

FINITE ELEMENT ANALYSIS OF CAR DOOR SEAL FOR BETTER PERFORMANCE

Submitted in partial fulfillment of the requirements for the award of

Bachelor of Engineering Degree in

Automobile Engineering

By

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DEPARTMENT OF AUTOMOBILE ENGINEERING

SCHOOL OF MECHANICAL ENGINEERING

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade “A” by NAAC

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APRIL 2021



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DEPARTMENT OF AUTOMOBILE ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of **PRANEETH S.V** (Reg. No. **37860023**), **SEELAM PAVAN KUMAR REDDY** (Reg. No.**37860033**) who carried out the project entitled “**FINITE ELEMENT ANALYSIS OF A CAR DOOR SEAL FOR BETTER PERFORMANCE**” under my supervision from **2020 to 2021**.

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Submitted for Viva voce Examination held on_____

Internal Examiner

External Examiner

DECLARATION

We, **PRANEETH S.V (37860023), SEELAM PAVAN KUMAR REDDY (37860033)** hereby declare that the Project Report entitled “**FINITE ELEMENT ANALYSIS OF A CAR DOOR SEAL FOR BETTER PERFORMANCE**” done by under the guidance of **Mr. S. YUVARAJA, M.E., Department of Automobile Engineering** is submitted in partial fulfillment of the requirements for the award of **Bachelor of Engineering** Degree in **Automobile Engineering**.

1.

DATE:

2.

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SIGNATURE OF THE CANDIDATES

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We are pleased to acknowledge my sincere thanks to **Board of Management of SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

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ABSTRACT

In this feasibility take a look, we analysed a vehicle door seal for higher performance. We laboured on “D” form of vehicle door seal. We delivered F20 polymer to make it extra-long lasting and resistance. We acquire the mechanical homes and bodily homes of F20polymer. We did numerous sorts of evaluation for that vehicle door seal like noise evaluation, thermal evaluation, shear pressure evaluation, shear stress evaluation, general deformation evaluation, warmness go with the drift evaluation. We did mesh for that vehicle door seal. We acquire and research such a lot of matters shape the reputed base papers and journals on vehicle door seal. Seals have huge software in car products. They are answerable for sealing the automobile in numerous elements consisting of the doors, the air consumption cover seal, and air consumption lighting fixtures seal. Strain and pressure research are very vital if you want to apprehend the conduct of polymeric materials that are commonly submitted to first-rate workload version and environmental affect. This takes a look at of F20 polymer becomes executed to outline the stress, pressure and yield pressure. Tensile and compression assessments have been executed on paintings pieces. The records have been required the usage of the CADD Ansys software program.

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LIST OF ABBRIVATIONS

EDM	ENGINEERING DEVELOPMENT METHOD
CAD	COMPUTER AIDED DESIGN
CR	COMPRESSION RATIO
ABS	ACRYLNITRILE BUTADIENE STYRENE
FEM	FINITE ELEMENT METHOD
FEA	FINITE ELEMENT ANALYSIS
SST	STEADY STATE THERMAL CONDITION

CHAPTER – 1

INTRODUCTION

Rubber merchandise has huge variety of utility with inside the automobile industries. The utility of rubber merchandise with inside the automobile enterprise may be categorized into tires, which might be patron merchandise and feature a much less existence span, and seals, which lasts for an extended period. Generally, seals are synthetic to last up to the cars. Thus, product recycling of waste substances has grown to be a critical thing for all of the industries with inside the world. When rubber merchandise is involved as far, the automobile and transportation industries are the largest purchasers of recent rubber. The fundamental packages of rubber seals in cars are; door seals, secondary door seals, air consumption lighting seal, elevate gate seals, ditch molding and outer waist belts. These are in flip divided into dynamic and static seals. The fundamental cause of the door seals is to offer a great seal between the door and the automobile's bodywork in excessive climatic conditions, to lessen outside noise, to contribute to the first-class of establishing and last of the door, and to guard the motive force and passengers in opposition to condition of the environment. Among diverse Hyper-elastic polymeric substances, F20 polymer has been of terrific hobby to engineers specifically with inside the automobile sector. F20 polymer is the brand-new cloth in seals and belongs to the organization of the thermo polymers. A huge spectrum of substances starting from elasticized F20 polymer strengthened with hyper-elastics. Four fundamental techniques had been proposed in those researches. The first method worries the effect of interfacial adhesion and its function on compatibility between the matrix and the elastomeric section. Thus, the numerical simulation of the F20 polymer thermal go with the drift is an exciting technique to be implemented, however calls for the problematic dedication of the simulation parameters related to the real forming method. The 2d organization concentrates at the consequences of elastomeric content, particle size, and particle distribution on mechanical conduct. The mechanism of deformation with inside the F20 polymer outcomes in crazing. F20 polymer a sort of change at micro-stage of adherence among debris and matrix phases. Thus, the usage of non-linear micro-mechanical version permits us to verify this interpretation. There is a courting among crazing and the crystalline

morphology. The mission of a dynamic seal can gift a device with a pattern bulb. Finite detail evaluation is in truth very critical to outline the precise layout traits of seals. Analysis achieved with the finite detail technique may be accomplished earlier than any prototype hardware is evolved if enough statistics on geometry and cloth assets is available. The ideal profile and conduct of seals can consequently be anticipated and optimized, saving terrific quantities of time on the manufacturing line. When the microstructure and rheological conduct are involved, the F20 polymer section modified from a dispersed section to a non-stop one, and once more to dispersed section. The layout of merchandise for the automobile enterprise typically makes use of the device with bulbs while there are terrific gaps among the doorways and the body of the automobile chassis. It has the feature of giving a higher look to the seal. Hyper-elastic substances already are used with inside the layout of automobile door seals. It is used greater with inside the seals of windshields and windows. Some researchers have proven that the usage of hyper-elastic substances with inside the layout of the seals reduces with the aid of using 30% the burden of the product. This document provides the validation of seals the use of CADD Ansys R15 software program primarily based totally at the theoretical fashions for hyper-elastic substances that describe the conduct of the cloth through pressure.

CHAPTER 2

LITERATURE SURVEY

- David, A. W., Kenneth, N. M., Gur, Y. and Madhu, R. K. (1997). Nonlinear analysis of automotive door weather-strips seals. Published by Finite Elements in Analysis and Design, Volume 28, Issue 1, December (1997), Pages 33-50.

This paper has made a try to enhance seal glass becoming popularity, which indicates higher NVH (Noise-Vibration-Harshness) best of window in excessive-velocity condition. The outside load at the window reasons unsteady strain on glass, which eventually transferred to window seals constraint version a lot extra difficult, for this reason impeding the similar evaluation and optimizing process. A new window seal layout approach turned into proposed offering in thinking about aerodynamics-prompted load and nonlinear constraint. A case looks at of window seal layout beneath excessive velocity is investigated. After seal, optimization primarily based totally on the brand-new approach, home windows seals maximal displacements have decreased. The stepped forward seal-glass becoming popularity indicates higher NVH best of window seal in excessive-velocity condition.

- Dikmen, E. and Basdogan, I. (2008). Material characteristics of a vehicle door seal and its effect on vehicle vibrations. Vehicle System Dynamics. Published by International journal of vehicle mechanics and mobility, volume 46, Issue 11, (2008), Pages 975-990.

This paper labored at the traits on a car door seal and its impact on car vibration. The vibration traits of the door seals had been laid low with the climate strip seals utilized in among doorways and car frame alongside the fringe of the doorways. The climate strip seals showcase non-linear and viscoelastic fabric residences that change with frequency, temperature, pressure price and amplitude, and former past of the load. In this study, they advanced hyper elastic and viscoelastic fashions of the weather-strip seal to are expecting dynamic overall performance of a car door and its impact on the general car dynamics. The version predictions had been

established the usage of experimental modal evaluation done at the car door with and without the seal. It turned into the found that the seal has a considerable impact on the car dynamics.

- Kumar, N., Kumar, R. and Nair, S. (2013). Experimental approach to improve the door slams noise quality in utility vehicles. SAE Paper No. 2013-26-0095, (2003).

This paper performed a test to enhance the door slam noise in application vehicles. In this paper they defined approximately the probable regions within the door to enhance the slam noise through trying changes within the door layout factors, which includes door alignments, door panel stiffness, door trims, window glass rattle, latch striker alignment, door seals, air extractor. Since the door ultimate occasion is a brief phenomenon, it calls for unique gear, which includes wavelet transforms, Zwicker loudness to apprehend the slam occasions precisely. Subjective jury critiques were performed to apprehend the impact of those changes primarily based totally on their contributions to the door slam noise.

- Vehicle door seal modeler for wind noise. Published by the Journal of the Acoustical Society of America Volume 108, <https://doi.org/10.1121/1.4743349>, Issue 5, 2527, (2000).

This paper focuses on the wind noise produced during the movement of the vehicle on the door seal of the vehicle. Wind noise aerodynamically generated on the outer surface of a vehicle can travel to the vehicle interior through body panels, window glass, and the seal space between door-opening panel. Experimental studies indicate that automotive door seal systems were generally major contributor to the vehicle wind-noise performance. Automotive door seals were designed using the “bread board” and other “build and test” procedures. Two new finite elements based acoustic structure analysis tools have been developed to evaluate the wind-noise performance of door sealing system. The unique methods, experimental validations, and implementation of these techniques on product design were presented according to the paper.

CHAPTER 3

AIM AND OBJECTIVES

3.1 AIM

- Our main aim is to improve the performance of the door seals in car using F20 Polyabs Polymer.
- To achieve the process of making the door seal more durable and to make the door withstand huge amount of pressure and vibration.

3.2 LIST OF ANALYSIS

- Noise analysis
- Pressure analysis
- Compression ratio analysis
- Total deformation analysis
- Shear elastic strain analysis
- Shear stress analysis
- Heat flow analysis of door seal

3.3 SCOPE AND OBJECTIVE

- To improve the performance of the door seal
- To make the door seal with stand several pressures and vibrations.
- While performing the analysis it was found that the F20 polymer door seals performed way better than the normal door seals.

