Design Optimization of Industrial and Automobile Clutches

Saddam Shakeel[1] Prof. Ranjeet Kumar[2] Dr. R.S. Sikarwar[3]
[1]M.Tech. Student [2]Faculty [3]Director
[1]Department of Machine Design [2]Department of Mechanical Engineering
[1,2,3]Vaishnavi Institute of Technology & Science, Bhopal (M.P.), India

Abstract— Clutches and the relevant systems are an important component in any automobile. Whenever any automobile is in moving condition, we need some system of power transmission. Clutches are employed for this vary role. Clutches may be of different types but for this current study, multiplate clutch used in Bajaj CT-100 bike has been considered. Conventionally structural steel (mild steel or low carbon steel) has been used for manufacturing the clutches but it is accompanied by a large weight which in turn increases the overall weight of vehicle. This increased weight increases the losses occurring in the vehicle during movement. It also reduces the thermal and mechanical efficiency. To counter these two problems, we must go for some other materials which can have lower weight & higher tensile strength, compressive strength etc. In this particular study six different materials have been tried & tested. These materials are Aluminium Alloy, High Strength Aluminium Alloy, Alumina, Cork, stainless steel, Kevlar and Asbestos. These materials have been analysed for weight, Equivalent Stress, Total Deformation, Maximum Principal Stress, Shear Stress, Maximum Shear Stress, Strain Energy, Equivalent Elastic Strain and Maximum Principal Elastic Strain. In the end a comparative analysis has been presented. In order to develop the model of disc brake rotor for conducting analytical solution in software, SOLIDWORKS-2019 software will be used to develop the model & ANSYS 19.2 will be used to analyze the model.

Keywords: SOLIDWORKS-2019, ANSYS 19.2, Clutches, Aluminium Alloy, Aluminium Alloy NL, Carbon Fibre, Carbon Epoxy UD, Carbon E-Glass Epoxy UD, Equivalent Stress, Weight

I. Introduction

A clutch is a mechanical device that engages and disengages power transmission, especially from a drive shaft (driving shaft) to a driven shaft. The clutch acts as a mechanical linkage between the engine and transmission; and briefly disconnects, or separates the engine from the drivetrain, and therefore the drive wheels, whenever the pedal is depressed, allowing the driver to smoothly change gears.

A composite material (also called a composition material or shortened to composite, which is the common name) is a material which is produced from two or more constituent materials. These constituent materials have notably dissimilar chemical or physical properties and are merged to create a material with properties unlike the individual elements. Within the finished structure, the individual elements remain separate and distinct, distinguishing composites from mixtures and solid solutions.

On the basis of gaps in literature following sections for current study have been specified-

- Design optimization of clutches through material variations.
- Design optimization of clutches through feature variations.
- Static structural analysis of clutches to be used in sports Bikes.
- Comparative analysis of the clutches for different materials.
- Suggestions for further future research in the field of clutches.

II. Problem Statement

This paper focuses on analyzing clutch and optimizing its design for determining a better material which can serve the purpose in a better way. For the current study purpose Bajaj CT-100 has been chosen and its multi plate clutch will be analysed for different materials in order to optimize its design.

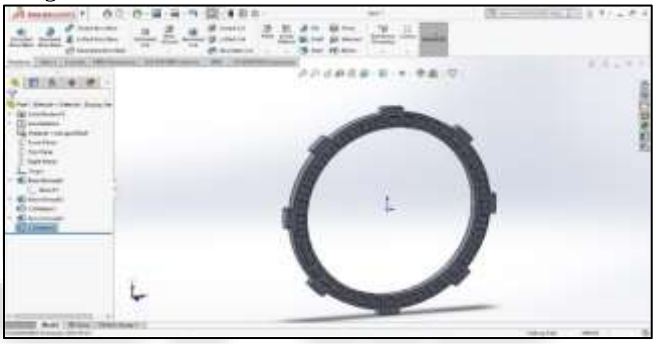

Fig. 1: Clutch plate modelled in Solidworks-2019

A. Performance Parameters

Different performance parameters will be analysed on the basis of which a comparative analysis would be performed in order to optimize the design of Multi plate clutch. Some of the performance parameters are as follows-

