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Conceptual Design and Analysis of Brake Pedal Profile

Dr.K.K.Dhande[1], Prof .N.I.Jamadar[2], Sandeep Ghatge[3]

Professor, Dept. of Mechanical Engineering, Pad. Dr. D. Y. Patil Institute of Engineering &Technology, Pimpri, Pune, India[1]

Assistant Professor. Dept. of Mechanical Engineering, Pad. Dr. D. Y. Patil Institute of Engineering &Technology, Pimpri, Pune, India[2]

M.E. Design, Dept. of Mechanical Engineering, Pad. Dr. D. Y. Patil Institute of Engineering &Technology, Pimpri, Pune, India[3]

ABSTRACT: The modern automotive industries are replacing acceletor and clutch pedal by light weight materials such as polymer composites, plastic, aluminium and its alloys, etc. The purpose of replacement is reduction weight, cost, and improvement in corrosion resistance.In aviation; the steel material is replaced by light materials. In this study various lightweight materials are compared with conventional steel for brake pedal. These materials are analyzed for different sections for different loading and boundary conditions. The aim of this study is to design and analyse the brake pedal using CATIA and ANSYS software

KEYWORDS: Automotive brake pedal, Polymer composites, Light weight.

I. INTRODUCTION

In recent year, the material competes with each other for existing and new market. Over a period of time many factors that make it possible for one material replace to another for certain application. The main factors affecting the properties of the materials are strength, cost and weight. In automobile industries it is mandatory to look for cheap and lightweight materials and which should be easily accessible. The constituents of a composite are generally arranged so that one or more discontinuous phases are embedded in a continuous phase. The discontinuous phase is termed the reinforcement and the continuous phase is the matrix. A brake pedal in motor vehicles has the task of providing the driver's command through foot leg on master cylinder of the brake system in a vehicle during stopping or reducing speed of a vehicle.

At present, brake pedals are largely made from metal but composite clutches and accelerator pedals are already successfully utilized in automotive vehicles. This study is mainly concentrated on variable-material for the conceptual design brake pedal profile, which is achieved 78% lighter in weight compared to the present metallic pedals and 64% light weight compared to aluminium. According to General Motors specifications, the maximum load of 2700 N was applied to brake pedal. It is assumed that this is a possible panic load on a brake pedal [5].

The automotive industries using various types of light weight material like steel, aluminium and composite in wide range of application shown in fig1.

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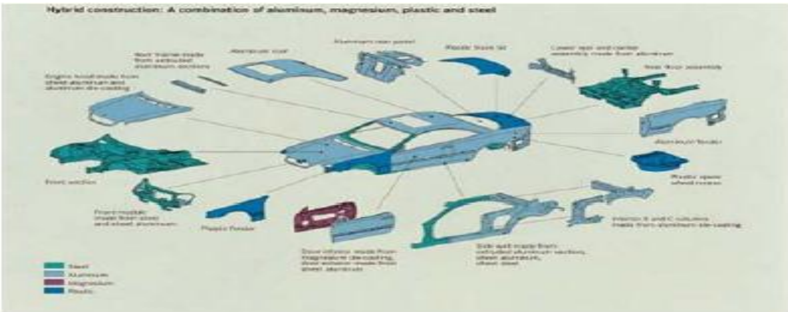