CHAPTER 4

EXPERIMENTAL METHODOLOGY

4.1 MESHING

Meshing is a necessary a part of the engineering simulation method wherein complicated geometry is divided into easy factors that may be used as discrete neighborhood approximations of the bigger one. The mesh affects the accuracy, convergence and pace of the simulation. Meshing in a cad device could have 3 meanings, specifically triangularization of a version to export it to different applications like render package & animation. Discretization of a version into factors appropriate for a FEM package, meshing of u- and v- parameter iso-curves to permit the consumer take a look at the great of a floor visually. The act of recreating a present floor with extra most suitable geometry. A not unusual place use-case is developing a clean, quad-primarily based totally mesh for animation, however it is also used for maximum any very last item that wishes textured, animated, or in any other case manipulated in a manner that sculpted meshes aren't conducive. Furthermore, seeing that meshing normally consumes a substantial part of the time it takes to get simulation consequences, the higher and extra automatic the meshing tools, the quicker and extra correct the answer. Ansys offers fashionable purpose, excessive-performance, automatic, shrewd meshing software program which produces the maximum suitable mesh for correct, green multi physics answers from easy, automated meshing to quite crafted mesh. Methods to be had cowl the meshing spectrum of excessive-order to linear factors, rapid tetrahedral and polyhedral to excessive great hexahedral, and Mosaic. Smart defaults are constructed into the software program to make Ansys offers fashionable purpose, excessive-performance, automatic, shrewd meshing software program which produces the maximum suitable mesh for correct, green multi physics answers from easy, automated meshing to quite crafted mesh. Methods to be had cowl the meshing spectrum of excessive-order to linear factors, rapid tetrahedral and polyhedral to excessive great hexahedral, and Mosaic. Smart defaults are constructed into the software program to make meshing a painless and intuitive undertaking turning in the desired decision to seize answer gradients well for reliable consequences. Perform selected evaluation for numerous extraordinary mesh sizes. Notice wherein excessive deformations or excessive

stresses occur, possibly it is far really well worth to refine mesh in the one's regions. Collect records from evaluation of every mesh outcome, range of nodes with inside the version, computing time. When the geometry is borderline among the type of 2D and 3D geometry, 2D shell factors are desired over 3-D. This is due to the fact shell factors being fewer stiff captures the mode shapes correctly and with a fewer range of nodes and factors. The geometry is modified; the mesh may also be up to date automatically. The boundary circumstance may be carried out at the geometry like a floor or edge. To efficaciously whole a finite detail evaluation, you ought to apprehend the conduct of diverse sorts of factors. A deep theoretical expertise of detail formulations is not always required despite the fact that an essential expertise of the way every detail kind behaves is critical with inside the choice of the proper detail sorts, so that you can cause right interplay with carried out masses and boundary conditions. Finite detail fashions along with an unmarried detail are one approach of analyzing the mechanics of factors. The inputs and outputs may be studied in element and as compared to strong mechanics answers. This approach is beneficial for knowledge the signal and naming conventions utilized by a specific solver. Adding extra than the desired boundary situations may be used to research even extra approximately detail conduct. Higher order factors are people with one or extra mid-facet nodes, or geometry-primarily based totally factors, which include p-model factors. These sorts of factors provide the advantages of ease of modeling and a better diploma of accuracy in step with detail. P-model kind factors even have an integrated cap potential to test convergence via way of means of growing the essential conduct. Element choice is primarily based totally at the kind of hassle you need to run, boundary situations, geometry considerations, and consequences required. Mesh density may be very depending on the choice of detail sorts consequently pick the detail kind this is suitable to resolve your hassle. Determine whether or not the shape must be taken into consideration as a shell kind or if a complete 3-D version is wanted to seize the country of stress, geometry, or neighborhood deflection.

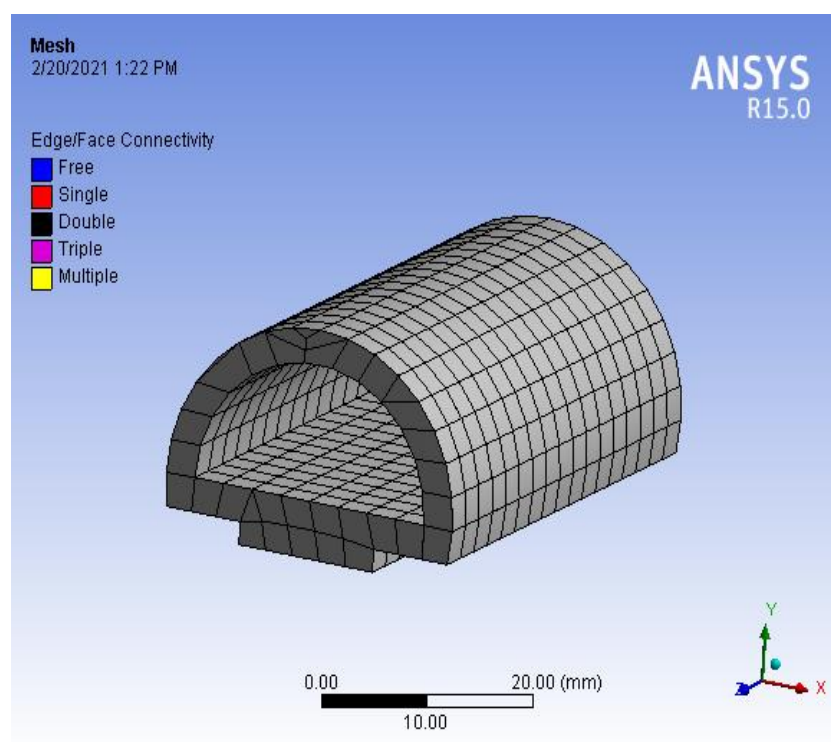


Figure 4.1: Meshing in Ansys R15

4.2 TOTAL DEFORMATION

Deformation tracking is the systematic size and monitoring of the alteration with inside the form or dimensions of an item due to stresses brought about with the aid of using implemented weights. When an enough load is implemented to a steel or different structural fabric, it is going to motive the fabric to extrude form. This extrude in form is referred to as deformation.

4.2.1 Elastic deformation

Change of dimensions accompanying strain with inside the elastic range, unique dimensions being restored upon launch of strain. Wherein the pressure is reversible, it is far referred to as elastic deformation. A brief form extrudes this is self-reversing after the pressure is removed, in order that the item returns to its unique form, is referred to as elastic deformation. When an enough load is carried out to a steel or different structural cloth, it will reason the cloth to extrude form. This extrudes in form is referred to as deformation. A brief form extrudes this is self-reversing after the pressure is removed, in order that the item returns to its unique form, is referred to as elastic deformation. It is an extruded form of a fabric at low strain this is recoverable after the strain is removed. This sort of deformation includes stretching of the bonds; however, the atoms do now no longer slip beyond every different.

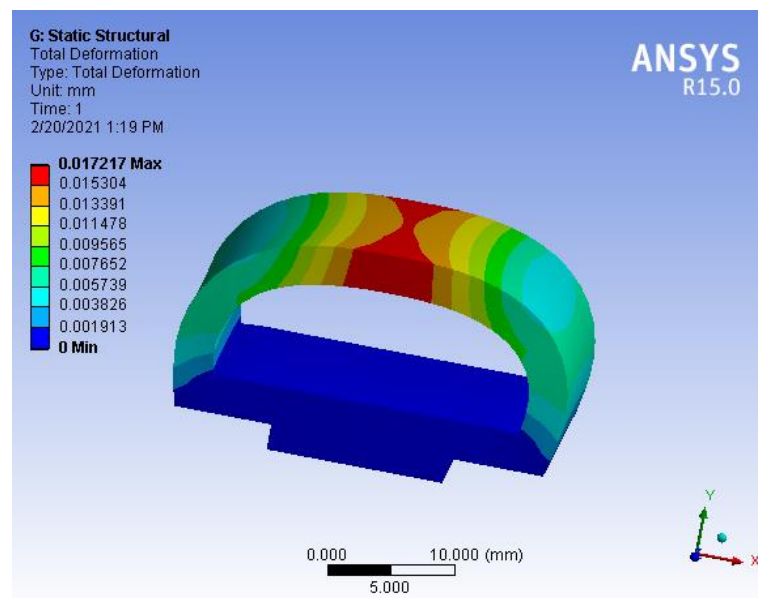


Figure 4.2: Elastic Deformation of a car door seal in Ansys R15

4.2.2 Slip bands

As mentioned with inside the segment of crystal defects, plastic deformation entails the breaking of a restrained quantity of atomic bonds with the aid of using the motion of irregular locations. Recall that the pressure wished to interrupt the bonds of all the atoms in a crystal aircraft all of sudden may be very great. However, the motion of dislocations permits atoms in crystal planes to slide beyond each other at a far decrease pressure level. Since the electricity required to transport is lowest alongside the densest planes of atoms, dislocations have a desired course of journey inside a grain of the material. These effects in slip that happens alongside parallel planes with inside the grain. These parallel slip planes organization collectively to shape slip bands, which may be visible with an optical microscope. A slip band seems as an unmarried line beneath neath the microscope however, it has far in truth made from intently spaced parallel slip planes.

4.2.3 Stretch ratios

The stretch ratio or extension ratio is a degree of the extensional or everyday pressure of a differential line element, which may be described at both the below fashioned configuration or the deformed content. It is described because of the ratio among the very last duration l and the preliminary duration L of the fabric line.

$$\lambda = \frac{l}{L}.$$

The extension ratio is approximately related to the engineering strain by

$$e = \frac{l - L}{L} = \lambda - 1$$

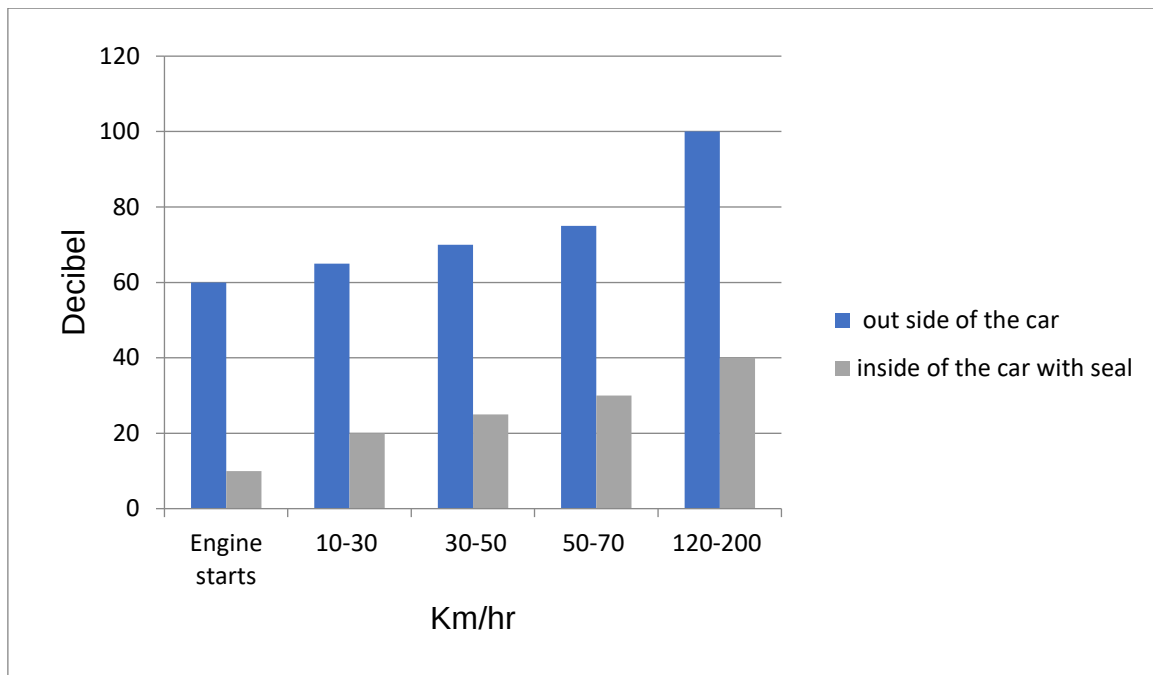
This equation means that the ordinary stress is zero, in order that there is no deformation while the stretch is identical to the unit. The stretch ratio is used with inside the evaluation of substances that showcase big deformations, inclusive of elastomers, which could maintain stretch ratios of 3 or 4 earlier than they are failed.