- Operating Pressure
- Axial Force
- Von-Mises Stress
- Total Deformation
- Stress Intensity
- Maximum Principal Stress

B. Materials to be analysed

Different types of conventional and non-conventional materials will be used to prepare the comparative analysis among materials and the primary objective will be to choose whether we can use any other material than the conventional material which is generally used for development of clutches in automobiles. Some of the materials are listed below-

- Cork
- Kevlar
- Asbestos
- Cast Iron
- Sintered Metal

– Alumina

III. ANSYS ANALYSIS OF CLUTCH PLATE

Modelling of the clutch has been conducted on Solidworks-2019. Step by step procedure for modelling of clutch is as discussed below-

- There are different procedures available for modelling of clutch namely top-down approach & bottom -up. Here we utilize bottom-up approach for the modelling of clutch-
- Create below cited sketch using the leaf spring data already calculated in the chapter of "Problem Statement". All the components (Only one component is there in this study) will be modelled separately according to bottom-up approach.
- After the modelling of all the components in Part Design workbench of Solidworks-2019, these will be assembled as and when needed.
- After designing the part, it will be exported to ANSYS for static structural analysis purpose.
- Now the materials to be used will be inserted

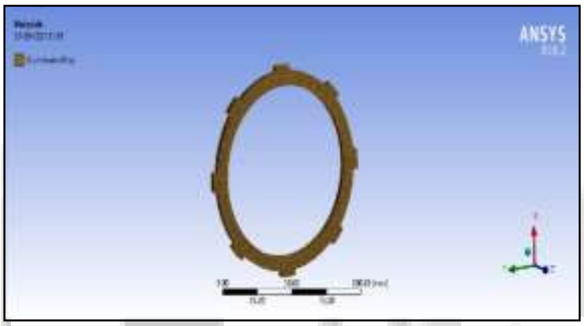

Fig. 2: Material Assignment on the part

- The part is to be meshed now with appropriate settings

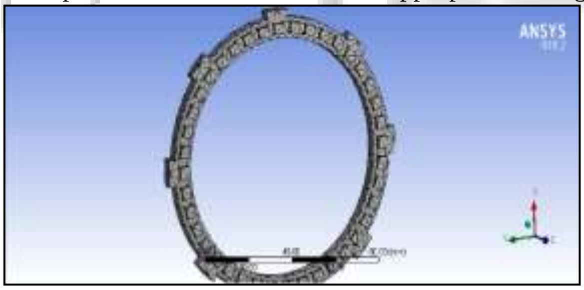

Fig. 3: Meshing of the material

- Boundary conditions will be applied now.

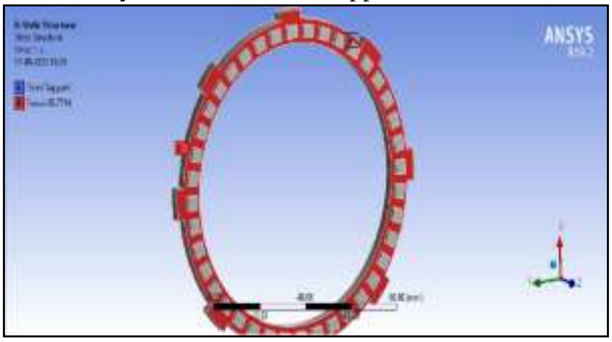

Fig. 4: Applying boundary conditions on the part

- Lastly the analysis is run and results are discussed.

In this analysis several process parameters have been evaluated for example Equivalent stress & total deformation. ANSYS simulation values of maximum Equivalent stress & maximum total deformation are found to be 0.029361 MPa & 7.3247 x 10-7 mm respectively.

