MODELLING & ANALYSIS OF GEAR BOX

Santosh Kulkarni[1], A. Shirisha[2],Anil Kumar Korra[3] , P. Swarna Sree[4]

[1]Assistant Professor, Department of Mechanical Engineering, CMR College of Engineering & Technology, Hyderabad, India.

[2,3,4]Student, Department of Mechanical Engineering, CMR College of Engineering & Technology, Hyderabad, India

Abstract

By applying the optimum design in the field of gear transmission design it ispossibletodefinetheoptimalrelationsbetweentheparametersofthecompletegeartransmission, and of each transmission stage separately. This paper presents a one criterionprocedure for gear transmission optimization and multi criterion optimization procedure foreachtransmissionstage.Secondpartofthepaperisfocusedonmodellingofcylindricalgearsthatarecommonusedmachineelementsandmainpartsofgeartransmissions.ThesemodelsaremadeusingpartandassemblydesignmoduleinCATIAV5software.Ontheendofpapersomeapplicationsofmodelsinfiniteelementsanalysisandoptimizationarealsodescribed.

Keywords:Gearbox,Catia,Ansys,ThermalAnalysis,HeatFlux.

1. INTRODUCTION

A machine consists of a power source and a power transmission system, whichprovides controlled application of the power. Merriam-Webster defines transmission as anassembly of parts including the speed-changing gears and the propeller shaft by which thepoweristransmittedfromanengine toaliveaxle. Often **transmission** referssimplytothe **gearbox** that uses gears and geartrains toprovide speed and torque conversionsfrom arotatingpower sourceto another device.In British English, the term transmission refers to the whole drive train, includingclutch,gearbox, propshaft (for rear-wheel drive),differential,and final drive shafts. InAmericanEnglish,however,thedistinctionismadethatagearboxisanydevicewhich convertsspeed and torque, whereas a transmission is a type of gearbox that can be "shifted"todynamicallychangethespeed-torqueratiosuch asinavehicle.The most common use is in motor vehicles, where the transmission adapts the outputof the internal combustion engine to the drive wheels. Such engines need to operate at arelativelyhighrotationalspeed,whichisinappropriateforstarting,stopping,andslo wertravel.Thetransmissionreducesthehigherenginespeedtotheslowerwheel speed,increasing torque intheprocess.Transmissionsarealsoused onpedalbicycles,fixedmachines,andanywhereelsewhererotationalspeedandtorqueneedstobeadapted.Often, a transmission will have multiple gear ratios (or simply “gears”), with the ability toswitchbetweenthemasspeedvaries.Thisswitchingmaybedonemanually(bytheoperator),or automatically. Directional (forward and reverse) control may also be provided. Single-ratiotransmissions also exist, which simply change the speed and torque (and sometimes direction)ofmotor output.Inmotorvehicles,thetransmission willgenerallybeconnectedtothecrankshaftoftheengine.Theoutputofthetransmissionistransmittedviadriveshaft tooneormore differentials,whichinturn,drivethewheels.Whileadifferentialmayalsoprovidegear reduction,itsPrimarypurposeistopermitthewheelsateitherendofanaxletorotateatdifferentspeeds(essentialtoavoidwheelslippageonturns)as itchanges thedirectionof rotation.