4.2.4 Noise analysis

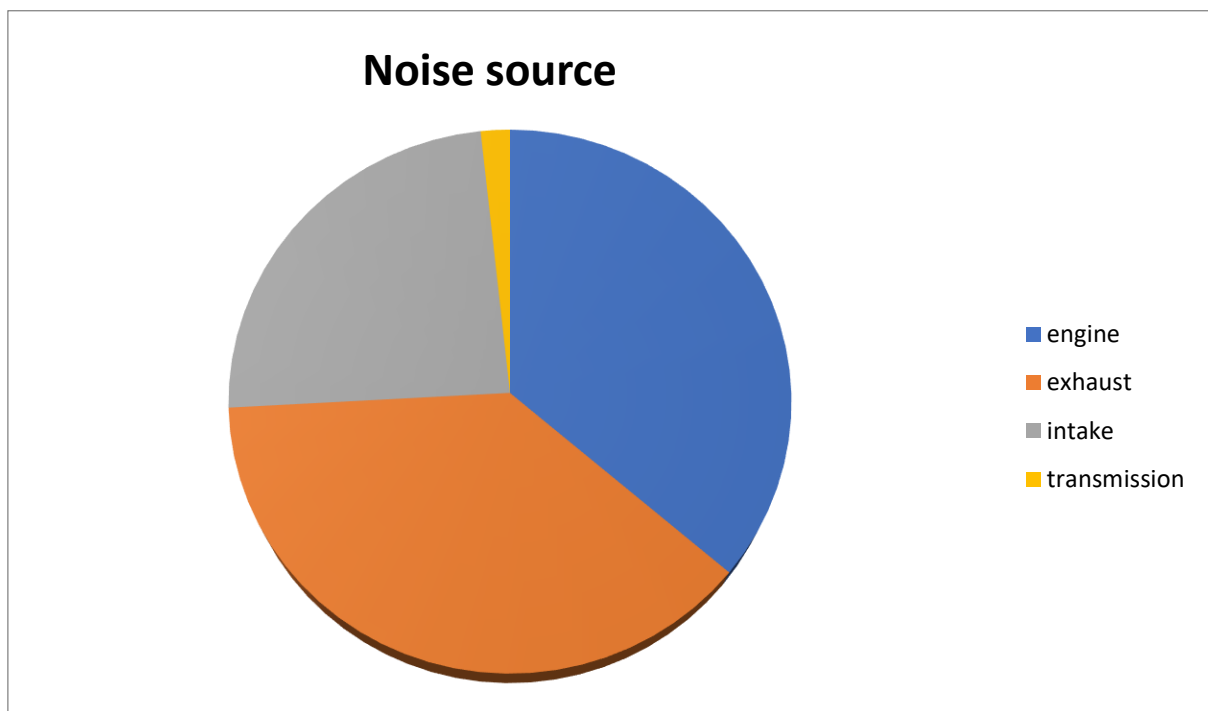
Wind noise turns into the most noise supply while a vehicle runs at excessive speeds. High frequency traits of wind noise supply and powerful overall performance of seal rubbers for insulating leakage noise make studies at the

transmission Loss of car door sealing structures are magnificent. The development of transmission Loss of car door sealing gadget may want to correctly lower the indoors noise because of wind noise for automobiles at excessive speeds. In this, the compression simulation of seal rubbers of a car door is obtained through a finite detail device first transmission Loss. pressurized geometries of the seal rubbers are acquired. Then, primarily based totally at the very last compressed geometries and pre-pressure modes of the car door seal rubbers. Door seals, which might be mounted among car doorframe and frame, now no longer most effective save you water and dirt going inside, however additionally insulate the car indoors compartment from the outdoors sound discipline. Seals also can relieve the vibration of structural panels. We analyzed the sound transmission Loss of leakages with inside the automobile sprint subsystem. The transmission loss distinction among appropriate and terrible seals with inside the sprint sub gadget turned into alternatively excessive, as much as 10~20 DB. Level. Sponger door seals typically have a terrific overall performance of sound insulation in excessive frequency bands. We centered on numerical examine and optimization of transmission loss of sound programs for car sprint and ground sub structures. They confirmed numerical and optimization methodologies had been very beneficial in engineering modules for higher sound insulation and lightweight overall performance of sound modules. Based on seals that have appropriate sound transmission loss, specifically in mid and excessive frequency bands. Therefore, it is far from brilliant significance to make studies at the sound insulation overall performance of car seals. We discovered that compression ratio had a power on sound insulation and sound insulation development of seal rubbers may be evaluation and simulation methods. Much better frequencies want to be taken into consideration for excessive frequency traits of wind noise. Parameters and variables of seal rubbers can have an effect on transmission loss of car door sealing structures. The membrane thickness of a seal wall and the space among seal partitions may want to have an effect on sound barrier overall performance of seal rubbers. The touch vicinity and the elastic homes had important to have an effect on at the stiffness-managed place and resonance frequency. The damping loss component of a seal rubber may want to direct Transmission Loss to have an effect on the sound transmission loss with inside the mass-air-mass resonance place. Moreover, automobiles journeying at

excessive speeds face aerodynamics excitation, which comes from the robust fluctuating floor strain with inside the turbulent boundary point. Both subtract sound discipline exaggeration and aerodynamics exaggeration for sound transmission loss measurements. The life of airflow round seal rubbers outdoor the car frame can lessen strain coefficients on outdoors floor of seal rubbers, generating strain distinction between inside and outside door. They have an effect on of seal guide homes at the noise generated from a plate. Wind noise turns into dominant while automobile velocity is over 80 km/h and wind noises will increase with velocity going up. Leak noise contributed extra than form noise to general indoors noise because of wind noise among mid and excessive frequency ranges. Seals for door, aspect view mirrors and aspect home windows are the maximum vital leak noise reassess for a vehicle. The common airborne noise stage of a nominally rated engine could be round one zero to five dB, while the most stage measured across the engine, and typically close to a turbocharger, could be approximately one hundred ten dB, however better for larger engines and decrease for smaller engines. By the spectrum take a look at of pass-with the aid of using noise in heavy-obligation automobiles, it turned into acknowledged that the time curve of pass-with the aid of using noise with inside the 6-velocity seemed to be the noise peak, and the height-time curve extended 4.1 dB the spectrum evaluation of noise discovered that the height frequency of 1380 Hz with inside the 1/three octave turned into better 11.4 dB. Passenger vehicle at sixty-five mph at 25 ft (seventy-seven dB). A competitive exhaust gadget can without problems throw out a one hundred ten-dB.



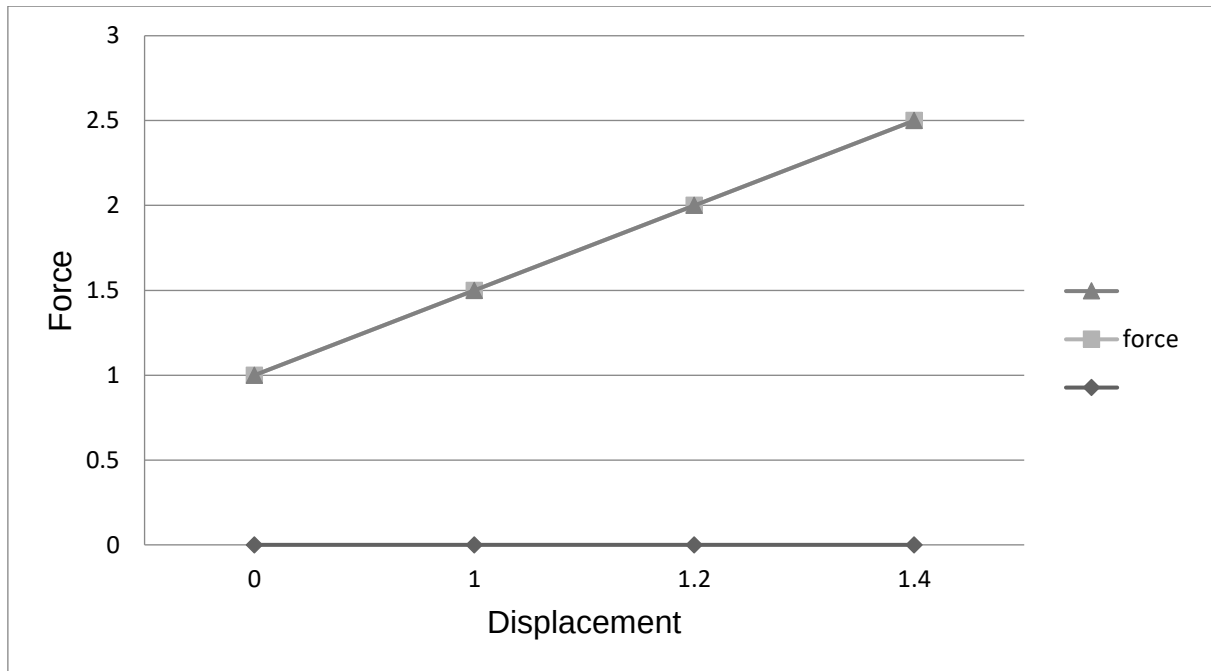
Graph 4.1: Noise difference b/w inside and outside of the car



Graph 4.2: Noise Source

4.2.5 Compression ratio

The compression ratio is defined as $CR = \frac{(D_i - D_0)}{D_0}$ where D_0 is the initial seal diameter and D_i the seal diameter at increments i . The seal deformed form and a contour plot of the regular touch stress distribution at some stage in compression. In general, those plots provide records at the distribution of stresses and lines with inside the seal and records. At the chance of air and water leakage, with the aid of using searching at how the touch location varies at some stage in compression. In this application, the geometry of the door-seal touch location to begin with is pretty easy and flat. However, because of the seal omega form, the touch stress in the end splits into touch areas. In an actual case in which the geometry of the door-seal touch location is, extra complex, wrapping round sharp corners also can arise growing the chance of air and water leakage via the seal. The force-displacement curve suggests the non-linear nature of the problem. A linear fabric version could have without a doubt underestimated the stiffness hardening-taking place above increment 6. During compression, the seal first softens and then, after increment 6, its stiffness will increase again. The seal may be taken into consideration as a non-linear spring with a spring coefficient various with the quantity of seal compression. In the proximity of the touch location, the mesh is subtle with iso-parametric tri-node undeniable pressure factors, with a characteristic's length. In the touch location, the door and the seal have comparable mesh refinements, which assure a higher convergence with inside the touch simulation. The traditional iso-parametric four-node and tri-node undeniable pressure factors are changed with the assumed pressure formulation, to higher constitute door-bending vibrations. The seal has $D_0=10\text{mm}$, $d_0=6\text{mm}$, and is fabricated from polymer. A five-time period-generalized Mooney- Revlon hyperactive elastic fabric version is used. The fabric coefficients are taken from literature.