Figure1: Hybrid vehicle combination of steel, aluminium, and plastic

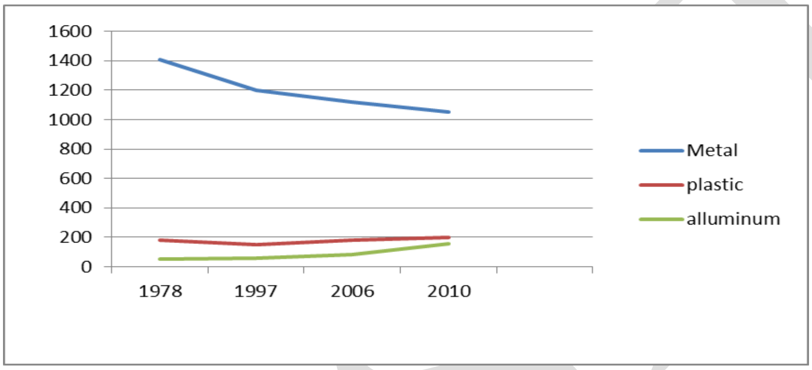

Figure2: Trends in usage of different materials

The most of common class of ferrous metals and alloys (cast iron, steel, and nickel) which represent 68% by weight, other non-ferrous metals used include copper, zinc, aluminium, magnesium, titanium and their alloys 10 to 15 &. The plastics contents commercial vehicles comprise about 20 to 30 % of all interior components [2]. The general trend in usage of different materials over the years is shown in figure 2.

The figure 2 explains about the trends in using metal, plastics and aluminium in the automobile industries. The trend shows that the use of plastics is gaining importance over metal and aluminium. The use of metal is drastically coming down.

II. LITERATURE SURVEY

According to American Chemistry council's plastic division initiated in improving advanced plastics and polymer composites appearance, functionality, and safety of automobiles by reducing vehicle weight and delivering as per the requirement of customers. In order to meet the progressively increasing efficiency and emissions standards by 2025 (Figure 3), it is critical that automakers continue to find new ways to lightweight their vehicles.

A similar study has been done by Pankaj Chhabra on accelerator pedal at 40N indicates that using composite pedal can save 80% of material weight for the same force and deflection. In his work assumed six sections of pedals to find the optimum section, it is conformed from results, I section is best among all sections.

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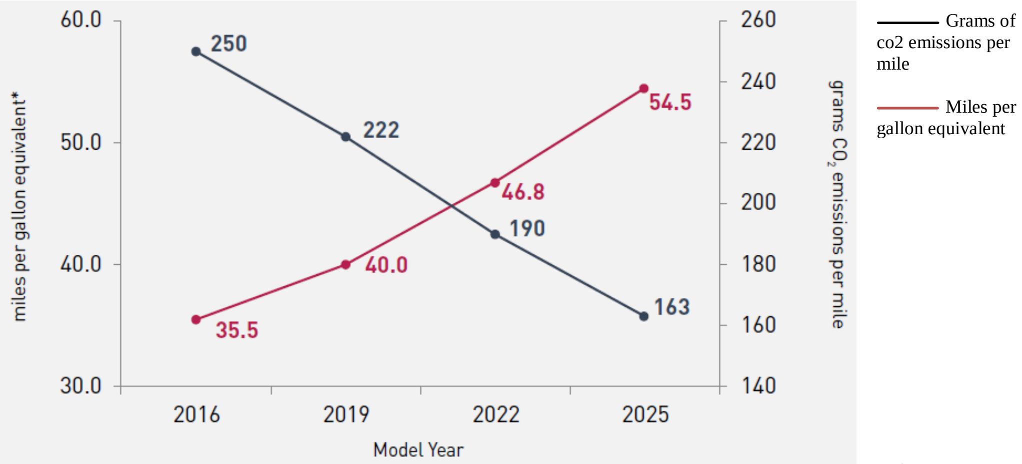

*Combined cars and trucks, if all GHG reductions are made through fuel economy improvements
Data source: U.S. Environmental Protection Agency, "EPA and NHTSA Set Standards to Reduce Greenhouse Gases and Improve Fuel Economy for Model Years 2017-2025 Cars and Light Trucks," http://www.epa.gov/otaq/climate/documents/420f12051.pdf.