Mathematically found maximum equivalent (von-mises) stress is 0.028 MPa. One can clearly observe that both these values are approximately similar hence we can say that ANSYS simulation is validated along with mathematically calculated data.

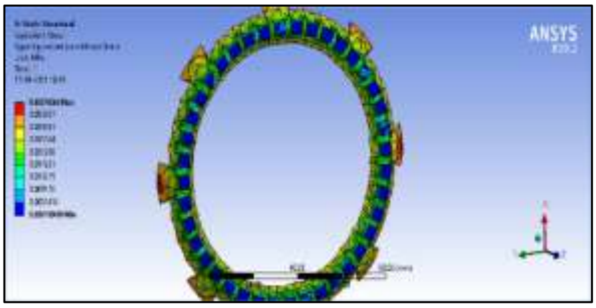

Fig. 5: Equivalent Stress distribution for structural steel

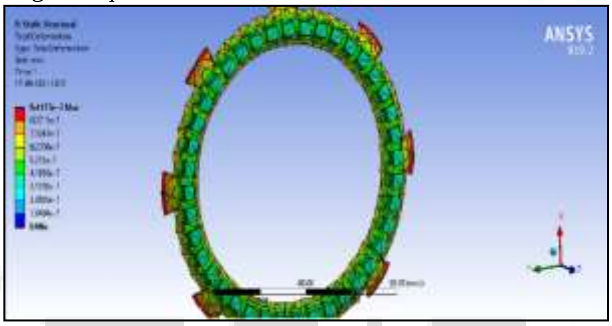

Fig. 6: Total Deformation for structural steel

After validating the model, it is analysed for different materials.

The result set for all the materials is being represented here.

S. No.	Material	Parameter	Parameter Value
01	Asbestos	Equivalent Stress	0.028427 MPa
02		Total Deformation	0.00084646 mm
03		Maximum Principal Stress	0.010035 MPa
04		Shear Stress	0.00349236 MPa
05		Maximum Shear Stress	0.015538 MPa
06		Strain Energy	4.0557×10^{-8} mJ
07		Equivalent Elastic Strain	1.4803×10^{-7} mm/mm
08		Maximum Principal Elastic Strain	6.9617×10^{-8} mm/mm
09		Weight	0.0247 Kg
10	Aluminium Alloy	Equivalent Stress	0.029723 MPa
11		Total Deformation	2.0948×10^{-6} mm
12		Maximum Principal Stress	0.010171 MPa

13		Shear Stress	0.0038215 MPa
14		Maximum Shear Stress	0.015795 MPa
15		Strain Energy	1.134×10^{-7} mJ
16		Equivalent Elastic Strain	4.2227×10^{-7} mm/mm
17		Maximum Principal Elastic Strain	2.0523×10^{-7} mm/mm
18		Weight	0.0427 Kg
19	Alumina	Equivalent Stress	0.028742 MPa
20		Total Deformation	4.3022×10^{-7} mm
21		Maximum Principal Stress	0.010123 MPa
22		Shear Stress	0.0028145 MPa
23		Maximum Shear Stress	0.015046 MPa
24		Strain Energy	2.4874×10^{-8} mJ
25		Equivalent Elastic Strain	8.7712×10^{-8} mm/mm
26		Maximum Principal Elastic Strain	3.9224×10^{-8} mm/mm
27		Weight	0.0571 Kg
28	Cork	Equivalent Stress	0.028853 MPa
29		Total Deformation	0.0044637 mm
30		Maximum Principal Stress	0.010149 MPa
31		Shear Stress	0.0029457 MPa
32		Maximum Shear Stress	0.015143 MPa
33		Strain Energy	0.00025601 mJ
34		Equivalent Elastic Strain	0.00090828 mm/mm
35		Maximum Principal Elastic Strain	0.00041092 mm/mm
36		Weight	0.00277 Kg
37	Kevlar	Equivalent Stress	0.030166 MPa
38		Total Deformation	0.0025595 mm
39		Maximum Principal Stress	0.01003 MPa
40		Shear Stress	0.0041523 MPa
41		Maximum Shear Stress	0.016094 MPa
42		Strain Energy	0.00013533mJ
43		Equivalent Elastic Strain	0.00051572 mm/mm
44		Maximum Principal Elastic Strain	0.00027174 mm/mm
45		Weight	0.0222 Kg
46	High Strength Aluminium Alloy	Equivalent Stress	0.029818 MPa
47		Total Deformation	2.0225×10^{-6} mm
48		Maximum Principal Stress	0.010147 MPa
49		Shear Stress	0.0038985 MPa
50		Maximum Shear Stress	0.015859 MPa
51		Strain Energy	1.089×10^{-7} mJ
52		Equivalent Elastic Strain	4.0757×10^{-7} mm/mm
53		Maximum Principal Elastic Strain	2.0199×10^{-7} mm/mm
54		Weight	0.0427 Kg