Graph 4.3: Force and Displacement

Pressure co-efficient,

$$C_{01} = 0.0902353 \text{ (MPa)},$$

$$C_{10} = 0.0932811 \text{ (MPa)},$$

$$C_{11} = 0.0063716 \text{ (MPa)},$$

$$C_{20} = 0.0063716 \text{ (MPa)},$$

$$C_{30} = 0.0003311 \text{ (MPa)}.$$

The material density is $\rho = 1200 \text{ kg/m}^3$. The seal is modeled with 443 nodes and 354 elements. The seal is meshed with iso-parametric four-node plain strain elements.

One (MPa) = 1000000 Newton/square meter. One Newton/square meter = 1.0E-6 (MPa).

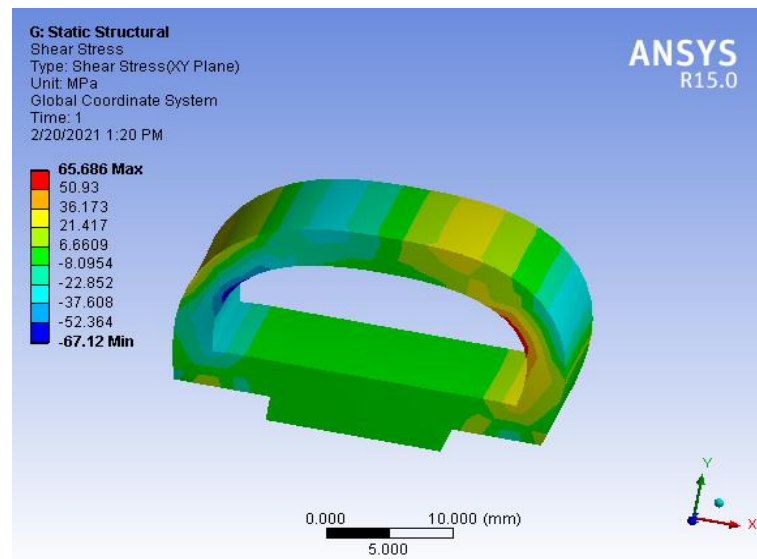


Figure 4.3: Shear stress on door seal

4.3 SHEAR ELASTIC STRESS

Shear stress, pressure tending to purpose deformation of a cloth via way of means of slippage alongside an aircraft or planes parallel to the imposed stress. The resultant shear is of first-rate significance in nature, being in detail associated with the down slope motion of earth substances and to earthquakes.

4.3.1 Hook's law in shear stress

Now we have to speak approximately shear. Let us move lower back to that imaginary dice of cloth. In addition to outside forces inflicting stresses, which might be regular to every floor of the dice, the forces can purpose stresses, which might be parallel to every dice face. In addition, as we know, stresses parallel to a go segment are shear stresses. Now that dice of cloth seems loads greater complicated, however it is not always too bad. On every floor there are shear stresses, and the subscripts inform you which of them one's route they factor in and which floor they are parallel to. For instance, take the proper faces of the dice. Stresses regular to this face are regular stresses with inside the x route. There are stresses parallel to this floor, one pointing within side the y route (denoted xy) and one pointing within side of the z route (denoted xz). In order for the dice to be in equilibrium, $xy = \tau_{yx}$ (otherwise, the dice could rotate). Therefore, there are actually six stresses ($\sigma_x, \sigma_y, \sigma_z, \tau_{xy}, \tau_{yz}, \tau_{xz}$) that represent the kingdom of pressure inside a homogenous, isotropic, elastic cloth. Hooke's regulation in Shear seems very comparable to. The equation we noticed for regular pressure and strain= $G\gamma$.

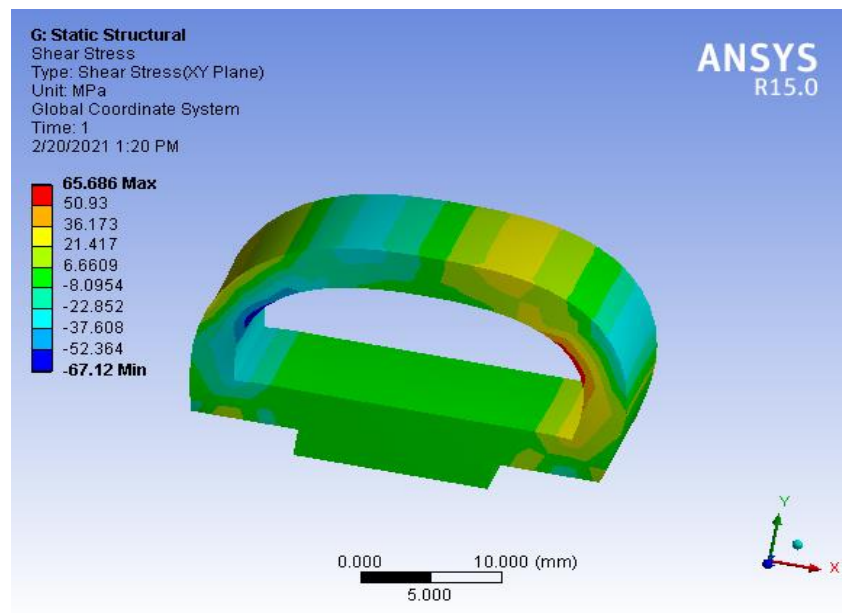


Figure 4.4: Shear elastic stress of a car door seal in Ansys R15

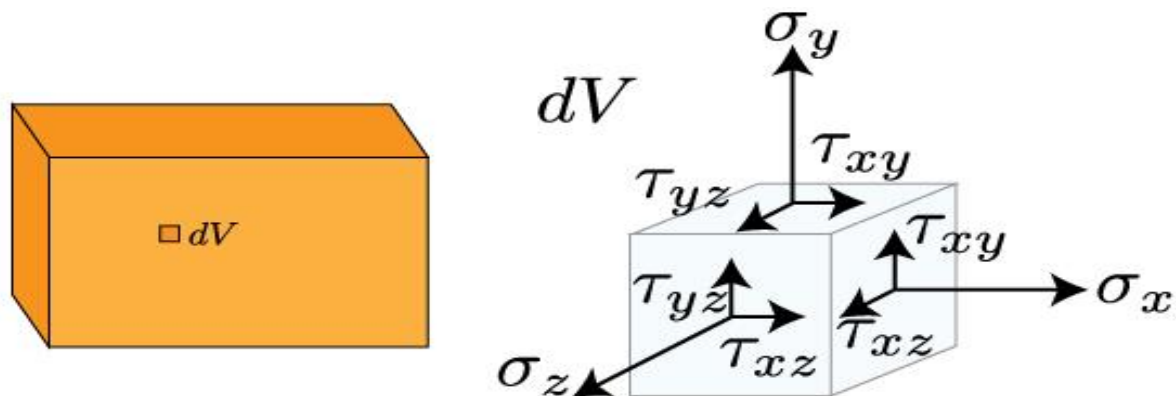


Figure 4.5: Six shear stresses of a material

Figure 4.5: six Shear stresses of a material in this equation, the proportionality between shear pressure and shear pressure is referred to as the shear modulus of a material. That is the equation in its preferred form, however we are able to rewrite it extra explicitly in phrases of its additives of x, and y and z, if we do it so will supply us the generalized form of Hooke's regulation for homogenous, isotropic, elastic materials.

$$\varepsilon_x = -\nu \frac{\sigma_y}{E} - \nu \frac{\sigma_y}{E} - \nu \frac{\sigma_z}{E}$$

$$\varepsilon_y = -\nu \frac{\sigma_y}{E} + \frac{\sigma_y}{E} - \nu \frac{\sigma_z}{E}$$

$$\varepsilon_z = -\nu \frac{\sigma_x}{E} - \nu \frac{\sigma_y}{E} + \frac{\sigma_z}{E}$$

$$\gamma_{xy} = \frac{\tau_{xy}}{G} \gamma_{yz} = \frac{\tau_{yz}}{G} \gamma_{zx} = \frac{\tau_{zx}}{G}$$

In our generalized Hooke's law, we have our six components of stress and strain, and 3 material properties as follows,

$$G = \frac{E}{2(1+\nu)}.$$

Shear elastic deformations which take place in crystalline solids, the volume to which elastic stress takes place can be very tiny, in the order of 0.5% or lesser. Therefore, we are able to count on that engineering stress and genuine stress are identical. In addition, we are able to count on that stress is proportional to pressure. This is legitimate for isotropic substances and for small strains. When a stable receives elastically deformed, it could go through alternate in its length, it could go through form alternate or it could go through rotation. Shear deformation is because of shear pressure. Shear deformation is depending on the character of pressure applied. In shear, a cloth may also go through rotation in addition to distortion. Stress is an amount that describes the importance of forces that purpose deformation. Stress is usually described as pressure according to unit area. When forces pull on an item and purpose its elongation, just like the stretching of an elastic band, we name such pressure a tensile pressure. When

forces purpose a compression of an item, we name it a compressive pressure. When an item is being squeezed from all sides, like a submarine with inside the depths of an ocean, we name this type of pressure a bulk pressure (or quantity pressure). In different situations, the appearing forces can be neither tensile nor compressive, and nonetheless produce a substantial deformation. For example, assume you preserve an eye-e book tightly among the arms of your hands, then with one hand you press-and-pull at the front cowl far from you, at the same time as with the opposite hand you press-and-pull at the again cowl in the direction of you. In one of these cases, while deforming forces act tangentially to the item's surface, we name them 'shear' forces and the pressure they purpose is known as shear pressure.

