Front Fork Oil Seal Analysis

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FRONT FORK OIL SEAL ANALYSIS

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Abstract.. Front fork is one of the part of suspension system. Front fork serves as rigidity component just like a frame in two and three wheeler vehicle. As it is an important part of the suspension system but the manufacturers of front fork assembly is facing the leakage problem. The purpose of the study is to detect and reduce M8 leakages in front fork assembly and to reduce the rejection rate due to leakages.

In this study also the analysis of different materials when used for manufacturing of oil seal has been carried and also the theoretical as well analytical analysis has been done. For analytical analysis Ansys workbench ver.2022 has been used.

There are various parameters responsible for M8 leakages in front fork assembly, few parameters like pressure and torque contributes to more rejection rate. So, these parameters are considered for study. This study and analysis of the parameters, will not only help to increase the profit of the company but also help to improve the quality of front forks assembly

Main text

Gabriel India Limited is the flagship company of ANAND and a leading name in the Indian Auto Company Industry. Established in 24 February 1961, the company provides the widest range of ride control products in India, including Shock Absorbers, Struts, and Front Forks, across every automotive segment with over 300 product models offered. Gabriel India Limited has located in various location such as Nasik Maharashtra, Devas Madhya Pradesh, Gurgaon Haryana, Pune Maharashtra, Parwanoo Himachal Pradesh, Hosur Tamil Nadu, Noida Uttar Pradesh, Ahmedabad Gujarat, Mumbai Maharashtra.

Every new technology is being developed and hence the competition is increased a lot. In order to survive in this competitive world there should be fast growth in company Quality with higher accuracy. After finishing our sixth semester exam we were recruited for the industrial training in "GABRIEL" India Limited Nasik Maharashtra.

In that company there are two shops, the first one is 'Front Fork' & the second one is 'Shock Absorbers'. We were in Shock Absorber division. In shock absorber there are two lines i.e. Assembly line and Production Line. We worked on both lines. In shock absorber, there are 3 main parts such as Outer tube, Inner tube and Piston rod assembly. During our training period we noticed the Hard Movement issue in shock damper assembly is more in all defect. From all these problems, we selected Hard Movement problem for our project. Shock absorber is used in suspension system of all vehicles to reduce the vibration occurring due to the uneven roads and balancing of vehicle is properly done.

It has been studied that the most of the front fork assembly parts are rejected due to the M8 leakages. According to the company production data available and the discussion with concerned authority, the rejection rate due to M8 leakages is around 5% of total production. The main aim of the project is to find solutions to reduce the number of rejections due M8 leakages. The analysis helps to increase the production of front

fork of any company. It would help to reduce the rework cost and increase the customer satisfaction for the product. The scope of the project is to study the process of the assembly line and study the various parameters that might affect the leakages in front fork.

Nomenclature			
I/T	Inner Tube	Kg/m^3	Kilogram per Meter Cube
O/T	Outer Tube	H_2S	Hydrogen Sulphide
$Kg\ Cm$	Kilogram Centimeter Torque Unit	CO_2	Carbon-di-oxide
Bar	PressureUnit	d_m	Diameter of Oil Seal
Φ	Diameter	t_m	Minimum Thickness
$IGES$	Initial Graphics Exchange	P	Pressure
N	Force in Newton	W	Weight
HO	Higher Order	σ_w	Longitudenal Stress
$N/Sq.M$	Newton per Square Meter	σ_x	Stress
ISO	International Organization of Standardization	σ_{eq}	Equivalent Stress
SAE	Society of Automotive Engineers	σ_c	Hooke's Stress
$lb/ln3$	Pound per Cubic Inch	σ_b	Bending Stress
$°C$	Degree Celsius	σ_R	Radial Stress
$°F$	Degree Ferranite	Mpa	Megapascal

Methodology

Considering the problem statement of this project, the production data has been collected from the production catalogue and analyzed by various statistical and analytical tools. The various leakage problems can be identified by study, observation and past history of production line. The important factors affecting the leakage can be identified by reliability analysis. After identifying the most important reason of leakage, the appropriate solution will be implemented reduce the rejection rate and ultimately to increase productivity.

2.1 Problem Selection:-

In company, there were two shops the first one is 'Front Fork' and the second one is 'Shocks'. We were in the Front Fork division. In Shock Assembly there were also lines i.e. Assembly Line & Production. We had worked in both Production as well as Assembly line for 'M8 Oil Leakages. During our training period, we had identified various problem in some machine and collect the data for rejection work. From these all the problems, we have selected one problem for our project i.e. M8 Oil Leakagae in Front Fork Assembly.

