Advanced Materials Research
ISSN: 1662-8985, Vol. 980, pp 263-268
doi:10.4028/www.scientific.net/AMR.980.263

Submitted: 2014-05-14
Accepted: 2014-05-15
Online: 2014-06-30

Design and Analysis of Automotive Instrument Panel

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Keywords: Instrument Panel (IP), Head Impact Simulation, Head Injury Criterion (HIC), ABS polymer.

Abstract. This study presents the automotive instrument panel (IP) design in order to improve the quality, cost, and safety of the existing design. A few conceptual designs were generated based on safety aspect and ergonomic design. The most suitable design was selected using concepts scoring. The IP head impact simulation was conducted using finite element analysis (FEA) to predict the head injury criterion (HIC) value of the front passenger in vehicle according to ECE-R21 regulation. The finite element (FE) model, which consist of upper IP, lower IP, carrier structure and head-form, was built-up to carry out head impact analysis of the IP assembly. The optimum IP design was proposed by analysis of different materials, which are 20% talc filled rubber modified polypropylene (PP+EPDM-TD20), acrylonitrile butadiene styrene (ABS) polymer, and polypropylene (PP) copolymer. The HIC value for all IP was compared using simulation result and theoretical calculation. The lowest HIC value will reduce the head occupant injury. In this study, only the raw material cost was considered in cost evaluation. The IP from ABS polymer performed the lowest HIC value, which were 179.7 but very costly compare to other materials.

Introduction

Automotive instrument panel (IP) is one of the most important parts in vehicle interior parts. Automotive manufacturer need to consider the quality, cost, and safety of the product when study the conceptual design of automotive parts.

In this vehicle design era, ergonomics design criteria is considered during design process. Ergonomics is the applied science which aims to match the demands of products and equipment, jobs and places of work, with the characteristics of the people who use them [1]. In the context of the IP, ergonomic design will ensure the display in the instrument cluster can be easily seen and the vehicle control system can be easily reached by the driver.

Law related with passenger protection against car crash was taken seriously by manufacturer. The most common sources of head and face injury in frontal crashes were from contact with the IP, driver steering and windscreen [2]. Therefore, the developed IP must fulfil the government regulation and standards, such as Federal Motor Vehicle Safety Standards Regulations 201 (FMVSS 201) for North America, and United Nations Economic Commission Regulations 21 (ECE-R 21) for Europe. These regulations describe the requirement for IP head impact. By using Computer Aided Engineering (CAE) technique for IP head impact, prototype use for physical test will be reduced.

The objectives of this study are to design and modelling the automotive IP in order to improve the quality, cost and safety of the existing design and to determine the head injury criterion (HIC) of front passenger occupant using different materials. Besides, to compare the value of HIC based on simulation and theoretical calculation.

Methodology

The solution or idea of IP design can be illustrated in a few conceptual designs. To choose final design, the best design selected using the concept scoring. The CAD modeling of final design was performed by using CATIA P3 V5R20 software. Besides, head impact simulation was conducted by using LS-DYNA V971 software.

Defining the Problem. It is important to interior designer to apply user-centered design method when designing product. The designer focuses on the user as the main source of innovation [3]. The customer's needs were identified by studying and observing surveys of current users regarding to current commercially available IP. The information about customer's need was taken from the journals, technical articles and consultants. Besides, the metrics criterion explains the customer's needs in the technical term. The relationships between customer's needs and metric criterion were explained as in the Needs-Metrics matrix. Table (refer with: Table 1) shows the Needs-Metrics matrix in order to design IP.

Table 1 The Needs-Metrics matrix

No.	Metrics / Needs	Low density material	Short assemble time	Low manufacturing cost	Low degree of defects	Long UV test duration	Safety aspect	High amount of load	Aesthetics	Ergonomic design
1	Is lightweights									
2	Is easy to install									
3	Is affordable for an amateur enthusiast									
4	Is not react with chemicals									
5	Is not deformed by sunlight									
6	Lasts a long time									
7	Can prevent occupants from fatal injury									
8	Has high scratch resistance									
9	Didn't has manufacturing defects									
10	Has high quality surface									
11	Can be recycle as new product									
12	Has the attractive design									
13	Dimensions is suitable for Asian people									

Concept Selection. The assessments show the comparison between the concept designs. The most suitable design was selected using concepts scoring. The maximum point was selected as the final design. Figures (refer with: Fig. 1, Fig.2 and Fig.3) show the each concept.

