DESIGN AND OPTIMIZATION OF SIDE IMPACT BEAM OF CAR

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ABSTRACT

Road safety is a very crucial concern nowadays. Many people die in road accidents every day. This research is based on previous researches on the side impact beam or intrusion beam of vehicle. The objective of this paper is to analyse and optimize the side impact beam based on resistance force and specific energy absorption during impact. Side impact causes more fatal injuries than front & rear impacts. And as we all know; passenger safety is the most important criteria while designing an automotive body. Side impact crashes can be fatal as there is no room for large deformation to protect the passenger from lateral impact. The side Door Intrusion Beam is one of the main energy-absorbing parts in event of a side impact. Till date, many types of research have been carried on side-impact & ways to reduce it. This paper begins with an overview of various cross-sections of the side impact beam, various materials, and their applications and importance. Also, we have done a simulation of a three-point bending test on a side impact beam with different combinations of material and cross-sections.

KEYWORDS: Side Impact Beam, Hypermesh, Three-Point Bending Test, Specific Energy Absorption.

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1. INTRODUCTION

In many accidents, the occupants are injuring severely and sometimes losing lives. There are different types of accidents, which are happening daily, like frontal, side-impact, rollover, and rear impact, etc. Side impact collisions are too dangerous as there is no space for more deformation of the side structures when compared with frontal collisions [2]. Side impact collision is the second most type of collision happening after frontal collisions. At an extreme level, the research is going on to increase the safety of vehicles by decreasing the effectiveness of collisions. With time, there are successful results in safeguarding the occupants from severe injuries during collisions [2]. The crashworthiness design of vehicles for passive safety aims to obtain a strong, crushproof passenger surviving cell connected to several components able to absorb and dissipate energy in a stable and controlled manner [16]. In the case of a side-impact collision, the side door beam which is installed in the door played a very important role to absorb a lot of energy, thereby reducing the amount of energy transferred to the occupants [16]. Intrusion beams are mainly designed as a feature in car doors for the security of the driver and passenger during the side-impact collision. Its purpose is to absorb and withstand the impact loads, which are developed during the side-impact collision. The deformation level cannot provide space for the side airbag to deploy. As the number of vehicles determining accident rate is increasing and higher and higher requirements are raised to their impact estimation and passengers' security, investigations on the above-ground vehicles' safety elements and energy-absorbing structures are very actual. Investigations of safety elements absorbing energy were initiated for the cases most often occurring during accidents – crashes and runs down [6]. As a result of this investigation, recommendations for deformation elements of front zones of vehicle, later used for rear body zones,

were performed. Gradually investigations of other safety elements were performed [6]. Analysis of car accidents testifies that side impacts make up 30% of all impacts and 35% of them are fatal ones [16].

2. METHODOLOGY

Figure 1: Methodology of our Project

The methodology of this research is to design and optimize the intrusion beam capable of absorbing maximum impact energy. These side-impact beams are fitted in the side doors of a passenger car to protect the passenger during a collision.

We studied various literature related to the side impact beam of the vehicle. From the study, we concluded that further improvement in the intrusion beam can be done by different combinations of best-suited parameters like cross-section, core material, composite laminates, etc. For the selection of material, cross-section & composite we compare results of various research paper related to intrusion beam design & we finalized Aluminium Alloy AA6061[10], Magnesium Alloy AMB60 [22] & AISI1008 [3] as our beam material & layer of carbon fibre [7] to be applied on two sides of the beam. We kept the section of the beam as a square with a single groove [21].