Before some months, the M8 Oil Leakages rejection were more coming in the company. The Hard Movement will come due to many reasons which has been listed above. This was a big problem for the company. This would may also affect the company's reputation in the market. There was 1.11 percent rejection work which was the main disadvantage forming for all the defect in shock absorber cell. Due to M8 Oil Leakage, there was 0.45 percent rejection work.

After selection of the problem we started to find the cause because of problem occurs. Then after finding the cause because of which the problem occurs; we started to find out the root cause of M8 Oil Leakage and jerky due to incomplete seal pressing in seal pressing machine. The machine is special purpose machine so only one operation was conducted on that machine. We also observed each and every process which was

carried out on different machine carefully in the assembly cell and find the cause to incomplete seal pressing and alignment in seal pressing is not good.

2.2. List of Problems Identified:-

1) The case cap was not ok or missing in the shock damper assembly:
   Cause: Human error or machine error.
2) Hard movement / Jerk in shock damper assembly:
   Cause: Child part was not as per drawing.
3) Inner tube or piston not ok:
   Cause: Spindle T.I.R. not ok.
4) Inner diameter not ok:
   Cause: Ball burnishing (from supplier side was not done/ok).
   It was detected after the assembly of the shock absorber.
5) Piston rod run out:
   Cause: Burr & chips accumulation in collet.
6) Oil quantity not ok:
   Cause: Filling excess or less quantity of oil in the outer tube due to manual setting in machine.

2.3. Problem Definition:-

Earlier in the company on shock damper assembly cell, there was machining operation done. Due to this operation, some Hard Movement will come. The Hard Movement was also come due to raw material. For raw material, the certain parameter was wrong. Due to this, Hard Movement was coming. For overall rejection (4508), the quality of Hard Movement is 2540 in shock damper assembly. If 1piece price is 200 then Rs. 5,08,000 are utilized for rework per month which was main disadvantage for company.

2.4. Objective:-
1)   To collect and analyze data related to front fork assembly.
2)   To identify various leakaging causes.
3)   To focus on the major problems and finding its solution.
4)   To reduce the leakages in the Front Fork assembly and rejection rate of the product.
5)   To increase the productivity of the company.
6)   To analyze the oil seal parameters with different materials and to carry ou the numerical as well simulation analysis of oil seal.

2.5. Steps involved in Problem Study:-
i.   Define the problem, improvement activity, opportunity for improvement, the project goals, and customer (internal and external) requirements.
ii.   Measure process performance.
iii. Analyze the process to determine root causes of variation, poor performance
iv.   Improve process performance by addressing and eliminating the root causes.
v.   Control the improved process and future process performance.
vi.   Also we will be carrying out the numerical analysis of oil seal and comparing the same with the analytical results along with the different materials.

3. SOLUTION

For numerical analysis of the oil seal we will doing the analysis as similar to pressure acting inside the hollow cylinder.

3.1. Numerical Analysis of Oil Seal

Oil Seal numerical analysis is being carried out to find the Longitudinal, Bending and Shear Stress. For this the diameter and thickness of oil seal is taken into consideration with pressure acting on oil seal, from which the Bending Stress, Shear Stress and Von-Misses Stress can be calculated. Figure 3.1. shows the forces acting on oil seal inert surface for which the further calculations are carried out.[Design of Pressure Vessel from PED book]

Diameter of Oil Seal, d_m = 1.50" = 38.1mm & Thickness/Length, t = 0.24" = 6.096mm(Company Ref.)

$$t = \frac{PR}{SE - 0.6P} = \frac{0.33 * \frac{38.1}{2}}{130 * 0.85 - 0.6 * 0.33} = 0.5699 mm.$$

Minimum thickness, t_{min}. "P" is the pressure acting due to oil on oil seal internal zone and "W" is the weight of the oil seal. Now, we will be calculating the different stresses acting on the oil seal.

Stress Calculation, Hook's Stress, $\sigma_c = \frac{P(d+t)}{4*6} = \frac{0.32(38.1+6)}{4*6} = 0.606 Mpa$

a) Longitudinal Stress is defined as the stress produced when a oil seal is subjected to internal pressure. The direction of the longitudinal stress in a oil seal is parallel to the longitudinal axis of its centerline axis, which means that the stress acts in the direction of the oil seal's width. Longitudinal stresses are classed as normal stresses and are tensile.