Figure3: National program to reduce emissions

In order to meet the progressively increasing efficiency and emissions standards by 2025 (see Figure 3), it is critical that automakers continue to find new ways to lightweight their vehicles. Ducker Worldwide estimates that 400 pounds—about 10 percent—needs to be removed from the average car to meet the proposed EPA emissions standards that are equivalent to 54.5 mpg.6 The industries producing metals like aluminum and advanced high-strength steel (AHSS) are working to attain light weighting gains to help meet these needs. Aluminum weighs about one-third as much as conventional steel, while AHSS provides weight-saving improvements at a modest incremental cost. Plastics and polymer composites continue to deliver significant weight savings to automakers. In addition to their current role as an excellent choice for light weighting, aesthetics, aerodynamic design, and value in many interior and exterior applications, plastics and polymer composites—particularly fiber reinforced composites—are also fast becoming a contender in structural applications like body-in-white and chassis components due to their ability to drastically reduce overall vehicle weight while maintaining or improving safety and performance

As per Jurgen Hirsch's research on "Aluminum in Innovative Light-Weight Car Design" he compared light-weight solutions are compared with that of other materials, like new steels, magnesium, plastics and composites. He concluded that when Aluminum is compared against the materials mentioned above there will be 34% weight reduction while maintaining safety and performance in a cost efficient way. He compared Aluminum for body chassis, seam welded tubes, body and heat exchanger. Based on these inputs we will be evaluating how steel, Aluminum and composite will help for brake pedal optimization.

III.MATERIAL SELECTION

The expert system criteria of material selection based on strength/stiffness, weigh ratio, mechanical, physical, chemical properties, low corrosion resistance and availability. The selected material must able to use for mass production and with less cost. The shown table 1 different steel material selection based on combine different properties physical and mechanical properties availability weight ratio, strength. Selected materials used in the development of pedal lever profile.

Description	FE-410	E-34	D-513	EDD-1079
Young's modulus MPa	2E5	2.06E5	2.10E5	2.2E5
Tensile strength MPa	387.79	450.79	367.69	340.53
Poisson ratio	0.315	0.34	0.35	0,34
Density Kg/m3	7.89e9	7.89e9	7.89e9	7.89e9

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Yield strength MPa	283.78	360	205.13	334.16
Creep resistance	Good	Good	Good	Good
Corrosion resistance	Good	Good	Good	Good

Table1: Properties of different steel materials

The aluminum material selection based on combine different properties in an efficient symbiosis like inner strength with superior surface appearance, corrosion resistance or formability, proof strength, and a suitable behavior with regard to loads from the manufacture (e.g. age-hardening during paint baking which is an important factor of brake pedal profile design properties of different aluminium materials shown in table 2

Description	Al99	AlCuMg1	AlSi(6009)	AlZnMg(7075)
Young's modulus, MPa	70000	72000	69000	71000
Tensile strength , MPa	140	370	340	530
Poisson ratio	0.3	0.32	0.29	0,31
Density Kg/m^3	2710	2800	2710	2850
Corrosion resistance	Good	Good	Good	Good
Elongation %	30	14	24	8
Fatigue failure MPa	65	-	117	-
Melting temp	660	510	650	640
Yield strength MPa	120	230	228	450

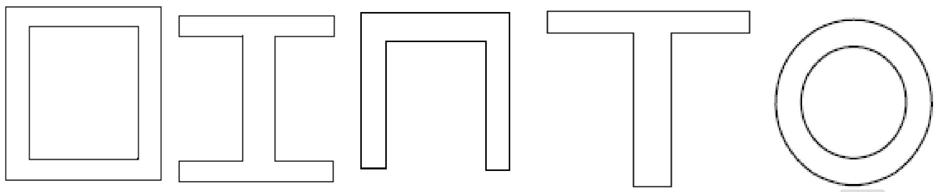
Table2: Properties of different aluminium materials

As per Mohd Sapuan Salit [6] there is polyamide (nylon) with short glass fibres in varying percentages. The long glass fibres are not suitable because of fibre intermeshes and their corners may be overlapped. Thus, from consideration of material strength and stiffness. The short glass fibre is lightest among materials, which has lowest density. Nylon with short fibre has high impact strength, which is an important factor of brake pedal profile design properties of different composite materials shown in above table3

Description	PP GF30%	PA6 GF30 %	PA66 GF30%	ABS GF30%
Percent of Glass field %	30	30	30	30
Young's modulus MPa	5000	9500	15000	6000
Tensile strength MPa	75	190	160	80
Poisson ratio	0.315	0.34	0.35	0,34
Density Kg/m3	1140	1400	1370	1190
Moisture absorption %	0.35	0.35	0.35	0.35
Creep resistance	Good	Good	Good	Good
Corrosion resistance	Good	Good	Good	Good