Table I: Result Analysis for Different Materials

IV. RESULT ANALYSIS

Weights for all the materials have been already listed in the table in previous section. Weight comparison among all the materials shows that when we use conventional structural steel, mass of the clutch is 0.121 Kg & as soon as we move to aluminium alloys & other materials, there is a drastic reduction in the mass of the clutch. If we are focused on weight criteria then we can easily identify from the graph that using all the other materials we can easily lower the total weight of system & thus we can reduce the overall losses but we need to inspect other data also before jumping into any kind of conclusion. The data is represented in form of a graph as follows-

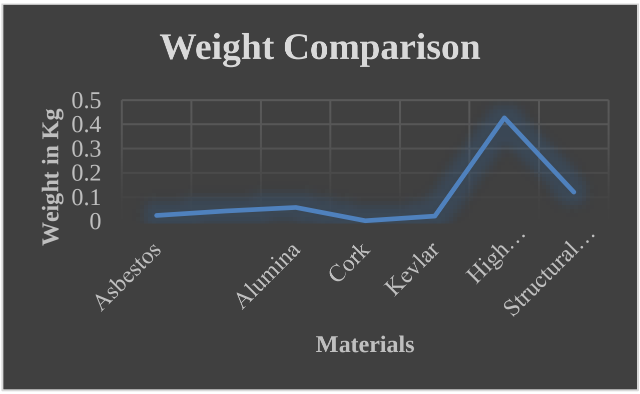

Fig. 7: Weight Comparison among materials

Equivalent (von-mises) stress for all the materials have been already listed in the table in previous chapter. The data is represented in form of a graph as follows-

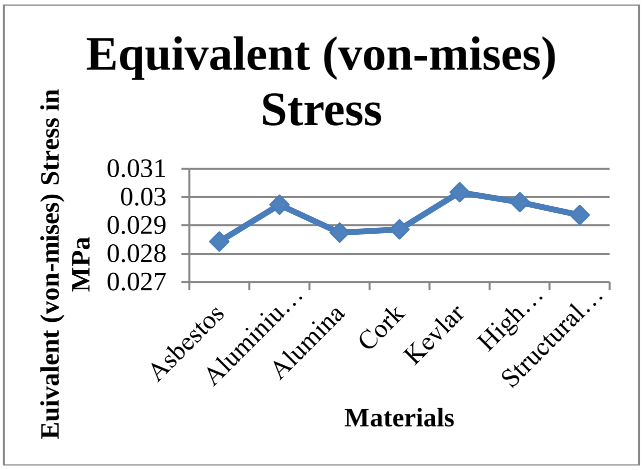

Fig. 8: Equivalent Stress Comparison among Materials

Equivalent (von-mises) stress distribution after applying given inputs for all the materials has been plotted in above cited graph which clearly indicates that as we move towards materials other than structural steel, the equivalent (von-mises) stress value suddenly decreases for Asbestos, Alumina and Cork but increases for Aluminium Alloy, Kevlar and High Strength Aluminium Alloy. Hence according to this criterion, Asbestos, Alumina and cork will produce better results. We can also see that although other newer materials are showing larger values of equivalent stress but when numerical values of equivalent stress for these materials are observed, these are quite similar to the equivalent stress of structural steel.