The SI unit of stress is Pascal (Pa). When one Newton of force is pressed on a unit surface area of one meter square, the result of stress is one Pascal:

$$\text{One Pascal} = 1Pa = \frac{1.0 \text{ N}}{1.0 \text{ m}^2} .$$

4.4 SHEAR ELASTIC STRAIN

Shear stress is the ratio of the alternate in deformation to its authentic duration perpendicular to the axes of the member because of shear. Shear pressure is pressure in parallel to the go phase of the structural member. Shear stress is measured as an alternate in attitude among strains that have been at first perpendicular. Consider an elemental region that undergoes a distortion that produces angular changes; however, which leaves the edges of the region about the equal duration, shear stress = $\Delta \times L$. The shear modulus is the proportionality steady in (Figure) and is described with the aid of using the ratio of pressure to stress. Shear stress pressure tending to reason deformation of a fabric with the aid of using slippage alongside an aircraft or planes parallel to the imposed pressure. The resultant shear is of excellent significance in nature, being in detail associated with the down slope motion of earth substances and to earthquakes. Similarly, the shear stress price is the spinoff with appreciate to time of the shear stress. Engineering shear stress may be described because of the angular displacement created with the aid of using an implemented shear pressure. It is in reality a ratio of the alternate in duration to the authentic duration. Deformations, which can be

implemented perpendicular to the go phase, are regular strains, even as deformations implemented parallel to the go phase are shear strains. For linear, elastic substances, pressure is linearly associated with stress with the aid of using Hooke's law. From the definition of the shear stress, its miles referred to that shear stress are depending on shear pressure and the shear modulus (a steady belonging of the fabric from which the structural member is cast). Shear pressure can arise in distinctive loading conditions, along with lateral loading, axial loading, and bending, and hence, exert stress on the member. The shear stress formula is $\gamma = \tau / G$, were γ = shear stress. τ = shear pressure (unit of pressure over unit of region: N/m² or Pascal with inside the International system of units, or kilos in line with rectangular inch (psi) with inside the British Imperial-System). G = shear modulus. An item or medium beneath neath pressure turns into deformed. The amount that describes this deformation is known as stress. Strain is given as a fractional alternate in both duration (beneath neath tensile) or quantity (beneath neath bulk) or geometry (beneath neath shear). Therefore, stress is a dimensionless number. Strain beneath neath a tensile pressure is known as tensile stress, stress beneath neath bulk pressure is known as bulk stress (or quantity stress), and that due to shear pressure is known as shear stress. Shear stress is measured as an alternate in attitude among strains that have been at first perpendicular. Consider an elemental region that undergoes a distortion that produces angular changes; however, which leaves the edges of the region about the equal duration. Direct stress is denoted with the aid of using Epsilon [ϵ].

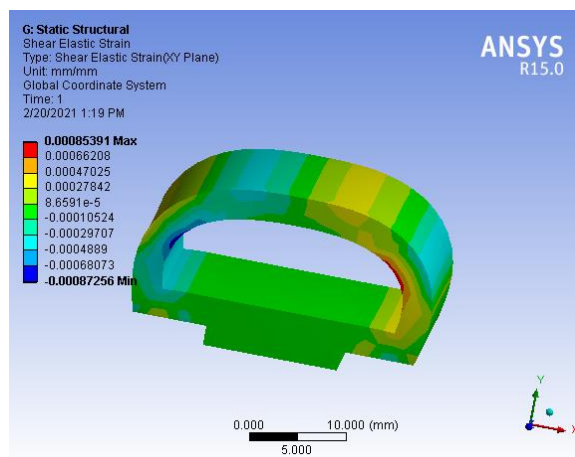


Figure 4.6: Shear elastic strain of a car door seal in Ansys R15

4.4.1 Concept of strain

If a bar is subjected to a direct load, and hence a stress the bar will change in length. If the bar has an original length L and changes by an amount dL , the strain produce is defined as follows:

$$\text{Strain}(\epsilon) = \frac{\text{change in length}}{\text{original length}} = \frac{\delta L}{L}$$

4.5 HEAT FLOW

The charge of warmth float is the quantity of warmth this is transferred consistent with a unit of time in a few materials, normally measured in watt (joules consistent with second). Heat is the float of thermal power pushed via way of means of thermal non-equilibrium, so that 'warmness float' is a redundancy. Heat should now no longer be pressured with saved thermal power, and transferring a warm item from one area to some other should now no longer be referred to as warmness transfer. However, notwithstanding most of these remarks, it's far not unusual place in ordinary parlance to say 'warmness float', to speak of 'warmness content'

The equation of heat flow is given by Fourier's Law of Heat Conduction.

The formula for the rate of heat flow is:

$$\frac{Q}{\Delta t} = -kA \frac{\Delta T}{\Delta x}$$

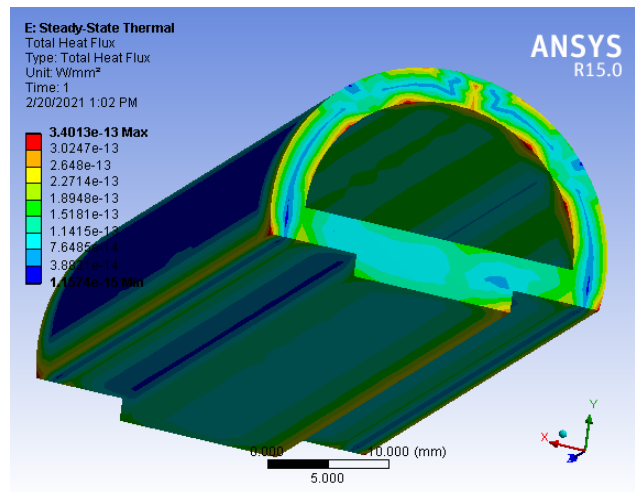


Figure 4.7: Heat flow of a car door seal in Ansys R15

Q net heat (energy) transfer

Δt the time taken

ΔT difference in temperature between the cold and hot sides

Δx thickness of the material conducting heat

K thermal conductivity

A surface area of the surface emitting heat

If a chunk of cloth whose cross-sectional vicinity is A and thickness is Δx with a temperature difference ΔT among its faces is observed, warmth flows between the 2 faces in a route perpendicular to the faces. The time charge of warmth glide, $Q/\Delta t$, for small Q , small Δt , is proportional to $A \times \Delta T / \Delta x$. In the restriction of infinitesimal thickness Δx , with temperature difference ΔT , this will become $H = -kA(\Delta T / \Delta x)$, in which $H = (Q/\Delta t)$ the time charge of warmth glide via the vicinity A is, $\Delta T / \Delta x$ is the temperature gradient throughout the cloth, and K , the proportionality constant, and is the thermal conductivity of the cloth. People regularly use K to symbolize this constant. The minus signal is there due to the fact the charge of

warmth glide is constantly negative- warmth flows from the facet at better temperature to the only at decrease temperature, now no longer the opposite manner around.

4.5.1 Heat Transfer

Heat switch is a field of thermal engineering that issues the generation, use, conversion, and trade of thermal power (warmness) among bodily systems. Heat switch is classed into numerous mechanisms, along with thermal conduction, thermal convection, thermal radiation, and switch of power via way of means of segment change. Engineers additionally recollect the switch of mass of differing chemical species, both bloodless or warm, to attain a warmness switch. While those mechanisms have wonderful characteristics, they regularly arise concurrently with inside the equal system. Heat conduction, additionally referred to as diffusion, is the direct microscopic trade of kinetic power of debris through the boundary among systems. When an item is at a distinct temperature from every other frame or its environment, warmness flows in order that the frame and the environment attain the equal temperature, at which factor they are in thermal equilibrium. Such spontaneous warmness switch constantly takes place from a location of excessive temperature to every other location of decrease temperature, as defined with inside the 2d regulation of thermodynamics. Heat convection takes place while the bulk float of a fluid (fuel line or liquid) contains warmness alongside the float of depend on with inside the fluid. The float of fluid can be pressured via way of means of outside procedures, or sometimes (in gravitational fields) via way of means of buoyancy forces brought about while thermal power expands the liquid. Thus, influencing its personal switch. The latter method is regularly referred to as "herbal convection". All convective procedures additionally flow warmness partially via way of means of diffusion, as well. Another shape of convection is pressured convection. The method of warmth float in solids is referred to as conduction. Conduction takes place while gadgets in touch with each other switch warmness among them because of a temperature difference. As with excessive-power gadgets offering their power to low-power gadgets through a conductor, warmness float occurs while a warm item transfers its warmness through a conductor to a chilly component. The conductor determines how quickly, and what sort of the warmth is transferred. Heat float in solids can most effective to appear

while the ones solids are in touch with each other. The method of warmth float in solids is referred to as conduction. Conduction takes place while gadgets in touch with each other switch warmness among them because of a temperature difference, just like the garments from the dryer. This occurs actually due to the fact the transferring molecules hit every other. The molecules with inside the warm garments hit the molecules to your bloodless skin, and this reasons the power to switch among them. The molecules themselves do now no longer pass anywhere; its miles simply power going from one location to every other.

4.5.2 Conduction

Conduction is the technique with the aid of using which warmth power is transmitted through collisions among neighboring atoms or molecules. Conduction takes place extra simply in solids and liquids, in which the debris are towards together, than in gases, in which debris are similarly apart.

4.5.3 Thermal Conduction

Thermal conduction is the switch of inner power via way of means of microscopic collisions of debris and motion of electrons inside a frame. The colliding debris, which consist of molecules, atoms and electrons, switch disorganized microscopic kinetic and ability power, at the same time called inner power. Conduction takes area in all phases: strong, liquid, and fuel line. Heat spontaneously flows from a warmer to a chillier frame. For example, warmth is performed from the hotplate of an electric powered range to the lowest of a saucepan in touch with it. In the absence of an opposing outside using power source, inside a frame or among our bodies, temperature variations decay over time, and thermal equilibrium is approached, temperature turning into greater way. In conduction, the warmth go with the drift is inside and through the frame itself. In contrast, in warmth switch via way of means of thermal radiation, the switch is frequently among our bodies, which can be separated spatially. Also, viable is the switch of warmth via way of means of an aggregate of conduction and thermal radiation. In convection, the inner power is carried among our bodies via way of means of a shifting cloth carrier. In solids, conduction is mediated via way of means of the aggregate of vibrations and collisions of molecules, of propagation and collisions of phonons, and of diffusion and collisions of unfastened electrons. In gases and liquids,

conduction is because of the collisions and diffusion of molecules at some stage in their random movement. Photons in this context do now no longer collide with one another, and so warmth shipping via way of means of electromagnetic radiation is conceptually awesome from warmth conduction via way of means of microscopic diffusion and collisions of cloth debris and phonons. However, the difference is frequently now no longer, without difficulty located until the cloth is semi-transparent. In the engineering sciences, warmth switch consists of the approaches of thermal radiation, convection, and sometimes-mass switch. Usually, greater than such an approach happens in a given state of affairs. The traditional image for thermal conductivity is okay. On a microscopic scale, conduction happens inside a frame taken into consideration as being stationary; because of this, the kinetic energy and ability energy of the majority movement of the frame are one by one followed. Internal power diffuses as unexpectedly shifting or vibrating atoms and molecules engage with neighboring debris, shifting a number of their microscopic kinetic and ability energies, those portions being described relative to the majority of the frame taken into consideration as being still. Heat is transferred via way of means of conduction while adjoining atoms or molecules collide, or as numerous electrons pass back and forth from atom to atom in a disorganized manner in order now no longer to shape a macroscopic electric powered contemporary, or as photons collide and scatter. Conduction is the maximum vast approach of warmth switch inside a strong or among strong items in thermal touch. Conduction is extra in solids due to the fact the community of rather near constant spatial relationships among atoms allows switching power among them via way of means of vibratory disturbance. Thermal conductance is to see the warmth conduction between strong bodies in touch. A decrease in temperature is always located in between the 2 surfaces in which are in touch. This phenomenon is stated to be an end result of a thermal touch resistance present among the contacting surfaces. Interfacial thermal resistance is a degree of an interface's resistance to thermal go with the drift. This thermal resistance differs from touch resistance, because it exists even at atomically ideal interfaces. Understanding the thermal resistance on the interface among substances is of number one importance with inside to examine of its thermal residences. Interfaces frequently make a contribution appreciably to the located residences of the substances. The inter-molecular switch of power might be more often than not