Table 3: Properties of different composite materials

IV. CONCEPTUAL DESING OF PEDAL LEVER ARM PROFILE



Section 1 Section 2 Section 3 Section 4 Section 5

Figure4: Section of brake pedal arm profile

The above listed materials are used in the development of pedal lever profile. For the study five different sections are selected as shown in figure 4. The conceptual design of the polymeric-based composite brake pedal is a primary stage to generate the solution. Various alternative designs have been considered. The conceptual design of the polymeric-based composite brake pedal concentrates on beam for the design of the brake pedal lever.

Requirement Static load	Force	Maximum deflection
Transverse Load	220 N	10 mm
Normal force	1100N	10mm
Maximum force	2700 N	15mm

Table4: Force and allowable deflection [3]

The above cross sections which are evaluated against the load in table 4. The outcome expectation is arrive at one Section which is stiffer and gives less stress compared other sections. The data required for brake pedal design were collected from General Motors (The above cross sections which are evaluated against the load in table 4 the outcome expectation is arrive at one 4). The brake pedal has to withstand 2,700 N maximum static loads. This load has caused the displacement of 10 mm when 220 N is applied as traverse load [3]

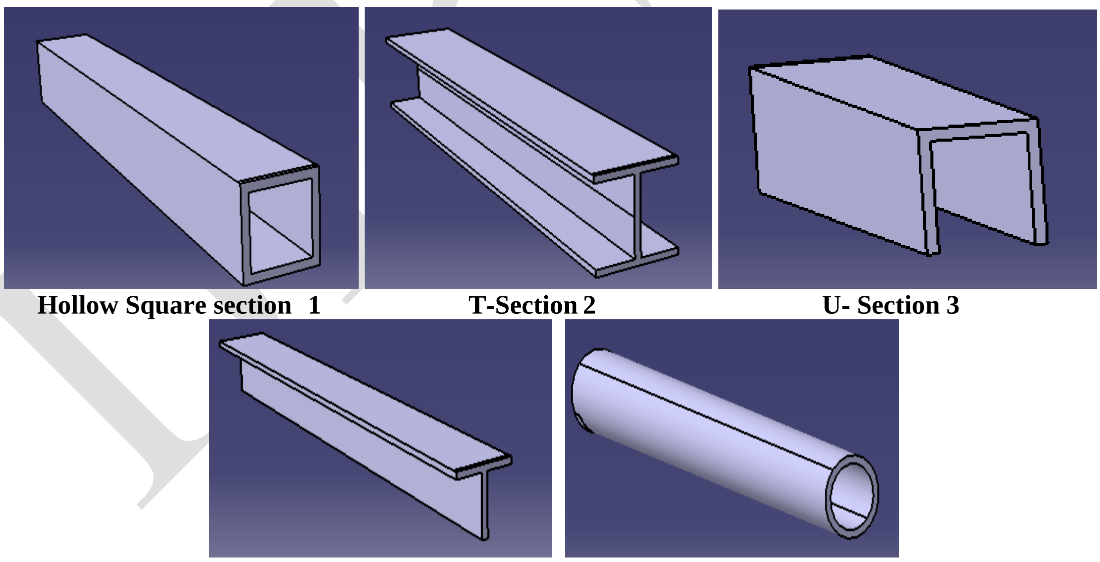


Figure5: CAD modelled sections

Figure 5 shows a 3D model of sections of brake pedal arm profile. The 3D models are generated using CATIA software and will be used for analysis. The concept evaluation begins with the calculation of each concept regarding