We decided to work on the following combinations for our project:

Table 1: Aluminium Alloy (AA6061) material Beam & Composite Thickness

Material	Aluminium Alloy AA6061								
Beam Thickness (mm)	1			1.2			1.4		
Composite Thickness (mm)	1	1.5	2	1	1.5	2	1	1.5	2

Table 2: Magnesium Alloy (AM60B) Material Beam and Composite Thickness

Material	Magnesium Alloy AM60B								
Beam Thickness (mm)	1			1.2			1.4		
Composite Thickness (mm)	1	1.5	2	1	1.5	2	1	1.5	2

Table 3: AISI1008 Material Beam & Composite Thickness

Material	AISI1008								
Beam Thickness (mm)	1			1.2			1.4		
Composite Thickness (mm)	1	1.5	2	1	1.5	2	1	1.5	2

We studied different samples of intrusion using three-point bending test simulation on hyper mesh software using Optistruct solver. We simulated a total of 27 different samples using a three-point bending test. Then we further optimized the intrusion beam using the full factorial DOE technique.

2.1. Three-Point Bending Test Simulation

We used CATIA & Hypermesh for modeling & simulation respectively. We took help from a previous research paper [3], where authors have done both simulation & actual experimentation. The experimental test door beam deformation pattern is similar to the FEA simulation. Hence, we decided to set up the exact model of simulation for our study.

We applied steel material for indenter & supports. Appropriate material & thickness were given to the beam as per cases mentioned in Table 1, Table 2, Table 3. The overall cross-section of the beam was 55 x 55 mm & the length was 1000 mm.

Figure 2: Simulation setup used in Hypermesh **Figure 3: Cross-section of Beam**

We applied the following boundary conditions for our setup.

- Distance between rigid supports is 900mm.
- The beam is rigidly constrained in all DOF (Degree of freedom) on two ends which is represented by rigid

cylinder supports of diameter 40 mm.

- An indenter of diameter 300 mm is used, which intrudes into the beam. It had five DOFs with the only displacement along the negative Z-axis.
- Surface to surface contact is applied between i. 'indenter' and 'Side door beam' ii. 'Cylinder supports' and 'Side door beam' 5. An imposed displacement is applied to the indenter & it is placed at the centre of the beam as shown in setup figure 4.

2.2 Optimization using Design of Experiment (DOE):

DOE is a structured, organized method for determining the relationship between factors affecting a process and the output of that process. A full factorial design of the experiment measures the response of every possible combination of factors and factor levels. These responses are analysed to provide information about every main effect and every interaction effect [23]. A full factorial DOE is practical when fewer than five factors are being investigated as testing all combinations of factor levels becomes too expensive and time-consuming with five or more factors [23]. In our experiment, factors affecting the resistance force & SEA are beam material, beam cross-section thickness & composite thickness. The total number of factors affecting the output is three. Also, numerical simulation requires less time & no cost; hence we decided to perform full factorial DOE.

Details of experimentation are given below:

Table 4: Details of factors & Levels Used in Full Factorial DOE

Factors	Levels		
Material	Al Alloy	Mg Alloy	AISI1008
Beam Thickness	1 mm	1.2 mm	1.4 mm
Composite Thickness	1 mm	1.5 mm	2 mm

There are three levels for each factor. Hence total of 27 combinations is required [Formula for total combinations = (Levels ^ factors)].

3. RESULTS

3.1. Three-Point Bending Test Results:

Figure 4: Contact Force 1.2 mm thick section with 1.5 mm thick composite (AISI 1008)

Figure 5: Strain Energy 1.2 mm thick section with 1.5 mm thick Composite (AISI 1008)

The above results are of contact force & strain energy obtained from simulation of three-point bending test on Hypermesh software.

Table 5: Numerical Simulation Results of three-point Bending Tests

No	Materials	Beam Thickness	Composite Layer Thickness	Contact Force (N)	Strain Energy (J)	SEA (J/kg)
1	Al Alloy	1 mm	1 mm	10409.266	925.94	853.400
			1.5 mm	15081.523	1179.371	996.090
			2 mm	16619.887	1249.653	974.008
		1.2 mm	1 mm	14565.707	1126.020	935.232
			1.5 mm	16338.323	1257.344	964.960
			2 mm	17925.057	1298.701	926.320
		1.4 mm	1 mm	14962.094	1101.683	832.715
			1.5 mm	17622.455	1335.890	939.444
			2 mm	19263.053	1414.585	930.036
2	AISI 1008	1 mm	1 mm	20032.285	1324.431	585.513
			1.5 mm	27318.121	1608.103	681.110
			2 mm	29273.371	1772.677	720.600
		1.2 mm	1 mm	25252.742	1429.611	548.163
			1.5 mm	30382.389	1898.341	701.271
			2 mm	32256.488	1982.043	706.358
		1.4 mm	1 mm	29502.266	2089.231	705.106
			1.5 mm	33349.461	2163.181	706.460