Total deformation for all the materials has been already listed in the table in previous chapter. The data is represented in form of a graph as drawn below. Total deformation distribution after applying given inputs for all the materials has been plotted in above cited graph which clearly indicates that for alumina, the total deformation is the least of all the materials being used for the analysis. Hence according to this criterion alumina is the best possible solution for the current problem.

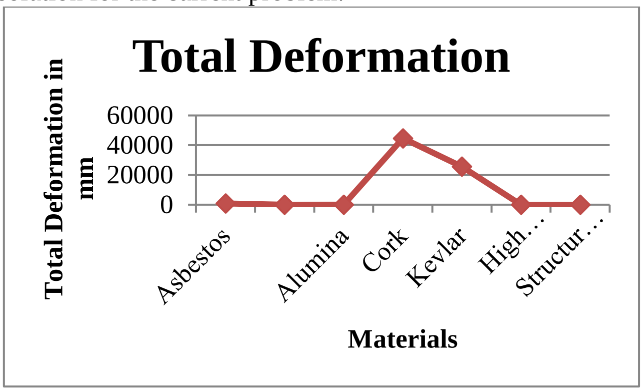

Fig. 9: Total Deformation Comparison among Materials

Maximum principal stress for all the materials have been already listed in the table in previous chapter. The data is represented in form of a graph as follows-

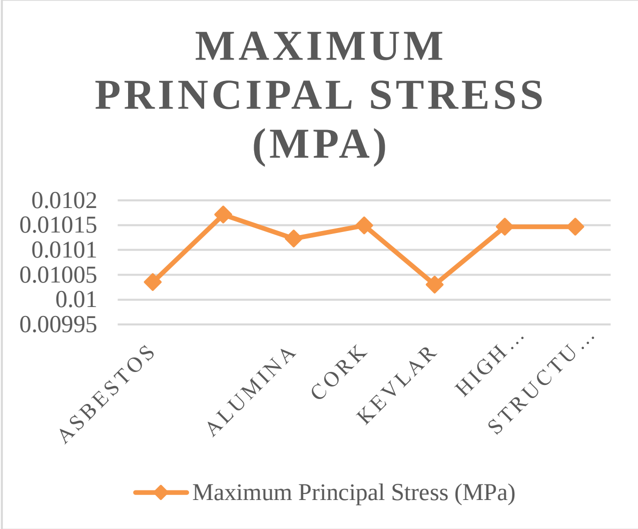

Fig. 10: Maximum Principal Stress Comparison

Maximum principal stress distribution after applying given inputs for all the materials has been plotted in above cited graph which clearly indicates that as we move towards composite materials, the maximum principal stress value remain approximately similar for all the materials with Kevlar showing the least maximum principal stress among all the materials.

Shear Stress for all the materials have been already listed in the table in previous chapter. The data is represented in form of a graph. Shear stress distribution after applying given inputs for all the materials has been plotted in below cited graph which clearly indicates that for all the materials except Kevlar, the value of shear stress is decreasing and hence all the other materials can be effectively used according to this criterion. Although Kevlar is having more shear stress than all the other materials but numerical value is very much less and hence Kevlar can also be used for clutch.