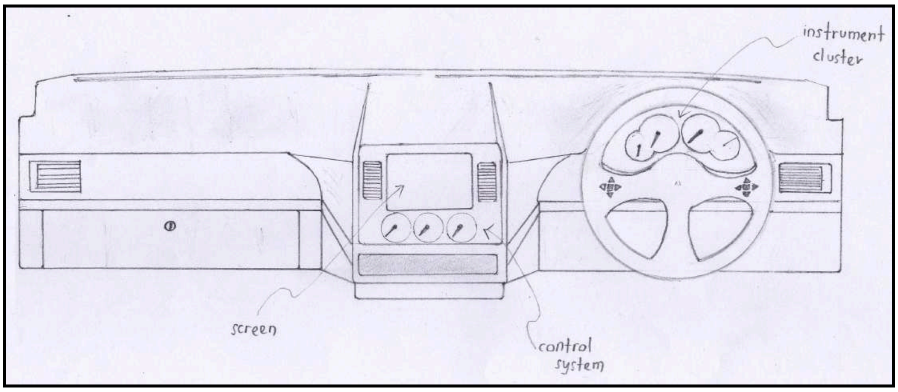

Fig 1 Concept 1

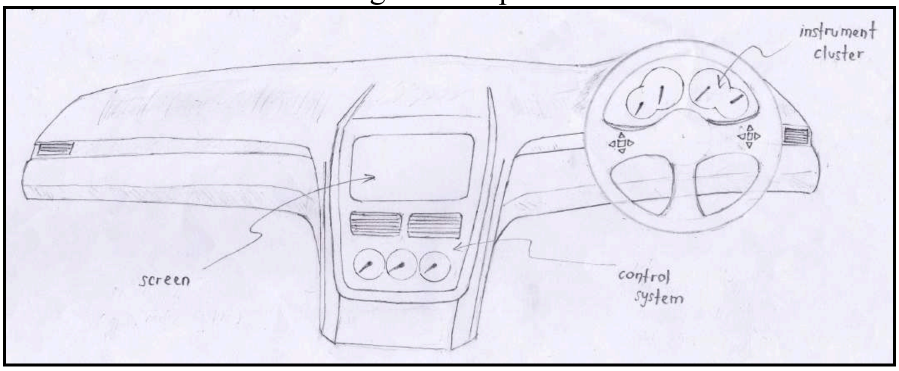

Fig 2 Concept 2

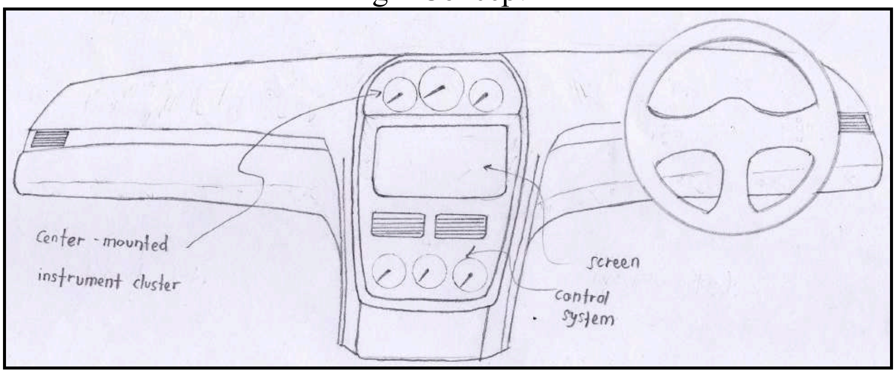

Fig 3 Concept 3

By comparing all the concepts, concept 1 was the highest point. Based on the concept scoring, concept 1 had the criterions such as ergonomic design, aesthetics, safety aspect, high quality and satisfies the regulations. Therefore, concept 1 was considered the best concept to be developed.

Preliminary Selection of Material. The raw of material for IP should be good mobility, excellent mold-ability and dimensional stability because of the large size and long cavity-filing distance of large plastic parts [4]. In this study, three resin materials were considered which are PP+EPDM-TD20, ABS polymer, and PP copolymer.