Longitudinal Stress due to weight of Oil Seal, $\sigma_{wt} = \frac{W}{\pi * d_m * t} = \frac{0.096 * 10}{\pi * (38.1+6) * 6} = 1.154 * 10^{-3} Mpa$

b) Bending stress is the normal stress that an object encounters when it is subjected to a large load at a particular point that causes the object to bend and become fatigued.

Bending Stress in Oil Seal, $\sigma_b = \frac{M}{\pi/4 * d_m^2 * t} = \frac{185 * 10^3}{\pi/4 * (38.1+6)^2 * 6} = 20.186 Mpa$

c) Shear Stress is the external force acting on an object or surface parallel to the slope or plane in which it lies; the stress tending to produce shear.

Shear Stress Offset Torque = T=500Nm $\tau = \frac{T}{\pi/2 * d_m^2 * t} = \frac{556 * 10^3}{\pi/2 * (38.1+6)^2 * 6} = 30.33$

Stresses, $\sigma_x = \sigma_L - \sigma_w + \sigma_b = 32.055 - (1.154 * 10^{-3}) + 20.186$ $\sigma_x = 52.23$ Mpa

$\sigma_y = \sigma_c = 0.606 Mpa$

Assuming Principle Stress Theory, $\sigma_1 = \frac{\sigma_x + \sigma_y}{2} + \sqrt{(\frac{\sigma_x - \sigma_y}{2})^2 + \tau^2}$

$\sigma_1 = \frac{52.23 + 0.606}{2} + \sqrt{(\frac{52.23 - 0.606}{2})^2 + 30.33^2}$ $\sigma_1 = 66.244$

Assuming Von-Misses Theory, Equivalent Stress, $\sigma_{eq} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau^2}$

$\sigma_{eq} = \sqrt{32.93^2 + 0.606^2 - 32.93 * 0.606 + 3 * 27.27^2} = 57.408$ MPa

Stresses due to External Pressure,

d) Circumferential or Hoop Stress: This is the stress which is set up in resisting the bursting effect of the applied internal pressure and can be most conveniently treated by considering the equilibrium of the cylinder. Circumferential Stress, $\sigma_c = \frac{P_o * D_o}{2t} = \frac{0.33 * 38.1}{2 * 6.096}$

Longitudenal Stress, $\sigma_L = \frac{P_o * D_o}{4t} = \frac{0.33 * 38.1}{4 * 6.096}$

e) Radial stress in a pipe can be defined as the effective stress acting in the radial direction i.e. the direction perpendicular to the longitudinal axis of the pipe. Radial Stress, $\sigma_R = -P_o = -0.33$

Hence, finally we have calculated the stress values of the oil seal. Now in Ansys 2022 version we will see the simulation of the same.

Now for the analytical solution we will be first designing the oil seal in the solidworks for which 2021 version has been used. The design of oil seal and the sheet for the same is as shown in figure 3.2. and 3.3. respectively.
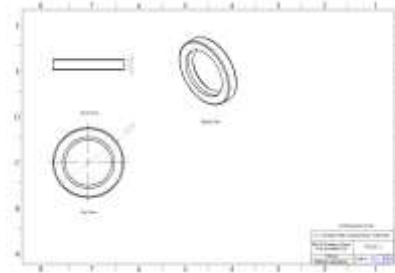

Figure.3.2. Oil Seal Design in Solidworks   Figure.3.3. Oil Seal Sheet in Solidworks

For the oil seal analysis in Ansys workbench we will convert the solidworks file to IGES file format. First for the analysis of oil seal we will create the model of oil seal in solid-works(2020 version used) as in figure[3.2.] and convert that model to IGES File for analysis in ansys Total Deformation of oil seal is carried out for the oil seal pressure analysis acting as shown in figure(iii). Oil Seal stress analysis is as shown in figure[3.1(iv, v and vi)]
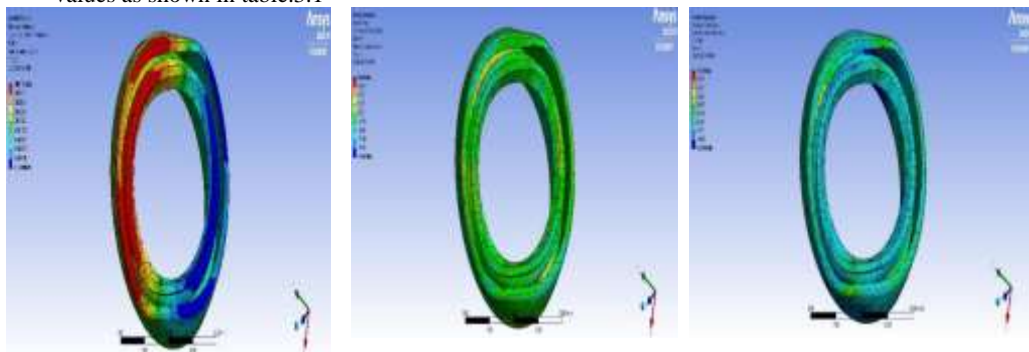