via way of means of elastic impact, as in fluids, or via way of means of unfastened-electron diffusion, as in metals, or phonon vibration, as in insulators. In insulators, the warmth flux is carried nearly totally via way of means of phonon vibrations. Metals for example copper, platinum, gold and many more are mostly similar conductors of thermal power. This is because of the manner that metals bond chemically: metal bonds (instead of covalent or ionic bonds) have unfastened-shifting electrons that switch thermal power unexpectedly through the metallic object. The electron liquid of a conductive metallic object strongly conducts maximum of the warmth flux through the strong. Phonon flux remains still however it incorporates much less as compared to that of the power. Electrons additionally behavior electric powered contemporary through conductive solids, and the thermal and electric conductivity of maximum metals have approximately the identical ratio. An accurate electric conductor, together with copper, additionally conducts warmth well. Thermoelectric is as a result of the interplay of warmth flux and electric powered contemporary. Heat conduction inside is at once analogous to diffusion of debris inside a fluid, with inside the state of affairs wherein there are not any fluid currents. In gases, warmth switch happens through collisions of fuel line molecules with one another. In the absence of convection, which pertains to a shifting fluid or fuel line section, thermal conduction through a fuel line section is particularly depending on the composition and stress of this section, and in particular, to imply unfastened direction of fuel line molecules relative to the dimensions of the fuel line gap, as given via way of means of the number. To quantify the convenience with which a specific medium behavior, engineers rent the thermal conductivity, additionally called the conductivity steady or conduction coefficient is fine. In thermal conductivity, okay is described as the amount of warmth, Q , transmitted in time (t) through a thickness (L), in a route ordinary to a floor of area (A), because of a temperature difference (ΔT). Thermal conductivity is a fabric asset this is more often than not depending on the medium's section, temperature, density, and molecular bonding. Thermal effusively is an amount derived from conductivity that is a degree of its capacity to alternate thermal power with its surroundings.

4.5.4 Steady State Thermal Conduction

Steady-state conduction is the shape of conduction that occurs while the temperature difference(s) driving the conduction are constant, so that (after an equilibrating time), the spatial distribution of temperatures (temperature field) within the engaging item does now no longer extrude any more. Thus, all partial derivatives of temperature regarding area might also additionally both be zero or have nonzero values, however all derivatives of temperature at any factor regarding time are uniformly zero. In steady-state conduction, the quantity of warmth getting into any location of an item is identical to the quantity of warmth coming out. For instance, a bar can be bloodless at one cease and warm on the other, however after a country of steady-state conduction is reached, the spatial gradient of temperatures alongside the bar does now no longer extrude any further, as time proceeds. Instead, the temperature stays regular at any given cross-segment of the rod every day in the course of warmth transfer, and this temperature varies linearly in area with inside the case in which there is no warmness technology with inside the rod. In steady-state conduction, all the proper ways of direct present day electric conduction may be carried out to “warmness currents”. In such cases, it is miles viable to take “thermal resistances” because of the analogue to electric resistances. In such cases, temperature performs the function of voltage, and warmth transferred according to unit time (warmness power) is the analogue of electrical present day. Steady-state structures may be modeled via way of means of networks of such thermal resistances in collection and parallel, in actual analogy to electric networks of resistors. See in basic terms resistive thermal circuits for an instance of this type of network.

CHAPTER 5

RESULTS

Table 5.1: System software and details

SYSTEM	CADD
SOFTWARE	ANSYS
VERSION	R15 RELEASE
MATERIAL DATA	YES
ANALYSIS DATA	YES

In this table we have shown the system software and details where the software used, version, material data, analysis data are available or not is elaborated.

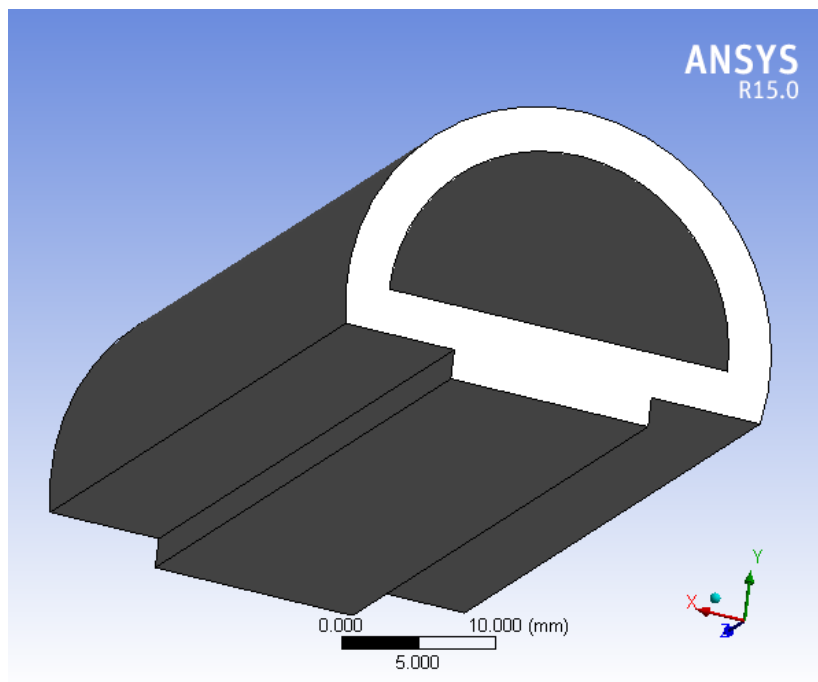


Figure 5.1: Model of a car door seal (D5)

Table 5.2: Unit systems of door seal

Unit System	Metric (mm, kg, N, s, mV, (mA)) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

In this table the unit systems of door seal are listed, where the unit system, angle, rotational velocity and temperature are given there by.

Table 5.1: Geometry of door seal

Object Name	Geometry
State	Fully Defined
Definition	
Source	C:\pavn\dtype.igs
Type	Iges
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	30. mm
Length Y	20. mm
Length Z	50. mm
Properties	
Volume	12231 mm ³
Mass	9.6017e-002 kg
Scale Factor Value	1.
Statistics	
Bodies	1
Active Bodies	1
Nodes	3686

Elements	578
Mesh Metric	None
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	No
Parameters	Yes
Parameter Key	DS
Attributes	No
Named Selections	No
Material Properties	No
Advanced Geometry Options	
Use Associatively	Yes
Coordinate Systems	No
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	No
Co (MPa)re Parts on Update	No
Attach File Via Temp File	Yes
Temporary Directory	C:\Users\CADDLAB\AppData\Local\Temp
Analysis Type	3-D
Mixed Import Resolution	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

In this table the components of geometry of door seal are listed above, where the definition, bounding box, properties, statistics, basic geometry options and advanced geometry options are elaborated in this table.

Table 5.2: Parts of MSBR

Object Name	MSBR
State	Meshed

Graphics Properties	
Visible	Yes
Glow	0
Shininess	1
Transparency	1
Secularity	1
Definition	
Suppressed	No
ID (Beta)	16
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Material	
Assignment	Polyabs F20
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	30. mm
Length Y	20. mm
Length Z	50. mm
Properties	
Volume	12231 mm ³
Mass	9.6017e-002 kg
Centroid X	-2.7126e-016 mm
Centroid Y	3.4658 mm
Centroid Z	25. mm
Moment of Inertia Ip1	23.642 kg·mm ²
Moment of Inertia Ip2	27.259 kg·mm ²
Moment of Inertia Ip3	11.004 kg·mm ²
Statistics	
Nodes	3686
Elements	578

Mesh Metric	None
-------------	------

The above table defines the parts of MSBR, where the graphical properties, definition, material, bounding box, properties and statistics are briefed and detailed.

Table 5.3: Coordinate systems of door seal

Object Name	Global Coordinate System
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0.
Origin	
Origin X	0. mm
Origin Y	0. mm
Origin Z	0. mm
Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]

This table defines the coordinate systems of door seal. The definition, origin and directorial vectors of the system is detailed.

Table 5.4: Properties of mesh

Object Name	Mesh
State	Solved
Defaults	
Physics Preference	Mechanical
Relevance	0
Sizing	
Use Advanced Size Function	Off

Relevance Center	Coarse
Element Size	Default
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Fast
Span Angle Center	Coarse
Minimum Edge Length	2.0 mm
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Patch Conforming Options	
Triangle Surface Mesher	Program Controlled
Patch Independent Options	
Topology Checking	Yes
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Shape Checking	Standard Mechanical
Element Mid side Nodes	Program Controlled
Straight Sided Elements	No
Number of Retries	Default (4)
Extra Retries for Assembly	Yes
Rigid Body Behavior	Dimensionally Reduced
Mesh Morphing	Disabled
De-featuring	
Pinch Tolerance	Please Define
Generate Pinch on Refresh	No

Automatic Mesh Based De-featuring	On
De-featuring Tolerance	Default
Statistics	
Nodes	3686
Elements	578
Mesh Metric	None

This table shows the properties of mesh, where the object name, defaults, sizing, inflation, patch conforming options, patch independent options, advanced properties, defeaturing properties and statistics are detailed in this table.

Table 5.5: Details of mesh analysis

Object Name	Modal (D5)
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Modal
Solver Target	Mechanical APDL
Options	
Environment Temperature	22. °C
Generate Input Only	No

This table shows the details of mesh analysis, where the object name, definition and options are detailed.

Table 5.6: Initial condition of mesh

Object Name	Pre-Stress (None)
State	Fully Defined
Definition	
Pre-Stress Environment	None

This table defines the initial conditions of mesh, where the object name, state, definition and pre-stress environment is briefed and detailed.