CAD Modeling. The 3D modeling was generated by using CATIA software. Figure (refer to: Fig. 4) shows the IP model of concept 1. This model also will be used in the CAE analysis. The thickness of this instrument panel was a 4 [mm].

FE Model and Impact Analysis. Both FMVSS 201 and ECE-R 21 regulations describe the requirements for IP head impact. The FMVSS 201 regulations stated that when that area of the IP that is within the head impact area is impacted by a 6.8 [kg], 165 [mm] diameter head form at 19 [km/hr], the deceleration of the head form shall not exceed 80 [g] continuously for more than 3 [ms]. This requirement is for vehicles with dual airbag; but if vehicle without airbag, the impact speed is 24.1 [km/hr]. Besides, the ECE-R 21 regulation stated virtually the same requirement except that the impact speed is 24 [km/hr] [5]. Figure (refer with: Fig. 5) shows FE model for IP head impact simulation. The spherical shape in was assumed as the head of the vehicle passenger. It was applied the head-form diameter 165 [mm] and weight 6.8 [kg] to the FE model modeling. It was assumed as a rigid body, which means it didn't affect the analysis result. Each part in impact simulation has 4 nodes and 3 nodes shell elements, but mostly was a 4 nodes shell elements. Areas for each element were set up to 4 [mm^2].

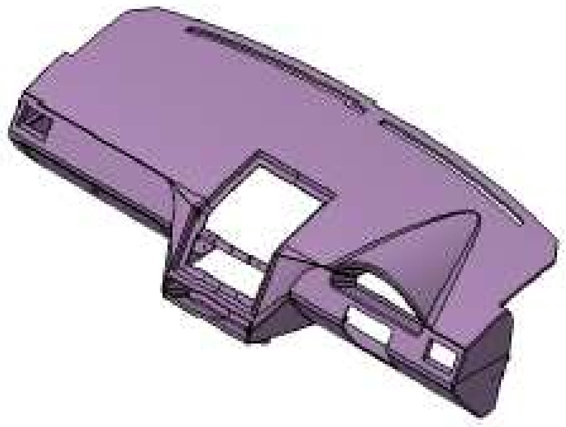

Fig. 4 The IP model

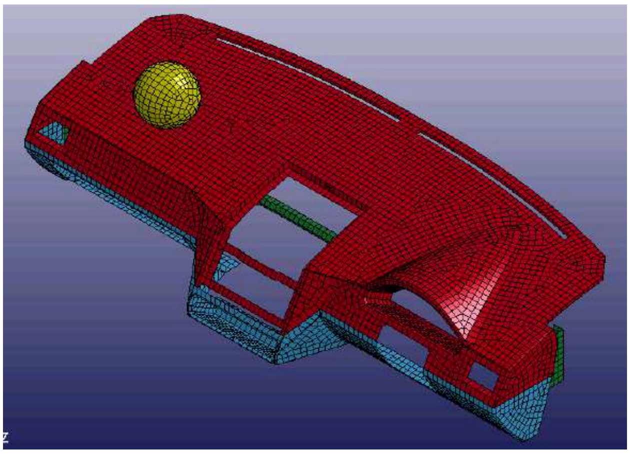

Fig. 5 The FE model for impact simulation

HIC Calculation. For most applications, the parameter that reflects the structure's performance is head injury criterion (HIC). A value of HIC below than 1000 units means that the structure provides satisfactory protection for passenger. Using data from the simulation, HIC can be calculated theoretically by using Eq.1.

$$HIC = \left[\frac{1}{t_2 - t_1} \times \int_{t_1}^{t_2} a\, dt \right]^{2.5} \times (t_2 - t_1) \tag{1}$$

The value for HIC was calculated by using head impact simulation data, times for head impact (t_1 and t_2) and acceleration of head (a). Notes that HIC from calculation need to divide by 1000 because the gravitational constant in simulation was a 0.00981 [mm/ms^2]. The percentage of error was calculated by using Eq. (2).

$$\%error = \left| \frac{HIC_{calculation} - HIC_{simulataion}}{HIC_{calculation}} \right| \times 100 \tag{2}$$

Cost Evaluation. In cost evaluation for IP design, only raw material cost was considered. Cost for manufacturing process, labor, and other cost was not considered in this study. Table (refer with: Table 2) shows the cost for a raw plastic in Feb 2012 markets. The value of mass can be calculated from the density-volume relationship. The IP volume can be obtained in the CATIA software.

