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DESIGN WEIGHT OPTIMIZATION AND THERMAL STRESS ANALYSIS OF OIL PAN BY FE ANALYSIS

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***Abstract*—** In an internal combustion engine of the reciprocating type the oil pan is the housing of the crankshaft. The enclosure forms the largest cavity in the engine and is located below the cylinder(s) which in a multi cylinder engine are usually integrated in to one or several cylinder blocks. Oil pan is located at the bottom of engine. It is used to store the engine oil. Oil will be pumped to the engine from the oil pan when required.

In this project modeling of oil pan used in heavy duty truck engine will be done. The aim of the project is to model Oil pan using CAD software solidworks2016 by using various tools and commands, than will perform transient thermal analysis in ansys workbench software to find out temperature distribution and heat flux throughout the surface area of oil pan due to hot oil, than will transfer the transient thermal solution data to static structural analysis module to find out the thermal stress and deformation due to thermal load on oil pan , analysis will perform on two different light weight material and will conclude the best material which can give better result of strength to weight ratio based on thermal load and thermal stresses.

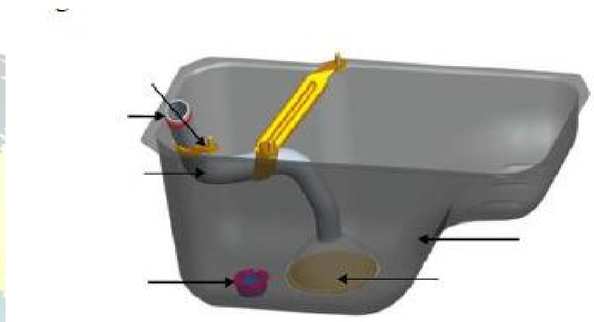

Fig: Oil pan model.

INTRODUCTION TO OIL-PAN

An oil pan is a component that typically seals the bottom side of four-stroke, internal combustion engines in automotive and other similar applications. While it is known as an oil pan in the U.S., other parts of the world may call it an oil sump. Its main purpose is to form the bottommost part of the crankcase and to contain the engine oil before and after it has been circulated through the engine. When an oil pan is removed, some components revealed usually include the crankshaft, oil pickup, and the bottom end of the dipstick.

During normal engine operation, an oil pump will draw oil from the pan and circulate it through the engine, where it is used to lubricate all the various components. After the oil has passed through the engine, it is allowed to return to the oil pan. In a wet sump system like this, the amount of oil that an engine can hold is directly related to the size of the oil pan. An engine can hold no more oil than can fit in the pan without reaching the crankshaft, since a submerged crankshaft will tend to aerate the oil, making it difficult or impossible for the oil pump to circulate it through the engine.

Fig: oil pan with oil

The drain plug used to change the engine oil is typically located somewhere on the oil pan. An easy way to locate an oil drain plug is to find the pan and then look for its lowest point. The pan may be slanted, have a bulge on one end, or be at a slight angle due to the position of the engine. This low point is usually where the drain plug is located so that nearly all of the oil in the pan can be drained through it.

Certain engines, such as those in race or high performance cars, may make use of what is known as a dry sump system. Instead of storing all the oil in the crank case, these engines have a divorced reservoir that it is pumped to and from. Oil pans on engines like these will typically be much smaller than those in wet sump systems, since the oil is returned to the reservoir after being used for lubrication.

WORKING:

Oil pans are detachable mechanisms made out of thin steel and bolted to the bottom of the crankcase. To maximize its function, it is molded into a deeper section and mounted at the bottom of the crankcase to serve as an oil reservoir. The oil pan also hosts the oil pump and on the bottom of which is the oil drain plug. When an engine is at rest, the oil pan gathers the oil as it flows down from the sides of the crankcase. The oil drain plug can be also removed to allow old oil to seep out of the car during an oil exchange. The plug is then screwed back into the drain hole after the used oil is drained out. Drain plugs are usually constructed with a magnet in it, which in turn collects metal fragments from the oil. Other varieties contain a replaceable washer to prevent leakage caused by corrosion or worn threads in the drain hole. Compared to other automotive parts, an engine oil pan is far more likely to leak. This is because it holds oil being thrown around which eventually finds a leak if there is one. Thus, extra care should be applied when installing an automotive oil pan. Most of the times, the metal at the bolt holes in the oil pan and front cover will be pushed inward around the bolt holes. This is caused by the gasket getting smashed due to their excessive tightening. As the oil pan attempts to stop oil leaks, the gaskets are rendered useless and the oil leak will just get worse. Careful attention must also be placed on the gasket when tightening the bolts and make sure that the gaskets are not being squeezed out from under the oil pan to prevent future oil leaks.