Figure:1 Slidingmesh gears

Early transmissions included the right-angle drives and other gearingin windmills,horse-powereddevices,and steamengines,insupportof pumping, milling,andhoisting.Mostmoderngearboxesareusedtoincreasetorque whilereducingthespeedofaprimemoveroutputshaft(e.g.amotorcrankshaft).Thismeansthattheoutputshaftofagearboxwillrotateat a slower rate than the input shaft, and this reduction in speed will produce a mechanicaladvantage, causing an increase in torque. A gearbox can be set up to do the opposite andprovide an increase in shaft speed with a reduction of torque. Some of the simplest gearboxesmerelychangethephysicaldirectionin whichpoweris transmitted.Many typical automobile transmissions include the ability to select one of severaldifferentgearratios.Inthiscase,mostofthegearratios(oftensimplycalled"gea rs")areusedto slow down the output speed of the engine and increase torque. However, the highest gearsmaybe"overdrive"typesthatincreasetheoutputspeed.The simplest transmissions, often called gearboxes to reflect their simplicity (althoughcomplexsystemsarealsocalled gearboxesinthevernacular),providegearreduction(or,morerarely, an increase in speed), sometimes in conjunction with a right-angle change in directionof the shaft (typically in helicopters, see picture). These are often used on PTO-poweredagricultural equipment, since the axial PTO shaft is at odds with the usual need for the drivenshaft,whichiseithervertical(aswith rotarymowers),orhorizontallyextendingfromonesideof the implement to another (as with manure spreaders, flail mowers, and forage wagons).Morecomplexequipment,suchassilagechoppersandsnowblowers,havedrivenwithoutputsinmorethan onedirection.The gearbox in a wind turbine converts the slow, high-torque rotation of the turbineintomuchfasterrotationofthe electricalgenerator.Thesearemuchlarger andmorecomplicatedthanthePTOgearboxesinfarmequipment.Theyweighseveraltonsandtypicallycontainthreestagestoachieveanoverallgearratiofrom40:1toover100:1,dependingonthesize of the turbine. (For aerodynamic and structural reasons, larger turbines have to turn moreslowly, but the generators all have to rotate at similar speeds of several thousand rpm.) Thefirst stage of the gearbox is usually a planetary gear, for compactness, and to distribute theenormous torque of the turbine over more teeth of the low-speed shaft. Durability of thesegearboxes hasbeen aserious problemforalong time.Regardless of where they are used, these simple transmissions all share an importantfeature: the gear ratio cannot be changed during use. It is fixed at the time the transmission isconstructed.

1. PROBLEMFORMULATION

Early transmissions included the right-angle drives and other gearing in windmills, horse-powereddevices,andsteamengines,insupportofpumping,milling,andhoisting.Mostmoderngearboxesareusedtoincreasetorquewhilereducingthespeedofaprime mover output shaft (e.g. a motor crankshaft). This means that the output shaft of agearbox will rotate at a slower rate than the input shaft, and this reduction in speed willproduce a mechanical advantage, causing an increase in torque. A gearbox can be set up todo the opposite and provide an increase in shaft speed with a reduction of torque. Some ofthesimplestgearboxesmerelychangethephysicaldirectioninwhichpoweristransmitted.Many typical automobile transmissions include the ability to select one of several differentgearratios.Inthiscase,mostofthe gearratios(oftensimplycalled"gears")are usedtoslowdown the output speed of the engine and increase torque. However, the highest gears maybe"overdrive"typesthatincreasetheoutputspeed.The aim of our project is to maintain the gearbox for long time with less maintenance costand we are going change the material as cast-iron, steel this material is using present butthis material is not suitable for long time due to the heat transform from the gearbox wherepowertransmissioningearboxismajorroletorunthevehiclesbecauseofthisheat producesfromthegearspowertransmissioneffectingthegearboxsowearechangingthematerialasgreycastironismoresuitable for longtimeand itcansuction theheatfromthegears.

2. OBJECTIVES

Theobjectivesofthegearboxofthegivenmaterialarethe:

- Highstiffness
- Machinability
- Vibrationdampening
- Highheatcapacity
- Highthermalconductivity
- Thelosses(correspondingtomaximizationofefficiency)
- Theoverallcosts.

3. METHODOLOGY

The introduced Modelling and analysis of Gearbox consists of a closed loop of gearbox designparameters selection and subsequent gearbox analysis. The gearbox design parameters fully definea specific gearbox var-ant. These parameters are set by a stochastic differential-evolutionalgorithm.

Therefore, there is no explicit strategy on how to deal with the interactions of theindividual gearbox components. This is contrary to conventional, manual design guidelines, whichrecommend a certain (usually recursive) sequence of macroscopic layout and subsequent detailedcomponent design.Suchexplicit,sequentialdesignstrategiesmayleadtosub-optimal results,since the variety of design options is strongly reduced. Instead, when using the optimizationapproach, the feasibility of given design parameters is checked by the gearbox analysis model and,if positive, their impact on the objectives is evaluated. The set of feasible solutions is comparedregarding the multiple objectives in form of a Pareto-front, to show the trade offs from which thedecision-makers can choose the best suit-able solution. So, in multi-objective optimization, there isno need to explicitly balance optimization targets in form of weighting factors.The objectives foroptimizationareminimizationofthelos sescorrespondingtomaximizationof efficiency.

