.

V. CONCLUSION

From graph shown in figure 12, the following conclusions are made:

1. ‘Square Shape’ and ‘I Shape’ cross section beams require higher ‘Bending force’ as compared to the traditional used ‘Circular’ cross section beams.
2. ‘I Shape’ cross section beam require maximum bending for than others.
3. Performance of side door beam also depends on the door mounting assembly.
4. ‘Square shape’ cross- section can be a better option due to availability of part in the market.
5. Maximum bending force for I cross-section is 8.6 KN.

6. If ‘I’ section is used as a replacement for circular beam, we can reduce part weight by 17% and load carrying capacity can be increased by with 34%.
7. If ‘Square’ section is used as a replacement for circular beam, we can reduce part weight by 10% and load carrying capacity can be increased by 24%.

VI. ACKNOWLEDGMENT

I gratefully acknowledge Mechanical Engineering Department of DYPCOE, Akurdi, Pune for their technical support. I would also like to thank to Prof. Arun Battu (Project guide), Dr. Panchagade (HOD, Mechanical Dept.), and Dr. Tapobrata Dey (PG coordinator) for their help and dedication toward my work. Also, I thank to my friends for their direct & indirect help, support and co-operation.

REFERENCES

[1] Evaluation of FMVSS 214 - Side Impact Protection: Dynamic Performance Requirement, NHTSA Technical Report, U.S. Department of Transportation, National Highway Traffic Safety Administration, 1999.-238p.

[2] Teng, T.L., Chang, K.C., Nguyen, T.H., “Crashworthiness evaluation of side-door beam of vehicle. -Technische Mechanik, 2008, Band 28, Heft 3-4, p.268-278.

[3] Rukuiža, E., Eidukynas, V., Dulevičius, J., “The influence of seat pad stiffness and damping on the intervertebral forces in the junction of thoracic and lumbar spinal curves”, -Mechanika. -Kaunas: Technologija, 2008, Nr.6 (74), p.52-55.

[4] Pathak, A., Kumar, A., and Lamba, R., "Effect of Beam Layout and Specification on Side Door Strength of Passenger Cars: An Experimental Approach to Analyze Its Effect and Contribution to Door Strength.," SAE Technical Paper 2017-26-0023, 2017, doi: 10.4271/2017-26-0023.

[5] Townsend, J., Kaczmar, M., and El-Sayed, M., "Modular door system for side impact safety of motor vehicles," SAE Technical Paper 2001-06-0167, 2001

[6] Avinash P. Pawar, S. H. Mankar, "Crashworthiness Evaluation of Low Weight. Recyclable Intrusion Beam for Side Impact.," International Engineering Research Journal Page No 1894-1898

[7] Hou, S., Li, Q., Long, S., Yang, X., Li, W., “Crashworthiness design for foam filled thin-wall structures”, Mater. Des. 2009, 30, 2024–2032.

[8] Weimer, K. “LS-DYNA User’s Guide Cad-Fem Gmbh”, PwS, 2001.-200p.

[9] Maker, B.N. Zhu, X. “Input parameters for metal forming simulation using LS-DYNA”, Livermore Software Technology Corporation, 2000, 10 p.

[10] Prentkovskis, O., Sokolovskij, E., Bartulis, V., “Investigating traffic accidents: a collision of two motor vehicles”, - Transport. -Vilnius: Technika, 2010 , N r . 2, p. 105 -115.

[11] S Erzen, Z Ren and I Anzel, “Analysis of FRP Side-Door Impact Beam”, Faculty of Mechanical Engineering, Maribor, Slovenia, 2002.

[12] Lau, I.V., Capp, J.P., Obermeyer, J.A., “ A Comparison of Frontal and Side Impact: Crash Dynamics, Countermeasures and Subsystem Tests”, -35th Stapp Car Crash Conference, San Diego, California, p.251, November 18-20 1991. 1991, p.1899-1914.

Internet

http://www.globalncap.org/
http://www.euroncap.com/
http://crash.ncac.gwu.edu/pradeep
http://www.autointeriors.biz