Table 5.7: Analysis settings of mesh analysis

Object Name	Analysis Settings
State	Fully Defined
Options	
Max Modes to Find	6
Limit Search to range	No
Solver Controls	
Damped	No
Solver Type	Program Controlled
Rotor dynamic Controls	
Coriolis Effect	Off
Campbell Diagram	Off
Output Controls	
Stress	No
Strain	No
Nodal Forces	No
Calculate Reactions	No
General Miscellaneous	No
Cache Results in Memory (Beta)	Never
Analysis Data Management	
Solver Files Directory	C:\Users\CADDLAB\AppData\Local\Temp\WB_CADDLAB-PC_CADDLAB_1684_2\unsaved project files\dp0\SYS-3\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL dB	No

Delete Un-needed Files	Yes
Solver Units	Active System
Solver Unit System	Nmm

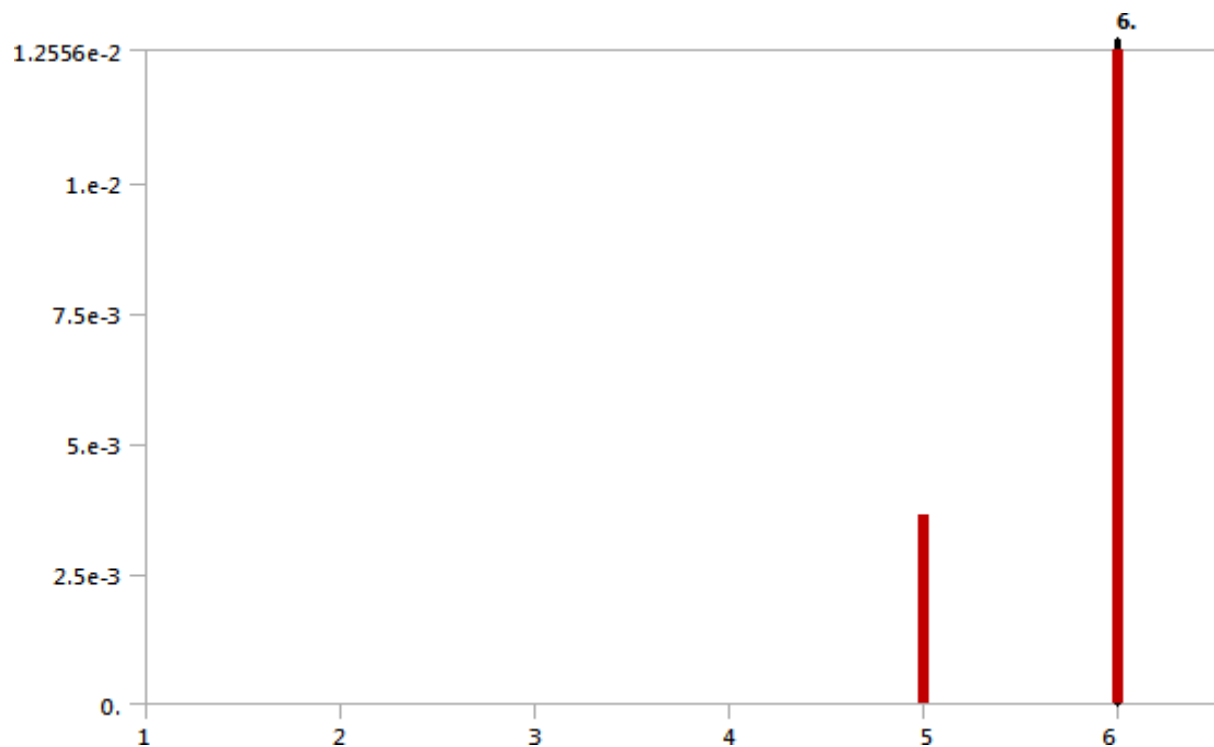
This table briefs the analysis settings of mesh analysis, where the object name, options, solver controls, rotor dynamic controls, output controls and analysis data management are detailed.

Table 5.8: Solution of mesh analysis

Object Name	Solution (D6)
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done

This table defines the solution of mesh analysis, where the object name, adaptive mesh refinement and information is detailed.

The following bar chart indicates the frequency at each calculated mode.



Graph 5.1: Solution of frequency of door seal

This graph defines the solution of the frequency of door seal in Hz. The minimum frequency value of car door seal is 0 and the maximum frequency value of car door seal is 1.2556e-002.

Table 5.9:Details of frequency

Mode	Frequency [Hz]
1.	0
2.	0
3.	0
4.	0
5.	3.6087e-003
6.	1.2556e-002

Table 5.10: Solution information of FE connectors

Object Name	Solution Information
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

This table defines the solution information of FE connectors, where the object name, solution information and FE connection visibility are detailed.

Table 5.11: Solution of steady state thermal

Object Name	Steady-State Thermal (E5)
State	Solved
Definition	
Physics Type	Thermal
Analysis Type	Steady-State
Solver Target	Mechanical APDL
Options	
Generate Input Only	No

This table defines the solution of steady state thermal, where the object name, definition and options are detailed.

Table 5.12: Initial condition of steady state thermal

Object Name	Initial Temperature
State	Fully Defined
Definition	
Initial Temperature	Uniform Temperature
Initial Temperature Value	22°C

This table defines the initial condition of steady state thermal, where the object name and definition are briefed and detailed.

Table 5.13: Analysis settings of steady state in Ansys

Object Name	Analysis Settings
State	Fully Defined
Step Controls	
Number of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Auto Time Stepping	
Solver Controls	
Solver Type	Program Controlled
Radiosity Controls	
Radiosity Solver	Program Controlled
Flux Convergence	1.e-004
Maximum Iteration	1000.
Solver Tolerance	1.e-007 W/mm ²
Over Relaxation	0.1
Hemi-cube Resolution	10.
Nonlinear Controls	

Heat Convergence	Program Controlled
Temperature Convergence	Program Controlled
Line Search	Program Controlled
Output Controls	
Calculate Thermal Flux	Yes
General Miscellaneous	No
Store Results At	All Time Points
Cache Results in Memory (Beta)	Never
Analysis Data Management	
Solver Files Directory	C:\Users\CADDLAB\AppData\Local\Temp\WB_CADDLAB-PC_CADDLAB_1684_2\unsaved project files\dp0\SYS-4\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL dB	No
Delete Un-needed Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	Nmm

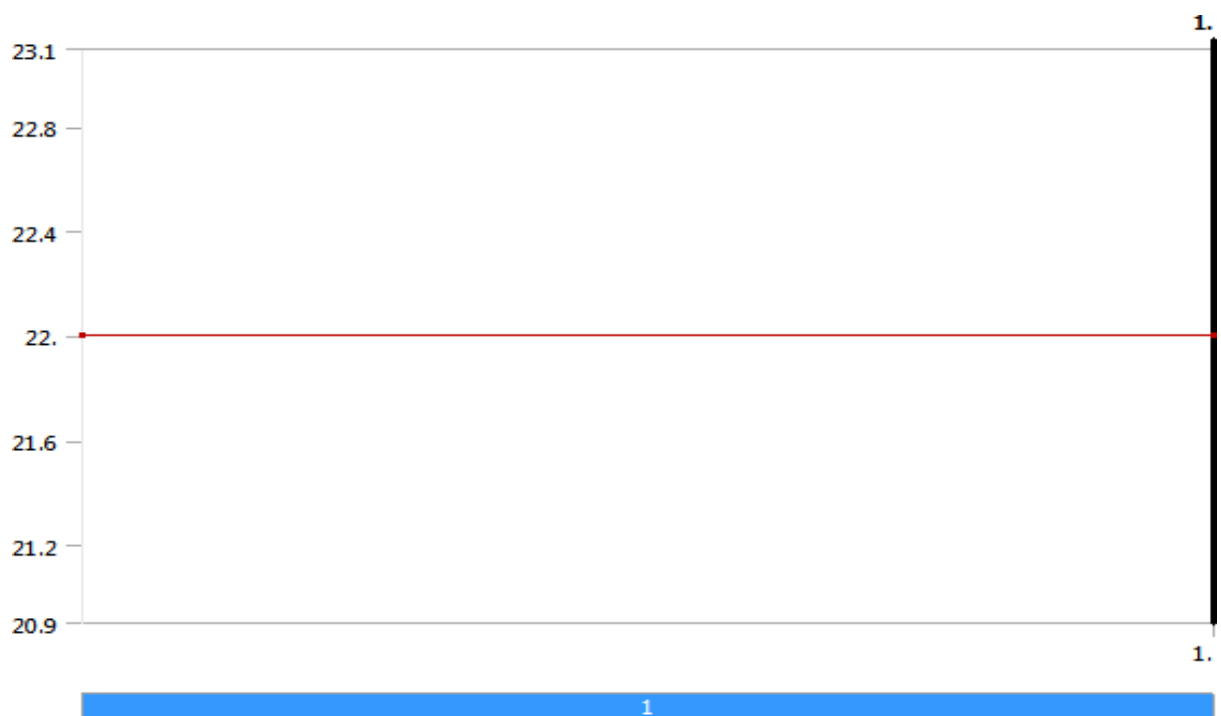
This table defines the analysis settings of steady state in Ansys, where the object name, step controls, solver controls, radiosity controls, non-linear controls, output controls and analysis data management are briefed and detailed.

Table 5.14: Steady-State thermal loads

Object Name	Temperature
State	Fully Defined
Scope	
Scoping Method	Geometry Selection

Geometry	1 Face
Definition	
ID (Beta)	34
Type	Temperature
Magnitude	22. °C (ramped)
Suppressed	No

This table shows the steady state thermal loads, where the object name, scope and definition are detailed.



Graph 5.2: Steady state thermal temperature

This graph shows us the steady state thermal temperature of car door seal is 22°C and it is considered as a normal room temperature inside the car cabin.

Table 5.17: Steady-State thermal solution

Object Name	<i>Solution (E6)</i>
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done

This table shows the steady state thermal solution, where the object name, adaptive mesh refinement and information are detailed.

Table 5.18: Results of Steady-State thermal temperature

Object Name	Solution Information
State	Solved
Solution Information	
Solution Output	Solver Output
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

This table defines the results of steady state thermal temperature, where the object name, solution information and FE connection visibility are detailed.

Table 5.19: Results of heat flux

Object Name	Total Heat Flux	Temperature
State	Solved	
Scope		
Scoping Method	Geometry Selection	
Geometry	All Bodies	
Shell	Top/Bottom	
Layer	Entire Section	
Definition		
Type	Total Heat Flux	Temperature
By	Time	
Display Time	Last	
Calculate Time History	Yes	
Identifier		
Suppressed	No	
Integration Point Results		
Display Option	Averaged	
Average Across Bodies	No	
Results		
Minimum	1.1574e-015 W/mm²	22. °C
Maximum	3.4013e-013 W/mm²	22. °C
Minimum Value Over Time		
Minimum	1.1574e-015 W/mm²	22. °C
Maximum	1.1574e-015 W/mm²	22. °C
Maximum Value Over Time		
Minimum	3.4013e-013	22. °C

	W/mm ²	
Maximum	3.4013e-013 W/mm ²	22. °C
Information		
Time	1. s	
Load Step	1	
Sub step	1	
Iteration Number	1	

This table shows the results of heat flux, where the object name, scope, definition, integration point results, results, minimum value over time, maximum value over time and information are detailed.

Table 5.20: Poly abs F20 constants

Density	7.85e-006 kg mm ⁻³
Coefficient of thermal expansion	1.2e-005 C ⁻¹
Specific Heat	4.34e+005 MJ kg ⁻¹ C ⁻¹
Thermal Conductivity	6.05e-002 W mm ⁻¹ C ⁻¹
Resistivity	1.7e-004-ohm mm

This table defines the F20 constants of Polyabs, where the density, coefficient of thermal expansion, specific heat, thermal conductivity and resistivity are detailed.