4. FLOWDIAGRAM

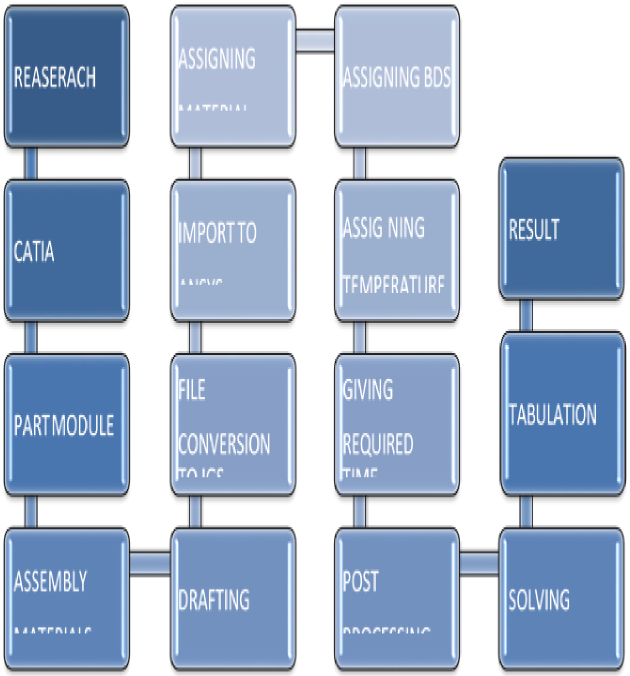


Figure:2 Flow diagram

5. MATERIALDETAILS

Thematerialsusedfortheprojectarethreematerials.Withthesethreematerialsonly,the projectwillberunning.Thematerials aregreycastiron,Stainless steel,Aluminumalloy.

Greycastiron:

Greyiron,orGreycastiron,isatypeofcastironthathasagraphiticmicrostructure.Itisnamedafterthegraycolorofthefractureitforms,whichisduetothepresenceofgraphite. Itisthemostcommoncastironandthemost widelyusedcastmaterialbased on weight. It is used for housings where the stiffness of the component is moreimportantthanitstensilestrength,suchasinternalcombustionenginecylinderblocks,pumphousings, valve bodies, electrical boxes, and decorative castings. Grey cast iron's highthermal conductivityand specific heat capacity are often exploited tomake cast ironcookware and disc brake rotors. Its former widespread use on brakes in freight trains hasbeen greatly reduced in the European Union over concerns regarding noise pollution.DeutscheBahnforexamplehadreplacedgreyironbrakeson53,000ofitsfreightcars(85%of their fleet) with newer, quieter models by 2019 in part to comply with a law that cameintoforcein December2020.Grey cast iron is characterized by its graphitic microstructure, which causesfractures of the material to have a grey appearance. It is the most commonly used cast ironand the most widely used cast material based on weight. Most cast irons have a chemicalcomposition of 2.5–4.0% carbon, 1–3% silicon, and the remainder iron. Grey cast iron hasless tensilestrength and shockresistance thansteel,butits compressivestrength iscomparable to low- and medium-carbon steel. These mechanical properties are controlledby the size and shape of the graphite flakes present in the microstructure and can becharacterizedaccordingto theguidelines given bytheASTM.

Stainlesssteel:

Stainlesssteelisanalloyofironthatisresistanttorustingandcorrosion.Itcontainsatleast11% chromium and may contain elements such as carbon, other non-metals and metals toobtain other desired properties. Stainless steel's resistance to corrosion results from thechromium, which forms a passive film that can protect the material and self-heal in thepresence of oxygen. The alloy's properties, such as luster and resistance to corrosion, areuseful in many applications. Stainless steel can be rolled into sheets, plates, bars, wire, andtubing. These can be used in cookware, cutlery, surgical instruments, major appliances,vehicles,constructionmateria linlargebuildings,industrialequipment(e.g.,inpapermills,chemical plants, water treatment), and storage tanks and tankers for chemicals and foodproducts.