			2 mm	35389.516	2167.299	685.637
3	Magnesium Alloy AM60B	1 mm	1 mm	8438.241	813.253	926.256
			1.5 mm	13267.151	954.263	976.727
			2 mm	14608.793	987.339	917.601
		1.2mm	1 mm	11718.500	919.164	959.461
			1.5 mm	13957.626	1036.579	980.680
			2 mm	15327.509	1153.898	998.181
		1.4 mm	1 mm	13203.775	968.345	932.894
			1.5 mm	14225.559	1122.905	987.603
			2 mm	15633.990	1194.059	966.067

From the above results, the maximum contact force (35.38 kN) is resisted by an AISI1008 beam with 1.4mm thickness & 2mm composite thickness, but the specific energy absorption by the same sample is only about 685.72 J/kg. Above mentioned beam has a weight of 3.16 kg which is the highest among all samples. This extra weight would affect the fuel economy of the vehicle. Hence, optimization needed to be performed on the beam. The optimized beam should have maximum SEA & optimum resistance force.

3.2 Design of Experiment (DOE) Results:

Contact Force:

The main effect plot & interaction plots of contact force are given below:

Figure 6: Main Effect Plot & Interaction Plot Of Contact Force

From the main effect plot of contact force, it is seen that intrusion beam material's contribution is significant compared to cross-section thickness & composite thickness. AISI1008 provides the highest contact force among all materials. The interaction plot is also showing the dominance of AISI1008 material on contact force.

Specific Energy Absorption (SEA):

The main effect plot of specific energy absorption (SEA) is given below:

Figure 7: Main Effect Plot & Interaction Plot of Specific Energy Absorption (SEA)

Although AISI1008 is the best-suited material for contact force, SEA for AISI1008 is very low compared to the other two materials. Composite thickness & cross-section thickness are not contributing significantly. SEA for samples with Magnesium alloy AM60B is highest. The interaction plot of SEA is showing the dominance of magnesium alloy AM60B on the SEA of the beam. From the above results, it is seen that we need to optimize the sample which can have maximum SEA & optimum contact force. Here, the response optimization technique is used. In the response optimizer, a target contact force of 17.5 kN & SEA of 950 J/kg is applied.

Response Optimizer: Setup						
Response	Goal	Lower	Target	Upper	Weight	Importance
Contact Force	Target	15000	17500	20000	1	1
SEA	Target	900	950	980	1	1

Figure 8: Response optimizer setup

Figure 9: Response optimizer results

Results of the response optimizer show the sample with aluminium alloy with section thickness 1.2mm & composite thickness of 2 mm can be suited for our requirement.

Contact Force = 18.6 kN

SEA = 944.19 J/kg.

The numerical simulation results of the same sample show contact force as 17.92 kN & SEA as 926.32 J/kg.

4. CONCLUSIONS

A comparison study on the side impact beam of a vehicle is carried out with the help of three points bending test numerical simulation on Hyperworks software. Side impact beam with AISI1008 showed the highest resistance force but very low SEA, on other hand Mg Alloy AM60B showed maximum SEA but very low resistance force. Full factorial DOE & response optimization technique is carried out to optimize the side impact beam for optimum resistance force & maximum specific energy absorption. From the above numerical simulation results & optimization, we can conclude that beam with Aluminum alloy AA6061 having a cross-section thickness of 1.2mm & composite thickness of 2 mm provides an optimum contact force of 17.92 KN & SEA as 926.32 J/kg.

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