Oil Seal IGES File(i)   Oil Seal Mesh(ii)   Oil Seal Fixed Support(iii)

i.   Fix the one end of the oil seal as in(iii).
ii.   Force are exerted on the other end of the oil seal a.
iii. Finally, after applying the forces on the oil seal and fixing the end of the oil seal stress values are calculated figure(iv), (v) & (vi) respectively and also compared with the analytical values as shown in table.3.1

Oil Seal Longitudenal Stress(iv)   Oil Seal Bending Stress (v)   Oil Seal Shear Stress(vi)

Figure.3.4. Oil Seal Analysis in Ansys Workbench

Table3.1.Oil Seal Analysis

Results(Mpa)	Analytical	Simualtion
Longitudenal Stress	0.001154	0.0011604
Bending Stress	20.186	20.614
Shear Stress	30.33	30.334

Comparative analysis of oil seal with different materials is carried out for Rubber, Neoprene-Rubber, Polyethylene, Silicon and PCB Laminate as shown in table 6.3.Table.3.2. Oil Seal Material Wise Comparison

Results(Mpa)/ Materials	Rubber		Neoprene-Rubber		Polyethylene		Silicon(Pure)		PCB Laminate	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
Longitudenal Stress	0.0011604	-0.001171	11.215	-9.9777	0.001388	-0.00139	1.083	-1.0279	0.00286	-0.00828
Bending Stress	20.61	-19.397	-	-	17.69	-17.796	187.46	-297.81	14.845	-14.866
Shear Stress	30.334	0.12416	-	-	25.533	0.31466	278.44	10.231	25.702	0.362

Table7.1. shows the cost analysis of oil seal when different materials used for manufacturing of the oil seal. With the help of this analysis Cost of raw material, material wise is calculated from which rejections and rework cost is calculated for a lot of 100 productions.

From the above analysis we can see that the silicon material can be also used for manufacturing of oil seal cause of which the rejection and rework cost as well be reduced.Table.3.3. Cost Analysis of Oil Seal

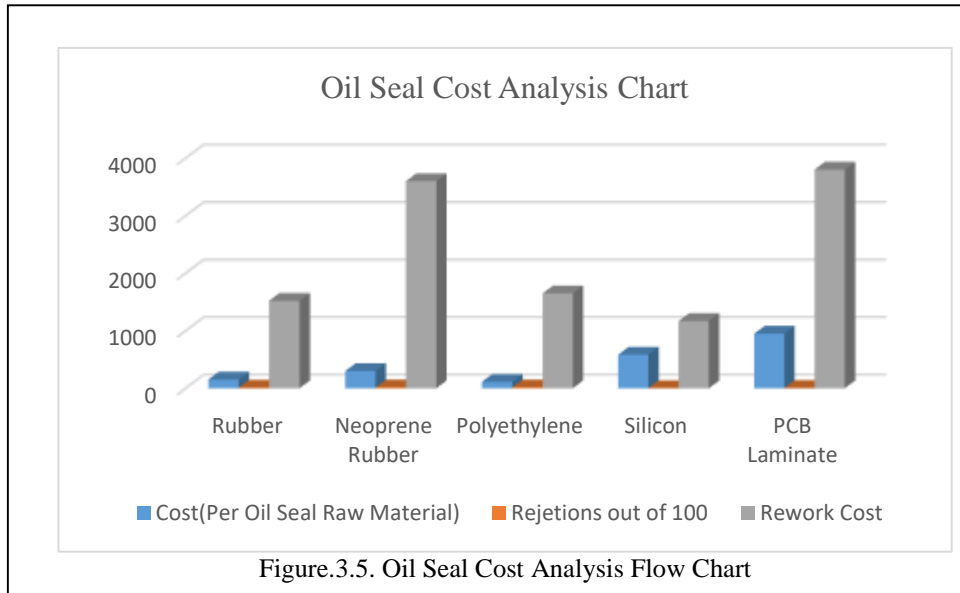| Material	Cost(Per Oil Seal Raw Material)	Rejections out of 100	Rework Cost
Rubber	152	10	1520
Neoprene Rubber	300	12	3600
Polyethylene	110	15	1650
Silicon	585	2	1170
PCB Laminate	950	4	3800