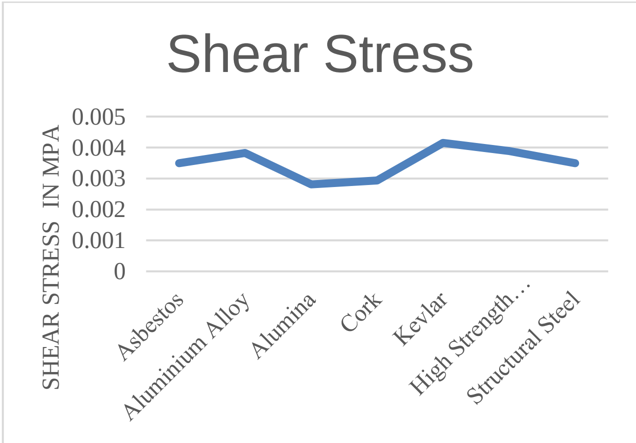

Fig. 11: Shear Stress Comparison among Materials

Maximum Shear Stress for all the materials have been already listed in the table in previous chapter. The data is represented in form of a graph. Shear stress distribution after applying given inputs for all the materials has been plotted in below cited graph which clearly indicates that for all the materials except Kevlar, the value of shear stress is decreasing and hence all the other materials can be effectively used according to this criterion. Although Kevlar is having more shear stress than all the other materials but numerical value is very much less and hence Kevlar can also be used for clutch.

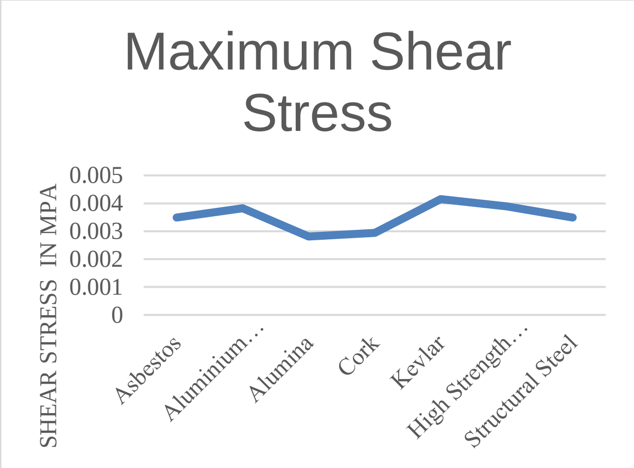

Fig. 12: Maximum Shear Stress Comparison among Materials

V. CONCLUSIONS

Primary objective of this dissertation was to optimize the material for the clutch of an automobile engine & conducting a comparative analysis among different kinds of materials which may be used for this particular application. In order to optimize any material all, the process parameters were thoroughly analysed and verified from previously available concepts. Hence each & every process parameter needed to be analysed separately. After conducting this rigorous analysis for optimizing the material for disc brake rotor and looking at the result pattern it is concluded that-

When one talks about equivalent stress generated on any material, it is desired that equivalent (von-mises) stress developed in any material during any given application must be less. Equivalent (von-mises) stress developed in this study when Alumina and Cork are used, is less than Structural Steel. Hence Alumina and Cork will be more beneficial to use. This concept will also hold good for maximum principal stress & Shear stress too.

When one talks about weight of the given component in rotation, it is desired that weight must be as less as possible because it will reduce losses, rotational inertia will be lesser & it will become easier to decelerate the component as & when required. It means that brake efficiency will be improved. One can clearly observe through the weight comparison section of last chapter that Asbestos, Alumina and Cork are more beneficial to use for the material of Clutch.

Looking at both the above results one can clearly conclude this work by proposing Alumina and cork as the best suitable material for this particular application.

REFERENCES

[1] Abhishek Borse, Ajinkya Deshmukh. Automatic Gear Transmission System. International Journal of Advanced Technology in Engineering and Science. Vol-04, Issue-02, Feb.-2016, 104-110.

[2] Amir Hussain Idrisi, Gaurang Deep, Vijay Sharma. Design and Analysis for Developing an Efficient Centrifugal Clutch Used in Automobile to Minimize the Deteriorating Effects. International Journal of Innovative Research in Science, Engineering and Technology, Vol. 5, Issue 9, September 2016, 16726-16733.