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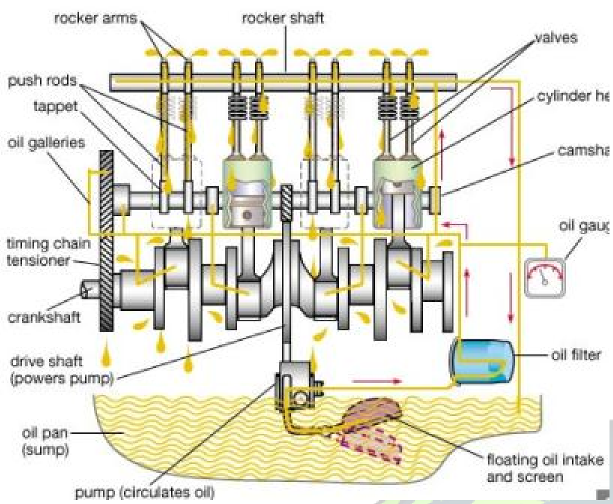

Fig: oil pan working

MANUFACTURING METHODS OF OIL-PAN

General Capabilities:

- Deep & Shallow Draw Stamping
- Plastic Injection Molding
- Rubber Injection Molding
- Die-cast, Sand cast and Gravity Casting
- Chrome and Vacuum Metallization
- Extrusion and CNC machining
- Wiring and electronic components

Oil pan specific capabilities:

- OEM replacement oil pans
- Fabrication ready oil pan cores
- Custom oil pump pick-ups and dipsticks.
- Wet sump fabricated to specifications
- Dry sump fabricated to specifications
- Fabrication components
- Custom finishes
- Highly customized work for volume customers

Manufacturing method is completely depends on importance of the usage of component and engine capacity and conditions.

In this project we are designing OIL PAN for submarine engine.

Material for oil pan casting

The materials used for die-casting are

1) Aluminum alloys
2) Zinc alloys
3) Magnesium alloys
4) Copper alloys
5) Lead alloys

SYSTEM DESCRIPTION

The system analyzed was a rear well oil sump for the new design of heavy duty 4 cylinder diesel engine developed in Ashok Leyland. The cross section of the engine is shown in Figure to understand the layout of sump and suction-strainer system.

The details of the system analyzed are given below:

1. Engine: 4 cylinder common rail engine

2. Engine oil: SAE 15W40

3. Oil sump capacity: 16L

4. Max oil level: 18L

5. Min oil level: 12L

6. Installation angle: 1.5°/3°- longitudinal, flywheel down.

Other loading conditions for a heavy duty truck as per internal company standards (ALS.010.05, 02.05.1999) are given below:

1. Max Deceleration (braking): 0.6g

2. Cornering (acceleration): 0.3g

Where "g" is acceleration due to gravity 9.81 m/s2

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The tilt angle targets for the system under study are discussed in detail in the following section.

SOLID WORKS

Solid Works is mechanical design automation software that takes advantage of the familiar Microsoft Windows graphical user interface.

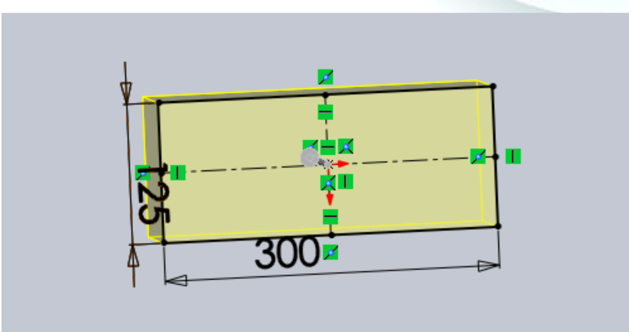
It is an easy-to-learn tool which makes it possible for mechanical designers to quickly sketch ideas, experiment with features and dimensions, and produce models and detailed drawings.

A Solid Works model consists of parts, assemblies, and drawings.

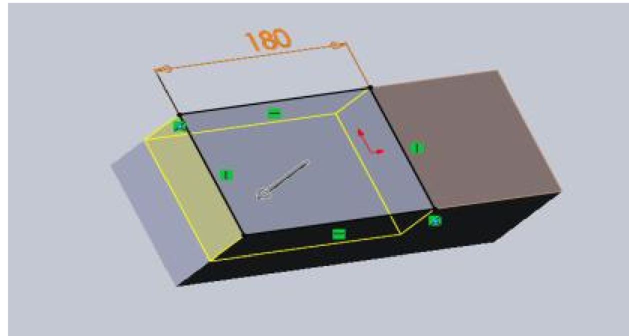
- Typically, we begin with a sketch, create a base feature, and then add more features to the model. (One can also begin with an imported surface or solid geometry).
- We are free to refine our design by adding, changing, or reordering features.
- Associatively between parts, assemblies, and drawings assures that changes made to one view are automatically made to all other views.
- We can generate drawings or assemblies at any time in the design process.
- The Solid works software lets us customize functionality to suit our needs.