Figure.3.5. Oil Seal Cost Analysis Flow Chart
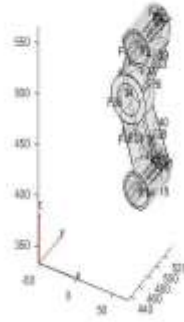
3.1. MATLAB Code for Analysis

```
model = createpde;
importGeometry(model,'Front Fork Tube.STL');
mesh=generateMesh(model,'Hmax',20,'GeometricOrder','linear');
pdeplot3D(model)
structuralmodel=createpde('structural');
importGeometry(structuralmodel,'Front Fork Tube.STL');
pdegplot(structuralmodel,'FaceLabel','on','FaceAlpha',0.5)
axis equal
generateMesh(structuralmodel);
structuralProperties(structuralmodel,'PoissonsRatio',0.3,'YoungsModulus',210E3);
structuralBC(structuralmodel,'Face',6,'Constraint','fixed');
structuralBoundaryLoad(structuralmodel,'Face',5,'SurfaceTraction',[0;0;-2]);
generateMesh(structuralmodel);
structuralresults = solve(structuralmodel);
figure
pdeplot3D(structuralmodel,'ColorMapData',structuralresults.VonMisesStress,'Deformation',structuralre-
sults.Displacement)
figure
pdeplot3D(structuralmodel,'ColorMapData',structuralresults.VonMisesStress,'Deformation',structuralre-
sults.Displacement,'DeformationScaleFactor',500)
```
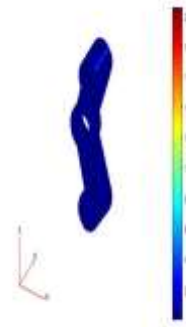
Similarly, by changing the part model we can do the analysis for other parts too.
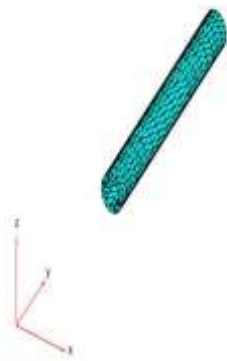
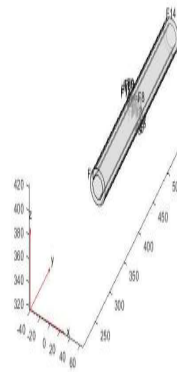Front Fork Connector Mesh(i)   Front Fork Connector Plot(ii)   Front Fork Connector Analysis(iii)
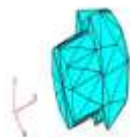

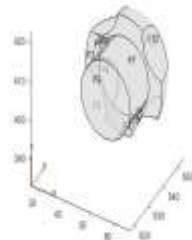Front Fork Piston Rod Mesh(i)   Front Fork Piston Rod Plot(ii)   Front Fork Piston Rod Analysis(iii)
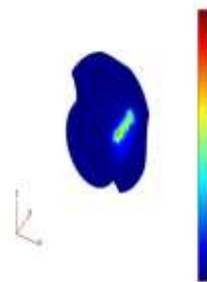