Table 2 Costs for a raw plastic [6]

Raw plastic Material	PP+EPDM-TD 20	ABS Polymer	PP Copolymer
Price (RM/kg)	3.70	5.87	2.45

Results

Figures (refer with: Fig. 6, Fig 7 and Fig. 8) shows the head impact simulation at a specific time and variation of acceleration at top of the head-form part in IP assembly for each material. For PP+EPDM-TD20, maximum deflection of IP was an approximately 58.29 [mm] between 19 and 26 [ms] and the HIC was 194.8. Besides for ABS polymer, maximum deflection of IP was an approximately 52.58 [mm] between 15 and 18 [ms] and the HIC was 179.9. For PP Copolymer, maximum deflection of IP was an approximately 58.29 [mm] between 19 and 26 [ms] and the HIC was 201.3.

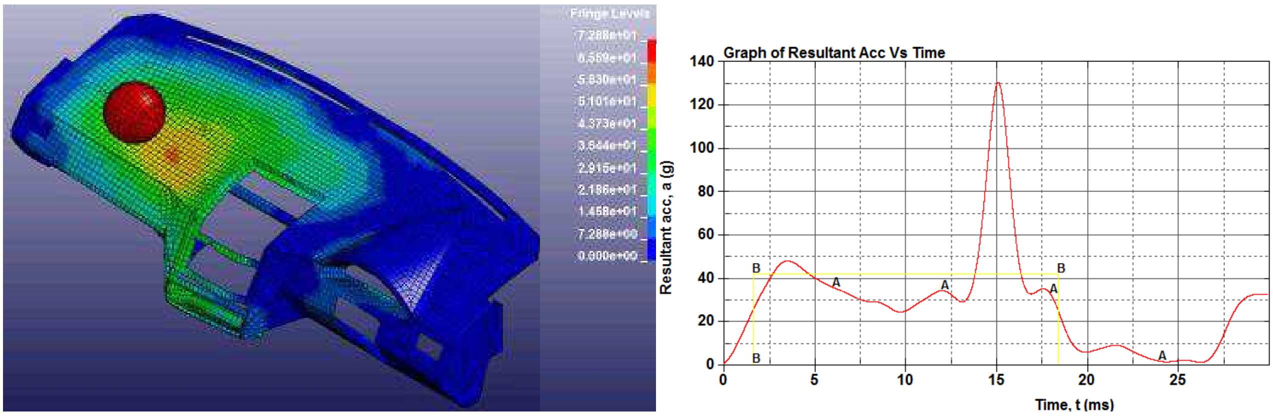

Fig. 6 Analysis results for PP+EPDM-TD20

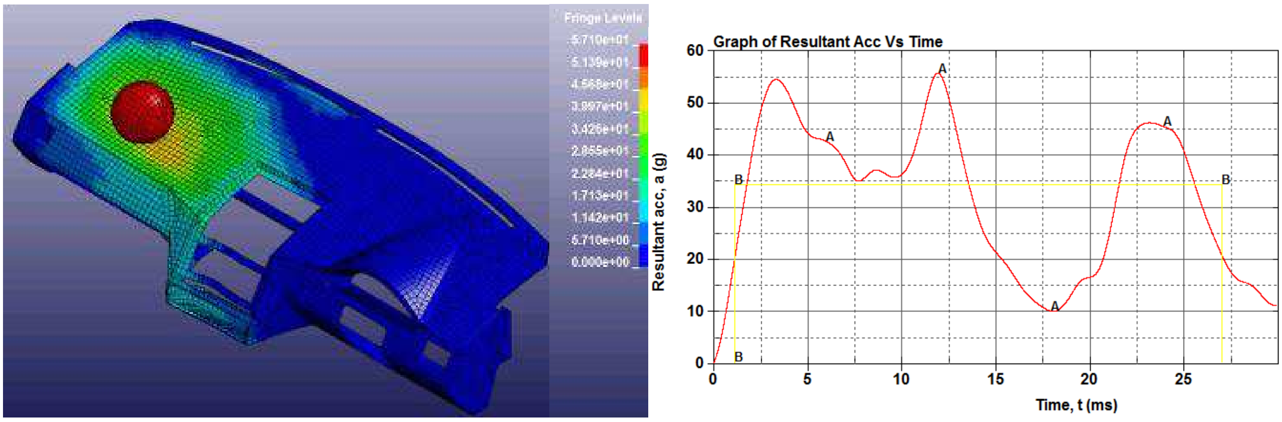

Fig. 7 Analysis results for ABS polymer

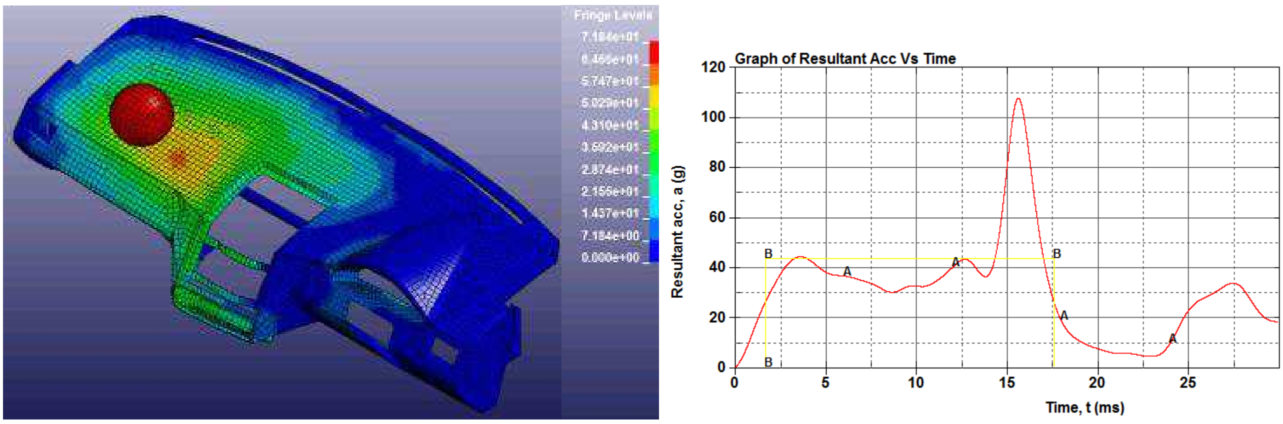

Fig. 8 Analysis results for PP Copolymer

Table (refer with: Table 3) shows the comparison of HIC value resulted from the simulation and calculation. The percentage of error was too small, it value was less than 3%.

Table 3 The comparison of HIC value

Material	t1 [ms]	t2 [ms]	a [g]	HIC simulation	HIC calculation	Percentage of error (%)
PP+EPDM-TD20	1.601	18.4	42	194.8	192.046	1.43
ABS polymer	1.133	27.1	34	179.9	174.830	2.90
PP Copolymer	1.654	17.6	44	201.3	204.778	1.70

Table (refer with: Table 4) shows the raw plastic material price of each material to produce the IP. The ABS polymer was the most expensive compare to other materials.