Aluminumalloy:

An aluminum alloy (or aluminum alloy; see spelling differences) is an alloy in whichaluminum (Al) is the predominant metal. The typical alloying, elements, are copper,magnesium,manganese,silicon,tin,nickellandzinc.Therearetwoprincipalclassifications,namely casting alloys and wrought alloys, both of which are further subdivided into thecategories heat-treatable and non-heat-treatable. About 85% of aluminumis used forwrought products, for example rolled plate, foils and extrusions. Cast aluminum alloysyield cost-effective products due to the low melting point, although they generally havelower tensile strengths than wrought alloys. The most important cast aluminum alloysystem is Al–Si, where the high levels of silicon (4–13%) contribute to give good castingcharacteristics.Aluminumalloysarewidelyusedinengineeringstructuresand components wherelightweightorcorrosionresistanceisrequired.Alloyscomposedmostlyofaluminum have been very important in aerospace manufacturing since the introduction ofmetal-skinnedaircraft.Aluminum–magnesiumalloysarebothlighterthanotheraluminumalloys and much less flammable than other alloys that contain a very high percentage ofmagnesium.Aluminum alloy surfaces will develop a white, protective layer of aluminum oxide if leftunprotected by anodizing and/or correct painting procedures. In a wetenvironment, galvanic corrosion can occur when an aluminum alloy is placed in electricalcontact with other metals with more positive corrosion potentials than aluminum, and anelectrolyteispresentthatallowsionexchange.Alsoreferredtoasdissimilar-metalcorrosion, this process can occur as exfoliation or as intergranular corrosion. Aluminumalloys can be improperly heat treated, causing internal element separation which corrodesthemetalfromtheinsideout.Aluminumalloycompositionsareregisteredwith TheAluminumAssociation.Manyorganizations publish more specific standards for the manufacture of aluminum alloy,includingthe SocietyofAutomotiveEngineers standardsorganization,specificallyitsaerospacestandardssubgroups,and ASTM International.

6. EXPERIMENTATION

Incatiadesignwewilldesignthemultispeed

gearboxwiththeexpecteddimensionsofthegearbox.

CatiaDesign ofgearbox:

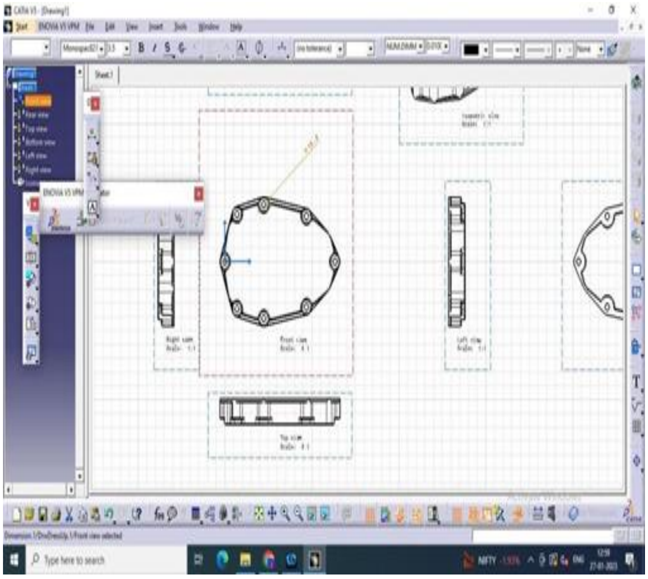


Figure:3 Catia designItshowsthegearboxdesigninCatia

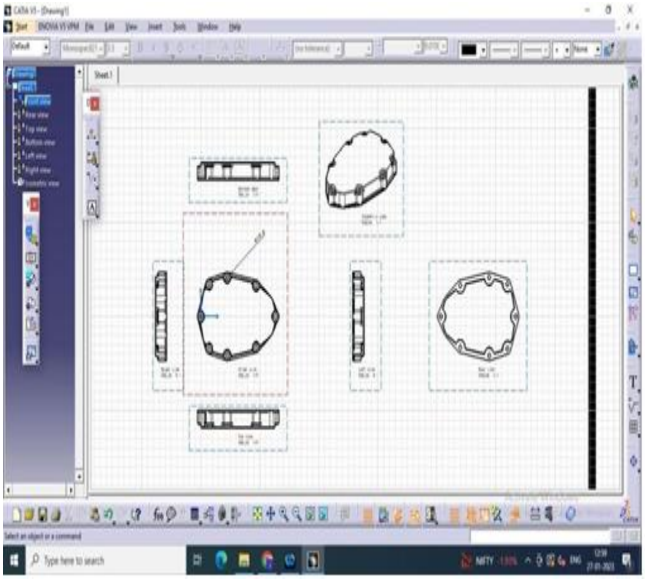
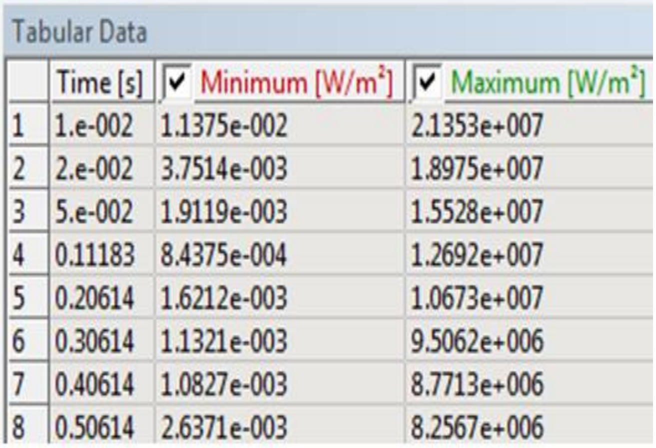


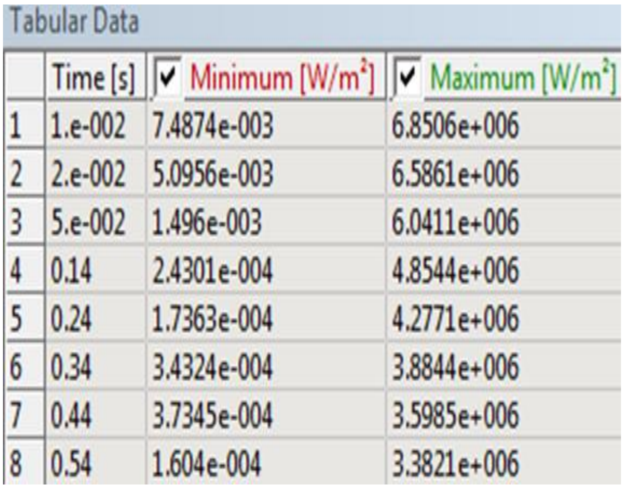
Figure:4 Catiadesignof gearboxItshowsthedimensionsofthegearboxincatia.



Tabular Data

	Time [s]	☑ Minimum [W/m^2]	☑ Maximum [W/m^2]
1	1.e-002	1.1375e-002	2.1353e+007
2	2.e-002	3.7514e-003	1.8975e+007
3	5.e-002	1.9119e-003	1.5528e+007
4	0.11183	8.4375e-004	1.2692e+007
5	0.20614	1.6212e-003	1.0673e+007
6	0.30614	1.1321e-003	9.5062e+006
7	0.40614	1.0827e-003	8.7713e+006
8	0.50614	2.6371e-003	8.2567e+006