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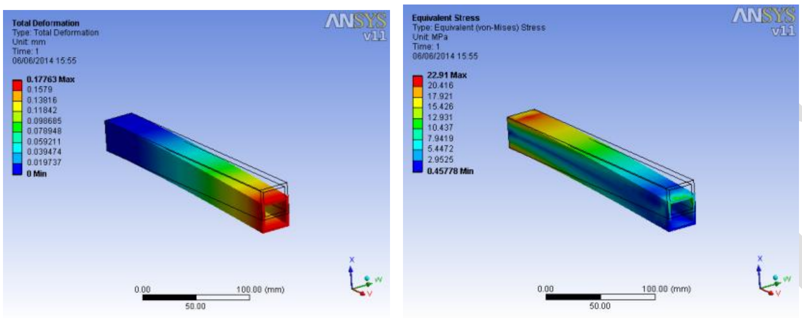
the weight of the beam and displacement in bending and tensile load. The calculation was performed using the conventional formulae and the finite element analysis.

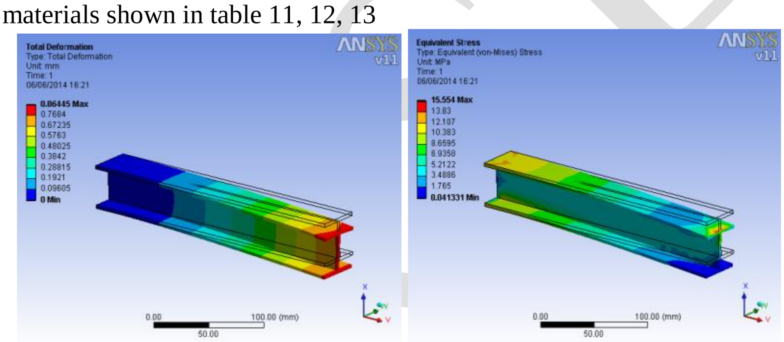
FEA analysis of brake pedal lever arm section (Mild Steel, FE-410)



Total deformation **Equivalent stress** (Von-misses)

Fig 6: Deformation and stress distribution of hollow square section

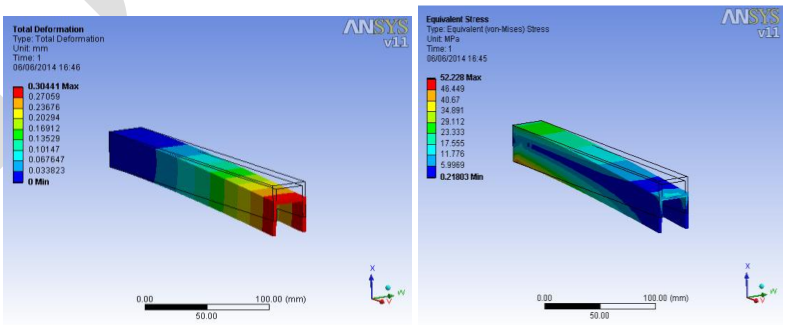
It is clear from the above figure 6, over the brake pedal lever arm profile the transverse load of 220N is applied, as a result the maximum deflection found to be 0.177mm which is lesser than 10mm [3]. As a result it yields equivalent stress (Von-misses) 22.91N/mm^2. Similarly deformation and stress plots are plotted for different materials aluminium and plastic materials shown in table 11, 12, 13



Total deformation **Equivalent stress** (Von-misses)

Fig 7: Deformation and stress distribution of I-section

The above show figure 7, over the brake pedal lever arm profile the transverse load of 220N is applied, as a result the maximum deflection found to be 0.8644mm which is lesser than 10mm [3]. As a result it yields equivalent stress (Von-misses) 15.554N/mm^2. Thus "I" section gives less deflection and maximum stiffness.