[3] Antonio Della Gatta, Luigi Iannelli, Mario Pisaturo, Adolfo Senatore, Francesco Vasca. A survey on modeling and engagement control for automotive dry clutch. Mechatronics 55 (2018) 63-75, https://doi.org/10.1016/j.mechatronics.2018.08.002

[4] C.M. Meenakshi, G. Kumar. Design and Fabrication of Automatic Electromagnetic Clutch. Volume 116 No. 19 2017, 487-490.

[5] Dr. Porag Kalita. Experimental Study on Automobile Clutch Plate Juddering. Experimental Study on Automobile Clutch Plate Juddering. Volume 3, Issue 1, January-2016, pp. 36-41 ISSN (O): 2349-7084.

[6] Gowtham Modepalli. Clutch Assembly Modeling and Dynamic Analysis. International Journal of Mechanical and Production Engineering, ISSN: 2320-2092, Volume-3, Issue-11, Nov.-2015, 102-107.

[7] Hailemariam N. Hailu, Daniel T. Redda. Design and Development of Power Transmission System for Green and Light Weight Vehicles: A Review. The Open Mechanical Engineering Journal, 2018, 12, 81-94, http://dx.doi.org/10.2174/1874155X01812010081

[8] J. Ando, H. Ando, T. Tsuda, K. Suzuki, Y. Niikawa. Development of Third-Generation Electronically Controlled AWD Coupling with New High-Performance Electromagnetic Clutch. JTEKT Engineering Journal English Edition No. 1011E (2014), 19-24.

[9] Kunal Saurabh, Mohammad Yusuf Khan, Inzamam Ali, Ayush Gupta. Fabrication of Electromagnetic Clutches & Braking System. ELK Asia Pacific Journals – 978-93-85537-06-6 ARIMPIE -2017.

[10] Mahendra Sahu, A.K. Jain. Design and structural analysis of single plate clutch by FEA: a review. 2018 IJRTI, International Journal for Research Trends and Innovation, Volume 3, Issue 6, 121-123.

[11] Mr. Amol A. Parihar, Mr. Amit C. Gunge, Mr. Udhav M. Parbhane. Dual Clutch Transmission of Automobile. International Journal of Modern Engineering Research (IJMER), Vol. 6, Iss. 11, November 2016, 1-7

[12] Mr. K. Venkatesh, Kandlagunta Saikumar Reddy. Design and Analysis of Combined Accelerator and Clutch Pedal in Accelerator Pedal. International Research Journal of Engineering and Technology (IRJET), Volume: 06 Issue: 12, Dec 2019, 1691-1694

[13] Nishant Dhengre, Ashish Mogra, Ankit Gupta. Investigating Behaviour of Multi-Clutch Plate Frictional Materials using ANSYS. International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 16 (2018) pp. 12657-12662.

[14] Pankaj, Dr. S.S. Banwait. Analysis of Clutch Housing and Gear Box Housing of 65 Hp Tractor. International Journal of Emerging Technologies in Engineering Research (IJETER), Volume 5, Issue 11, November (2017)

[15] Pappuri Hazarathaiah, Y. Ashok Kumar Reddy. Design and Analysis of Clutch Plate Using Steel Material. International Journal for Research in Engineering Application & Management (IJREAM), ISSN: 2454-9150 Vol-04, Issue-11, Feb 2019. 362-366