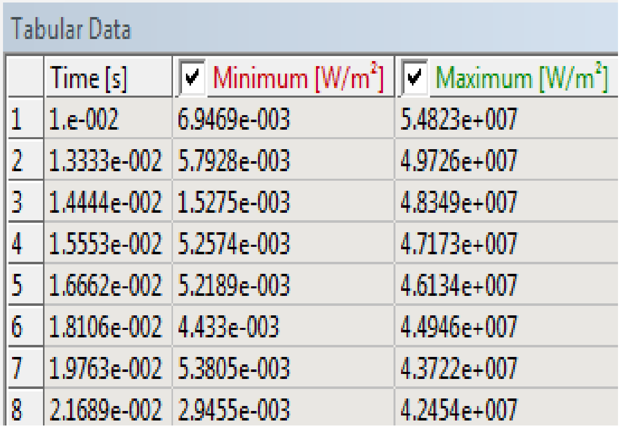
Figure: 5 GreyCast Iron Table



Tabular Data

	Time [s]	☑ Minimum [W/m^2]	☑ Maximum [W/m^2]
1	1.e-002	7.4874e-003	6.8506e+006
2	2.e-002	5.0956e-003	6.5861e+006
3	5.e-002	1.496e-003	6.0411e+006
4	0.14	2.4301e-004	4.8544e+006
5	0.24	1.7363e-004	4.2771e+006
6	0.34	3.4324e-004	3.8844e+006
7	0.44	3.7345e-004	3.5985e+006
8	0.54	1.604e-004	3.3821e+006

Table:6 stain lesssteel



Tabular Data

	Time [s]	☑ Minimum [W/m^2]	☑ Maximum [W/m^2]
1	1.e-002	6.9469e-003	5.4823e+007
2	1.3333e-002	5.7928e-003	4.9726e+007
3	1.4444e-002	1.5275e-003	4.8349e+007
4	1.5553e-002	5.2574e-003	4.7173e+007
5	1.6662e-002	5.2189e-003	4.6134e+007
6	1.8106e-002	4.433e-003	4.4946e+007
7	1.9763e-002	5.3805e-003	4.3722e+007
8	2.1689e-002	2.9455e-003	4.2454e+007

Table:7 Aluminumalloy

7. RESULT&DISCUSSION

GRAPH:

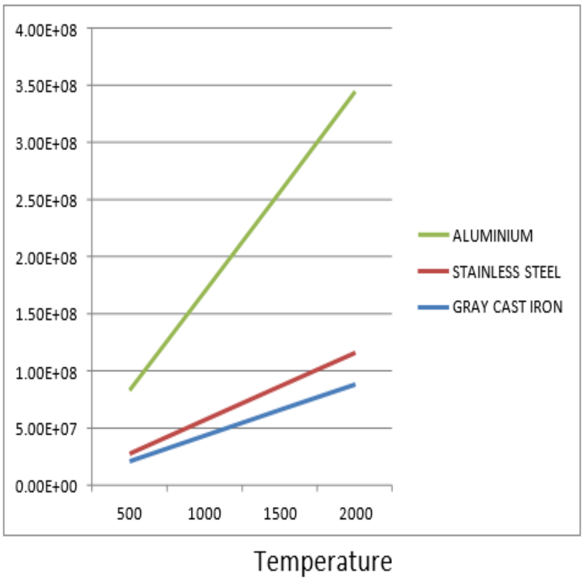
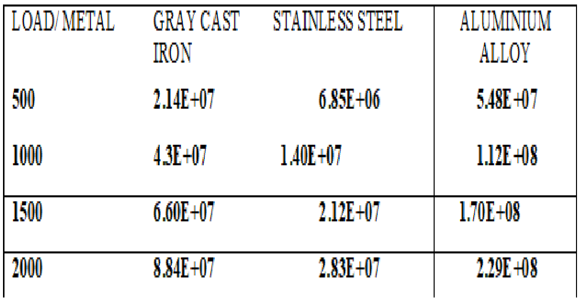


Figure:8 HeatfluxvsTemperature

The graph shows the different heat flux values based on the temperature of thedifferentmaterialslikegreycastiron,stainlesssteelandaluminumalloyatdifferenttemperatures like500,1000, 1500and 1000willshow thegraphlineatdifferentstages.

Table:

Table showsthe valuesofthe heatfluxofthedifferent materials.



LOAD/ METAL	GRAY CAST IRON	STAINLESS STEEL	ALUMINIUM ALLOY
500	2.14E+07	6.85E+06	5.48E+07
1000	4.3E+07	1.40E+07	1.12E+08
1500	6.60E+07	2.12E+07	1.70E+08
2000	8.84E+07	2.83E+07	2.29E+08

Table:6.1 resultvalues

The table shows the different heat flux values based on the temperature of the differentmaterials like grey cast iron, stainless steel and aluminum alloy at different temperatureslike 500, 1000, 1500 and 1000 will show the different values of heat flux at differenttemperature.