Total deformation **Equivalent stress** (Von-misses)

Fig 8: Deformation and stress distribution of U-section

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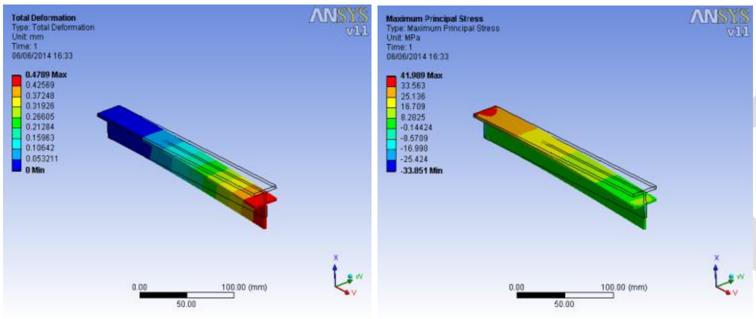
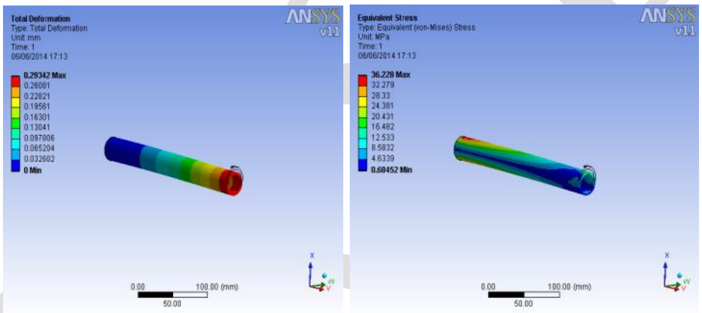
It is clear from the above figure 8 over the brake pedal lever arm profile the transverse load of 220N is applied, as a result the maximum deflection found to be 0.30 which is lesser than 10mm [3]. As a result it yields equivalent stress (Von-misses) 52.228N/mm^2. Thus similarly using aluminium and plastic various materials applied on U section found maximum deflection of aluminium 0.83 and plastic 8mm.



Total deformation **Equivalent stress** (Von-misses)

Fig 9: Deformation and stress distribution of T-section

It is clear from the above figure 9, over the brake pedal lever arm profile the transverse load of 220N is applied, as a result the maximum deflection found to be 0.4789mm which is lesser than 10mm [3]. As a result it yields equivalent stress (Von-misses) 41.98N/mm^2.



Total deformation **Equivalent stress** (Von-misses)

Fig 10: Deformation and stress distribution of tube section

The above figure 10, over the brake pedal lever arm profile the transverse load of 220N is applied, as a result the maximum deflection found to be 0.2934mm which is lesser than 10mm [3]. As a result it yields equivalent stress (Von-misses) 36.228N/mm^2.

Section	Mass (Kg)	Volume e5 m^2	Maximum deflection "mm"		Maximum stress (N/mm2)	
			Analytical	**FEA**	**Analytical**	**FEA**
1	0.66	8.2	0.1712	0.177	21.94	22.91
2	0.712	9.6	0.1011	0.0903	13	15.51
3	0.525	6.6	0.3	0.30441	38.456	52.32
4	0.356	4.53	0.379	0.478	47.33	43.989
5	0.53	6.7	0.34	0.2	48.78	43.78

Table5: Analytical and FEA results

The FEA and analytical outcomes are listed in the table 5 and also the weight of the brake pedal is also given. This table helps in comparing different sections based on weight, stress and deflection. This will be the first data point for the subsequent analysis. Table 5 shows section 2 i.e. "I" section gives less deflection and maximum stiffness among various sections.

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Section	Weight ratio	Maximum deflection Ratio	Maximum Stress Ratio
1	1	1	1
2	1.07	0.52	0.55
3	0.79	1.71	1.69
4	0.53	2.7	2.08
5	0.8	1.12	2.2

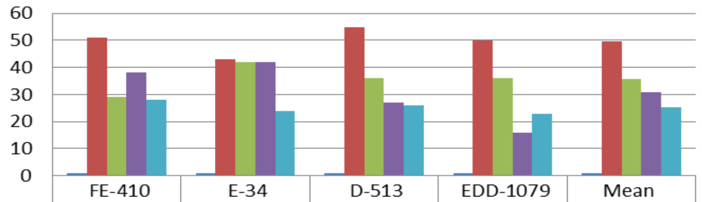
Table6: Minimum weight, maximum deflection, and stress