[16] Peng Han, Xiusheng Cheng, Hu Li, Lichen Yang, Wei Feng. Study on Intelligent Starting Control of Dual Clutch Transmission. 978-1-4799-2827-9/13/$31.00 ©2013 IEEE.
[17] Pranav R. Morchapure, Dr K. S. Zakiuddin, Nitin S. Sawarkar. Comparative Study on Flexible Type of Clutches. International Journal of Innovations in Engineering and Science, Vol 5, No.9, 2020, www.ijies.net, DOI: 10.46335/IJIES.2020.5.9.7
[18] Prof. Jignesh J. Patel, Mr. Kaushal R. Ajmera, Mr. Raghav K. Thanki, Mr. Rohit B. Maitar. Design and Theoretical Analysis of Single Plate Clutch by Varying Friction Lining Materials. International Journal of Advance Engineering and Research Development, Volume 2, Issue 11, November -2015, 68-72
[19] Pulavarthi Krishram Raju, P. Siva Subramanyam, K. N. D. Malleswara Rao. Optimal Design and Analysis of Multi Friction Plates Using Creo and FEA Package. J. Technological Advances and Scientific Res./ eISSN-2454-1788, pISSN- 2395-5600/ Vol. 1/ Issue 04/ Oct-Dec. 2015, 366-372
[20] S Murali et al 2017 IOP Conf. Ser.: Mater. Sci. Eng. 183 012019, doi:10.1088/1757-899X/183/1/012019
[21] S. Yuvaraja, G. Arunkumar, B. Venu Sai, P. Rajan. V. Dhinakaran. Design and Development of a Compliant Clutch Fork using Topology Optimization. International Journal of Innovative Technology and Exploring Engineering (IJITEE), ISSN: 2278-3075, Volume-8 Issue-11, September 2019.
[22] Sagar Chaudhari, Vaibhav Bansode. Development of Dual Clutch Transmission System by Considering Various Working Parameters. International Conference on Ideas, Impact and Innovation in Mechanical Engineering (ICIIIME 2017), ISSN: 2321-8169, Volume: 5, Issue: 6, 219 – 221
[23] Sandeep Badlani, Prof. Roopesh Tiwari. Wear Analysis of Clutch Material. International Journal of Engineering Sciences & Research Technology, July- 2015, 4 (7), 317-320.
[24] Seyed Reza Aghazadeh, Mehdi Miri and Hossein Shirmohammadi. An ergonomic evaluation of clutch pedal in a few models of common cars within taxi service lines in Tehran. Global Journal of Scientific Researches, Available online at gjsr.blue-ap.org, Vol. 5(4), pp. 82-89, 30 July, 2017 E-ISSN: 2311-732X.
[25] Shiv Pratap Singh Yadav, Sandeep G M, Aditya Kedilaya, Arjun B Curam, C V Srihari Raghavan, Kalyan Chilakamarri. A Review on Single Plate Clutch. International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, IJERTV6IS040587, www.ijert.org, Vol. 6, Issue 04, April-2017, 697-700.
[26] Shivendra Kumar Dubey. Analysis of an Electromagnetic Clutch. International Journal of Science and Research (IJSR), Volume 8 Issue 1, January 2019, 71-73
[27] Sunny Narayan, Ivan Grujic, Nadica Stojanovic, Kaisan Muhammad Usman, Abubakar Shitu, Faisal O. Mahroogi. Design and Analysis of An Automotive Single Plate Clutch. Mobility & Vehicle Mechanics, DOI: 10.24874/mvm.2018.44.01.02
[28] Suraj S Raut, D.P. Mali. Automatic Transmission Gearbox with Centrifugal Clutches. IJRET: International Journal of Research in Engineering and Technology, Volume: 03 Issue: 10, Oct-2014, 307-309
[29] U. M. Saravanan, T. Karthik, K. Hariprasath, M. Ajithmugi. Design and Fabrication of Electromagnetic Clutch. International Journal for Scientific Research & Development, Vol. 6, Issue 03, 2018, 854-855
[30] Yunjiang Cheng, Peng Dong, Shuai Yang, Xiangyang Xu. Virtual Clutch Controller for Clutch-to-Clutch Shifts in Planetary-Type Automatic Transmission. Hindawi Publishing Corporation Mathematical Problems in Engineering, Volume 2015, Article ID 213162, 16 pages http://dx.doi.org/10.1155/2015/213162
[31] Zongxuan Sun and Kumar Hebbale. Challenges and Opportunities in Automotive Transmission Control. 2005 American Control Conference, June 8-10, 2005. Portland, OR, USA, 3284-3289.