8. CONCLUSION

The complete design of a gears and the assembly of a gearbox in CATIA using features of the software and analyzed on gears and shafts such as Thermal analysis or worked in Ansys 15.0 and complete analysis results are obtained such as Temperature heat flux has been obtained by using materials gray cast iron, aluminum alloy, stainless steel. The gear cast iron is the best material for the multi speed gear box.

2. REFERENCES

1. Cong Thanh Nguyen, Paul D. Walker, Nong Zhang et. all [1], (2021) In this paper, the electric vehicle equipped with dual motors and four-speed automated manual transmission is studied for improving energy economy, The Optimization and coordinated control of gear shift and mode transition for a dual-motor electric vehicle. https://doi.org/10.1016/j.ymssp.2021.107731

2. Ujjayan Magumdar, et. all [2], (2021) investigated The described the study of shaft material, gear box components and types of gearing etc.

Utkarsh Patil et. all [3], (2020) the analyzation discussed in this paper the transmission system of the vehicle but they mainly

1. *focused on the different type of the differentialgearboxes.*
2. Jianqun Zhang , Baoming Xu , Zhenya Wang , Jun Zhang *et. all [4], (2021),* An FSK-MBCNNbasedmethodforcompoundfaultdiagnosisinwindturbinegearboxes.Thispaperproposed a novel fault recognition method named FSK-MBCNN to diagnose compoundfault of wind turbine gearboxes. The validity of the proposed FSK-MBCNN method isprovedbytheanalysisresultsofadatasetcollectedfromourlaboratory. https://doi.org/10.1016/j.measurement.2020.108933
3. Weiguo Huang, Zeshu Song, Cheng Zhang, Jun Wang, Juanjuan Shi, Xingxing Jiang,ZhongkuiZhu*et.all[5],(2020)*Inthisstudy,amulti-sourcefidelitysparserepresentation(MFSR)methodisproposed,whichcanaccuratelyrealizethecompoundfaultdiagnosisofthegearbox withoutpriorknowledge.https://doi.org/10.1016/j.jsv.2020.115879.
4. VamsiInturiN.Shreyas,KarthickChetti,G.R.Sabareesh*et.all[6]*,(2020)Inthisinvestigation, a multi-level classification scheme for predicting the location, defect typeanddefectseveritylevelatvariousspeedstagesofawindturbinegearboxisproposed.*https://doi.org/10.1016/j.apacoust.2020.107738*.
5. Jiachi Yao, Chao Liu, Keyu Song, Chenlong Feng, Dongxiang Jiang, *et. all [7], (2021)*Fault diagnosis of planetary gearbox based on acoustic signals. In this work, the acousticsensor is utilized for monitoring and diagnosis the planetary gearbox. Compared with thevibrationsignals.https://doi.org/10.1016/j.apacoust.2021.108151
6. Yingchao Luo, Lingli Cui, Jianfeng Ma *et. all [8], (2021)* Effect of bolt constraint of ringgear on the vibration response of the planetary gearbox. Based on LPM and the Euler–Bernoulli beam theory, a new vibration signal model of the planetary gearbox consideringtheboltconstraintofthe ringgearisestablishedhttps://doi.org/10.1016/j.mechmachtheory.2021.104260.
7. Hui Hou, Hongquan Ji *et. all [9], (2021)* , In this work, an improved feature selectionstrategy and a corresponding multiclass SVDD method have been proposed for planetarygearbox fault diagnosis. Improved multiclass support vector data description for

planetarygearboxfaultdiagnosis.https://doi.org/10.1016/j.conengprac.2021.104867

8. Marco Nicola Mastrone , Franco Concli *et. all [10], (2021* The application of simulationtoolsinmechanicaldesignhasincreasedalotoverthelastyears,CFDsimulationofgreaselubrication: Analysis of the power losses and lubricant flows inside a back-to-back test riggearbox.https://doi.org/10.1016/j.jnnfm.2021.104652