Front Fork Socket Bolt Mesh(vii)   Front Fork Socket Bolt Plot(viii)   Front Fork Socket Bolt
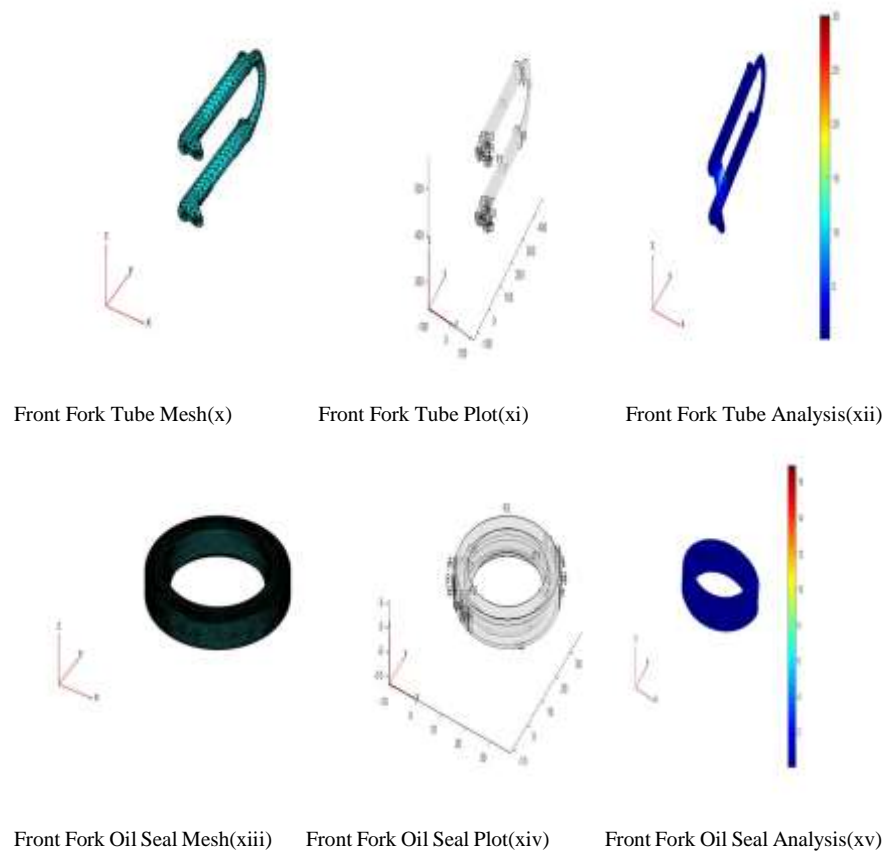
Analysis(ix)

Front Fork Tube Mesh(x)   Front Fork Tube Plot(xi)   Front Fork Tube Analysis(xii)

Front Fork Oil Seal Mesh(xiii)   Front Fork Oil Seal Plot(xiv)   Front Fork Oil Seal Analysis(xv)

Figure.3.6. Front Fork Parts and Oil Seal Analysis in MATLAB`

4. CONCLUSION AND FUTURESCOPE

- This project was carried out in GABRIEL INDIA LIMITED, NASHIK.
- The identification and analysis of various parameters which affects the leakage in front fork assembly is studied and out of this, two parameters which is majorly contributing to leakage was studied deeply and subsequent solution is found.
- By applying that solutions, the leakage which was 5% of the total production is reduced to 1% of the total production.
- Thus, the aim of the study project was to help company to increase their productivity by solving the leakage problems.
- Theoretical and Analytical analysis of Oil Seal and Different Materials effect on Oil Seal manufacturing has been carried out.
- Also the analysis of Front Fork and Oil Seal carried out in Ansys Workbench 2022 version and MATLAB too.
- Hence, Silicon can be considered as more preferable material for manufacturing of oil seal due to its stress factor and rejection rates.

Conclusion:- The identification and analysis of various parameters which affects the leakage in front fork assembly is studied and out of this, two parameters which is majorly contributing to leakage was studied deeply and subsequent solution is found.

Future Scope:-
This project monitoring can be used to design a real-time intelligent pipeline leak detection and localisation system.
Extensive simulation and practical experiments can be conducted to study the effects of leakage parameters, like size and shape, on the flow mechanism and validate different material models.
The COVID-19 pandemic has negatively impacted the oil seals market, witnessing a significant plunge in 2020. With a number of end users affected in regions like North America, Europe and Asia-Pacific, the supply and shortage in demand are expected to result in a significant drop in Y-O-Y growth, yet FMI expects global oil seals market to grow at 3.3% CAGR through 2031.

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[8]   https://drive.google.com/drive/folders/1MxNwIN3H_5J12kievkwoZc88vNwqkW9c(Google Drive Link)

[9]   https://m.youtube.com/watch?v=ZuNa7sgzlHQ&feature=youtu.be

[10]   https://www.youtube.com/watch?v=ZuNa7sgzlHQ(Front Fork Solidworks Design)

[11]   https://www.youtube.com/watch?v=dIuf6MiNqzc(Front Fork Solidworks Analysis)

[12]   https://www.youtube.com/watch?v=kmh_fAoxik8(CFD Analysis)

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