The result was performed using analytical and FEA analysis are shown in Table 5 and they are considered for concept evaluation method. Section1 is chosen as reference for relative weight, volume, maximum deflection, maximum stress are taken as reference parameters. The corresponding values for other concepts are calculated in comparison to section 1 as shown in Table 6 [6]

No	Criteria	Weight factor	Rating				Weight Factor Rating			
			S2	S3	S4	S5	S2	S3	S4	S5
1	Minimum Weight	3	5	3	2	4	15	9	6	12
2	Maximum Deflection	4	4	1	5	3	16	4	20	12
3	Maximum Stress	4	5	4	3	1	20	16	12	4
	Total						**51**	**29**	**38**	**28**

Table7: Matrix evolution

A matrix evaluation is performed to select the best concept among section2, section3, section4 and section5 based on the results in Table7. Lastly, decision matrix is evaluated by multiplying the each concept rating by weight factor assigned for each criterion. The weight factor is on the scale from 1 to 5. Total highest score 51section 2, thus -I-section selected as the best profile for design brake pedal profile.



	FE-410	E-34	D-513	EDD-1079	Mean
Section 1	1	1	1	1	1
Section 2	51	43	55	50	49.75
Section 3	29	42	36	36	35.72
Section 4	38	42	27	16	30.75
Section 5	28	24	26	23	25.25

Figure11: Matrix evolution of variable steel materials

Using above matrix evolution method applied of variable steel materials and selected best design of brake pedal lever arm profile,.Total highest score 49.75 section 2 shown in Fig11 .thus -I-section is selected as the best

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profile for design brake pedal. Since strength and material play a decisive role with regard to both the quality and cost of a car, selection of the correct materials and profile at the earliest possible stage of the Design is of vital importance.

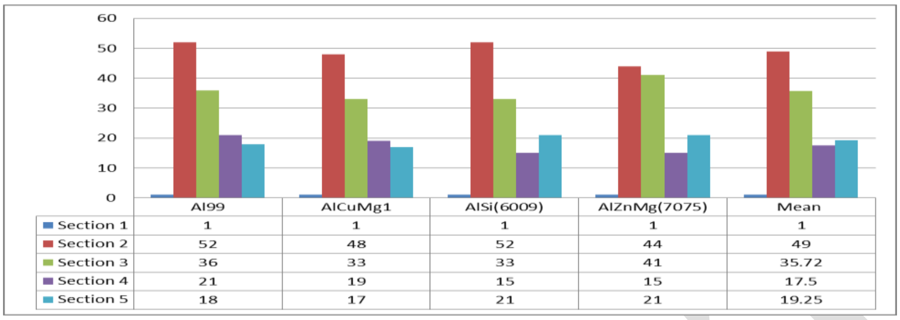

Figure12: Matrix evolution of variable aluminium materials

Similarly Using matrix evolution method applied of variable Aluminium materials and selected best design of brake pedal lever arm profile,.Total highest score 49 section 2 shown in Fig 12.thus -I-section is selected as the best profile for design brake pedal. Even the body structure such as closures and exterior attachments, chassis and suspension parts, presently I section profile is mostly used in cars,

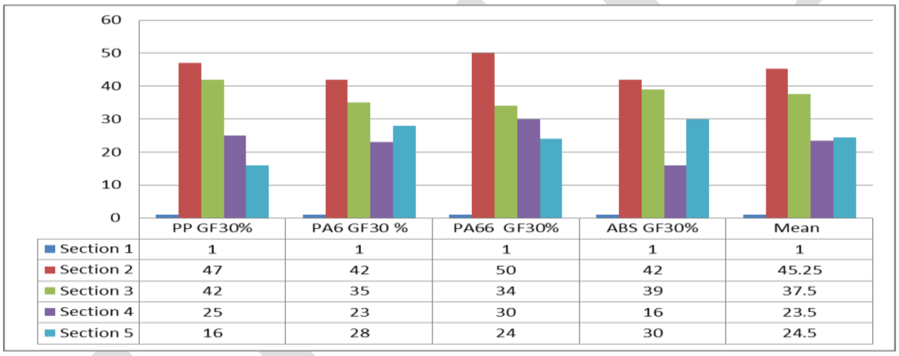

Figure13: Matrix evaluation variable composite materials

Similarly Using matrix evolution method applied of variable composite materials and selected best design of brake pedal lever arm profile,.Total highest score 45.25section 2 shown in Fig 13.thus -I-section is stiffer among all the sections under matrix evolution study that's I section best profile for design brake pedal,