Table 5.21: Compressive ultimate strength of Polyabs F20

Compressive Ultimate Strength (MPa)
0

Table 5.22: Compressive yield strength of Polyabs F20

Compressive Yield Strength (MPa)
250

Table 5.23: Tensile yield strength of Polyabs F20

Tensile Yield Strength (MPa)
250

Table 5.24: Ultimate strength of Polyabs F20

Tensile Ultimate Strength (MPa)
460

Table 5.25: Thermal expansion of Polyabs F20

Reference Temperature C
22

Table 5.26: Alternating stress mean stress of Polyabs F20

Alternating Stress (MPa)	Cycles	Mean Stress (MPa)
3999	10	0
2827	20	0
1896	50	0
1413	100	0
1069	200	0
441	2000	0
262	10000	0
214	20000	0
138	1.e+005	0
114	2.e+005	0
86.2	1.e+006	0

This table shows the alternating stress mean stress of Polyabs F20, where the alternating stress, cycles and mean stress are detailed.

Table 5.27: Strain-Life parameters of Polyabs F20

Strength coefficient (MPa)	920
Strength exponent	-0.106
Ductility coefficient	0.213
Ductility exponent	-0.47
Cyclic strength coefficient (MPa)	1000
Cyclic strain hardening exponent	0.2

This table defines the strain life parameters of Polyabs F20, where the strength coefficient, strength exponent, ductility coefficient, ductility exponent, cyclic strength coefficient and cyclic strain hardening exponent are detailed.

Table 5.28: Isotropic elasticity of Polyabs F20

Temperature C	30°C
Young's modulus (MPa)	2.e+005
Poisson's ratio	0.3
Bulk modulus (MPa)	1.6667e+005
Shear modulus (MPa)	76923

This table shows the isotropic elasticity of Polyabs F20, where the temperature C, young's modulus, Poisson's ratio, bulk modulus and shear modulus are detailed.

Table 5.29: Isotropic relative permeability of Polyabs F20

Relative Permeability
10000

Table 5.30: Analysis of environment temperature

Object Name	Modal (F5)
State	Not Solved
Definition	
Physics Type	Structural

Analysis Type	Modal
Solver Target	Mechanical APDL
Options	
Environment Temperature	22. °C
Generate Input Only	No

This table defines the analysis of environment temperature, where the object name, definition and options are detailed.

Table 5.31: Initial condition of pre-stress

Object Name	Pre-Stress (None)
State	Fully Defined
Definition	
Pre-Stress Environment	None

This table defines the initial condition of pre-stress, where the object name, state, definition and pre-stress environment are detailed.

Table 5.32: Analysis settings of controls

Object Name	Analysis Settings
State	Fully Defined
Options	
Max Modes to Find	6
Limit Search to Range	No
Solver Controls	
Damped	No
Solver Type	Program Controlled
Rotor dynamics Controls	
Coriolis Effect	Off
Campbell Diagram	Off
Output Controls	
Stress	No
Strain	No

Nodal Forces	No
Calculate Reactions	No
General Miscellaneous	No
Cache Results in Memory (Beta)	Never
Analysis Data Management	
Solver Files Directory	C:\Users\CADDLAB\AppData\Local\Temp\WB_CADDLAB-PC_CADDLAB_1684_2\unsaved project files\dp0\SYS-5\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL dB	No
Delete Unneeded Files	Yes
Solver Units	Active System
Solver Unit System	Nmm

This table defines the analysis settings of controls, where the object name, options, solver controls, rotor dynamic controls, output controls and analysis data management are detailed.

Table 5.33: Solution of adaptive mesh refinement

Object Name	Solution (F6)
State	Not Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Solve Required

This table defines the solution of adaptive mesh refinement, where the object name, state, adaptive mesh refinement, max refinement loops, refinement depth, information and status are detailed.

Table 5.34: Solution of FE connection visibility

Object Name	Solution Information
State	Not Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

This table defines the solution of Fe connection visibility, where the object name, solution information and FE connection visibility are detailed.

Table 5.35: Static structural Analysis

Object Name	Static Structural (G5)
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	

Environment Temperature	22. °C
Generate Input Only	No

This table defines the static structural analysis, where the object name, definition and options are detailed.

Table 5.36: Static structural analysis of data management

Object name	Analysis Settings
State	Fully defined
Step controls	
Number of steps	1
Current step number	1
Step end time	1.s
Time stepping	Program controlled
Solver controls	
Solver type	Program controlled
Weak springs	Program controlled
Large deflection	Off
Restart controls	
Generate restart points	Program controlled
Retain files after full solve	No
Non-linear controls	
Newton-Raphson option	Program controlled
Force convergence	Program controlled

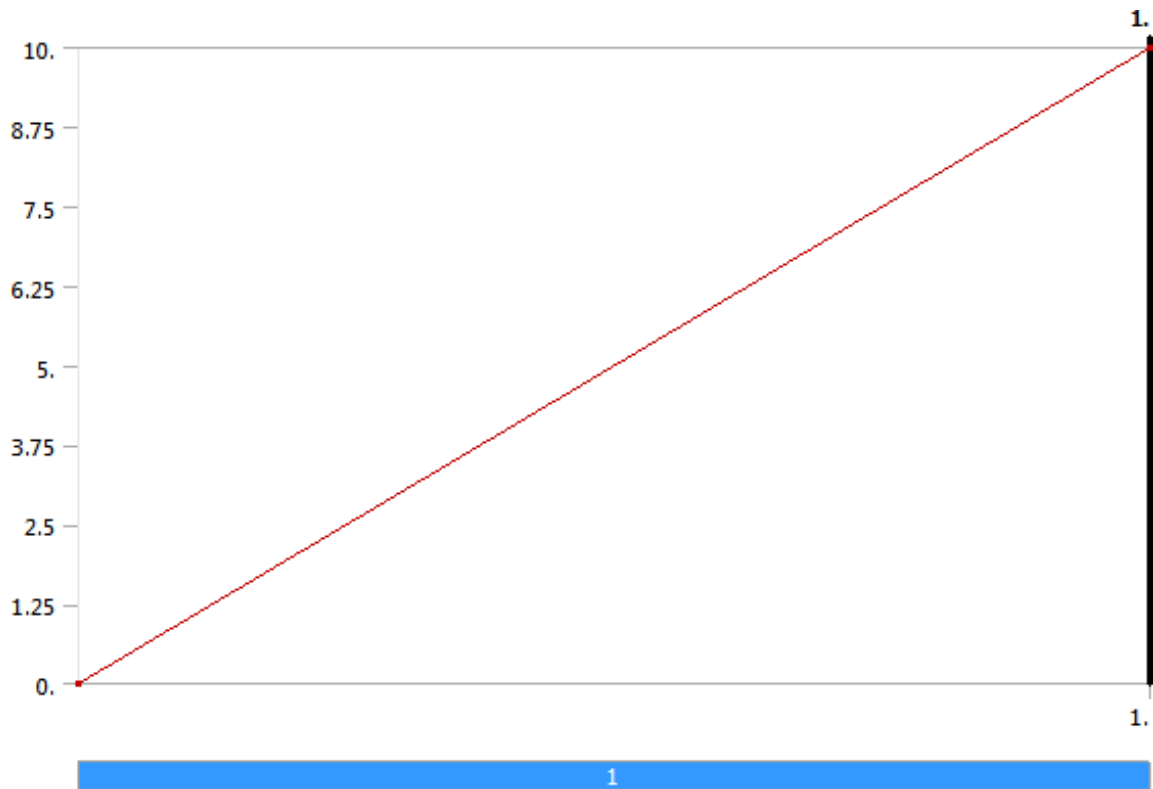
Moment convergence	Program controlled
Displacement convergence	Program controlled
Rotation convergence	Program controlled
Line search	Program controlled
Stabilization	Off
Output Controls	
Stress	Yes
Strain	Yes
Nodal forces	No
Contact miscellaneous	No
General miscellaneous	No
Store results at	All time points
Cache results in memory (beta)	Never
Analysis Data Management	
Solver files	C:\users\CADDLAB\unsaved project
Future analysis	None

This table defines the static structural analysis of data management, where the object name, step controls, solver controls, restart controls, non-linear controls, output controls and analysis data management are detailed.

Table 5.37: Static structural loads

Object Name	Pressure	Fixed Support
State	Fully Defined	
Scope		
Scoping Method	Geometry Selection	
Geometry	1 Face	5 Faces
Definition		
ID (Beta)	30	32
Type	Pressure	Fixed Support
Defined by	Vector	
Magnitude	10.(MPa) (Ramped)	
Direction	Defined	
Suppressed	No	

This table defines the static structural loads, where the object name, scope, geometry, definition, pressure and defined by are detailed.



Graph 5.3: Static structural pressure

This graph defines the static structural pressure of car door seal and the velocity of car increases with the structural pressure simultaneously.

Table 5.38: Static structural solution of mesh refinement

Object Name		Solution (G6)
State		Solved
	Adaptive Mesh Refinement	
Max Refinement Loops		1.
Refinement Depth		2.
	Information	
Status		Done

This table defines the static structural solution of mesh refinement, where the object name, adaptive mesh refinement and information are briefed and detailed.

Table 5.39: Static structural solution analysis

Object Name	Solution Information
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Update Interval	2.5 s
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

This table defines the static structural solution analysis, where the object name, solution information and FE connection visibility are detailed.

TOTAL DEFORMATION

SHEAR ELASTIC STRAIN

SHEAR ELASTIC STRESS

Table 5.40: Analysis of TD, Shear elastic stress

Object name	Total deformation, shear elastic strain, shear stress
State	Solved
Scope	
Scoping method	Geometry selection
Geometry	All bodies
Shell	Top/bottom
layer	Entire section
Definition	

Type	Total deformation, shear elastic strain, shear stress
By	Time
Display time	Last
Calculate history	Yes
Identifier	
suppressed	No
Orientation	XY plane
Coordinate system	Global co-ordinate system
Results	
Minimum	0 mm
Maximum	1.7217e-002 mm
Information	
Time	1. s
Load step	1
Sub step	1
Iteration number	1
Integration point results	
Display option	Averaged
Average across bodies	No

This table defines the analysis of TD, shear elastic stress, where the object name, scope, definition, results, information and integration point results are detailed.

5.41: Shear modulus of Polyabs F20

Temperature C	Young's Modulus (MPa)	Poisson's Ratio	Bulk Modulus (MPa)	Shear Modulus (MPa)
	2e+005	0.3	1.6667e+005	76923

This table defines the shear modulus of Polyabs F20, where the temperature, young's modulus, Poisson's ratio, bulk modulus and shear modulus are detailed.

Table 5.42: Relative permeability

Relative Permeability
10000

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 SUMMARY

In this project, we have changed the existing door seal with a new door seal made with a F20 polymer material for more durable and long-lasting performance. With help of these, several analyses done on the ANSYS workbench have given clear output that the F20 polymer is a very durable material.

The analyses done on the Ansys workbench are as follows: -

- Noise analysis
- Pressure analysis
- Compression ratio analysis
- Total deformation analysis
- Shear elastic strain analysis
- Shear stress analysis
- Heat flow analysis

6.2 CONCLUSION

We finally conclude saying that, door seal material made up of F20 polymer is a very durable material as well long-lasting material and also can withstand heavy loads and vibrations applied on the door seal. In addition, the outputs retrieved in the Ansys workbench analyses have given us an idea to conclude that our material is stronger and more durable than the older door seals made up of rubber material.

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