Table 4 The raw plastic material price of each material

Material	Volume, V [mm^3]	Density, ρ [kg/ mm^3]	Mass, M [kg]	Raw plastic price [RM/kg]	Price [RM]
PP+EPDM-TD 20	6E+6	1.04E-6	6.24	3.70	23.09
ABS Polymer	6E+6	1.04E-6	6.24	5.87	36.63
PP Copolymer	6E+6	0.93E-6	5.59	2.45	13.67

Summary

There were many factors which should be considered while designing automotive IP. Apart from the producing attractive designs, this study also focusing on ergonomic and safety design. This study was trying to simulate the real event for front passenger head when impacting the IP due to frontal crashes. Three different materials for IP model were analysed based on head impact simulation, which are PP+EPDM-TD20, ABS polymer, and PP copolymer.

The HIC value for head impact on IP that use all these three materials were less than 1000 units. It was also satisfying the FMVSS 201 and ECE-R21 regulations requirement. Design model from ABS polymer performed the lowest HIC value compared to the PP+EPDM-TD20 and PP copolymer. The HIC value for different IP material, PP+EPDM-TD20, ABS polymer, and PP copolymer was 194.8, 179.9, and 201.3, respectively.

Based on dynamics analysis, IP model that using ABS polymer as product material, will prevent occupant head impacting or stuck with carrier structure. This material was able to reduce head acceleration and capable to absorb energy due to impact.

Therefore, ABS polymer material was the most suitable for this IP design although the raw material cost was expensive.

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