V. RESULT AND DISCUSSION

Materials	Deformation "mm"	Weight in Kg	Section
Aluminium	0.08	0.63	I
Steel	0.08	0.71	I
Composite	0.08	0.59	I

Table8: Summary of result

1. A summary of results presented above.
   a. For a given load and boundary condition it is clear that I section provides more rigid compared to rest of the sections.
   b. For I section and same deflection composite material is 20% lighter in weight than steel and 7% lighter than aluminium.
   c. Aluminium is 13% lighter compared to steel.

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2. The FEA and analytical calculations are correlate to each other and the error is within 4% which shows the prediction models are accurate to compare different sections.
3. Aluminium is also a viable solution as a light weight material after composite.

VI.CONCLUSION

A complete approach is presented here to compare the 3 different materials against deflection, weight and stress. Also various sections are evaluated in order to arrive a most optimal section which is stiffer compared to other sections. The results clearly show that I section is most preferred to design brake pedal for automobile applications. Also the composite material is preferred material when compared against aluminium and steel in terms of weight. Going further a more detailed study on various materials on I section can be evaluated.

REFERENCES

[1] Cameron D .McMahon, Murray L.Scott "Innovative Technique for the finite element analysis and optimisation of composite structures" Institute of technology, Melbourne, Victoria 3001 Australia (2002)
[2] Dr Hossein saidpour "Light weight high performance material for car body structure" NTI Technology conference CEME, Ford Motors Company 16June2004
[3] Hansmann, J, and Bartezak, A, (1991).Clutch and brake pedal made of plastics. Kunststoffie German Plastics81:26-28
[4] Jurgen Hirsch "Aluminium in Innovative Light-Weight Car Design" Material Transactions, Vol. 52, No.5 (2011) pp. 818 to 824 Special Issue on Aluminium Alloys 2010 # 2011 the Japan Institute of Light Metals Hydro Aluminium Deutschland GmbH, R&D, P. O. Box 2468-53117 Bonn, Germany
[5] Katrina Szeteova "Automotive material plastic automotive markets today" Institute of production technologies machine technology and material faculty of material science and technology in Tranava Slovak University Of technology Bratislava
[6] Mohd Sapuan Salit, Mohd Syed Ali Molla "Conceptual design of an Automotive composite brake pedal"Aug 3, 2005 University Putra Malaysia Sedrang, Selangor Malaysia
[7] Pankaj Chhabra, Puneet Katyal and Vishal Gultai "Concurrent Design and Prototyping of Composite Accelerator Pedal" Mechanical Engg Department, GJ University of science and technology Hisar, Haryana India (octobor2011)
[8] S.m.sapuan "A Computer-Aided material selection for design of automotive safety critical Component with novel material" Department of Mechanical and Manufacturing Engineering University putra Malaysia (Malaysian Journal of Computer science December 1999)
[9] S.m.sapuan, S. S.S.Imihezri, S.Sulaiman, M.Hamdan and E.S.Zainudin "Comparison of Simulated and Actual Product of Polymeric Composite Automotive Clutch Pedal" Department of Mechanical and Manufacturing Engineering University putra Malaysia (International Journal Of Mechanical and Material Engineering (IJMME) 2007)
[10] S.m.sapuan "A Conceptual Design of the "Concurrent Engineering Design System for Polymeric-Based Composite Automotive Pedals" Department of Mechanical and Manufact ruing Engineering University putra Malaysia (American Journal of Applied Science 2005)
[11] Takeo SAKURAI "The Latest Trends in Aluminium Alloy Sheets for Automotive Body Panels" Material & Process Research Section, Aluminium Sheets & Coils Department Moka Plant, Aluminium & Copper Company