MODELING OF OIL PAN

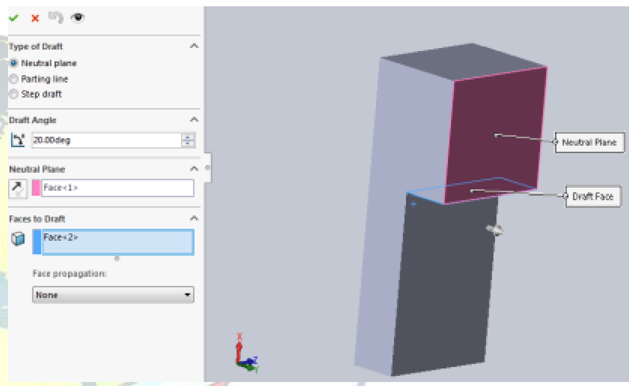
Draw sketch as follow and extrude.

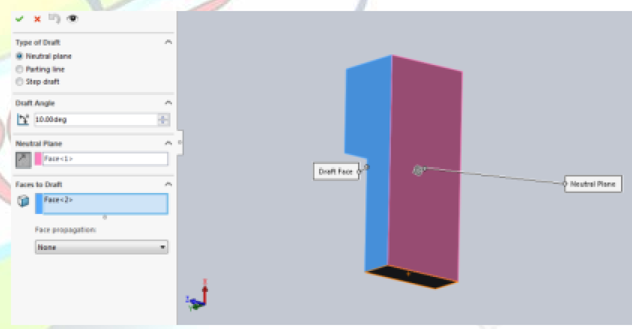


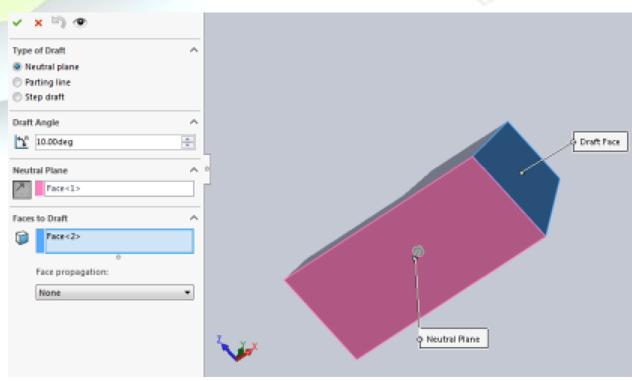
Draw sketch as follow use cut extrude



Provide drafts as follow







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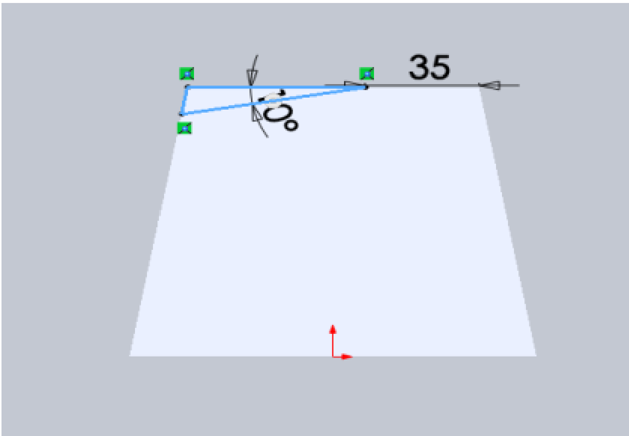
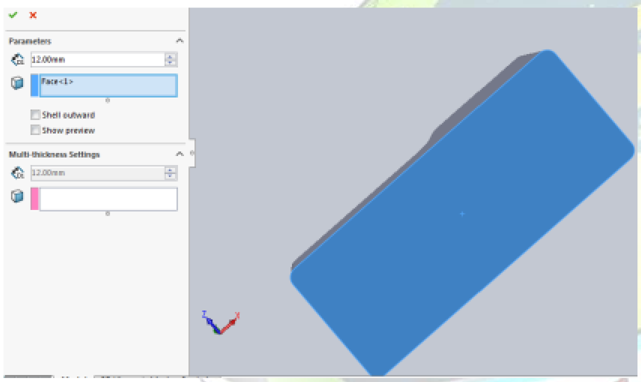
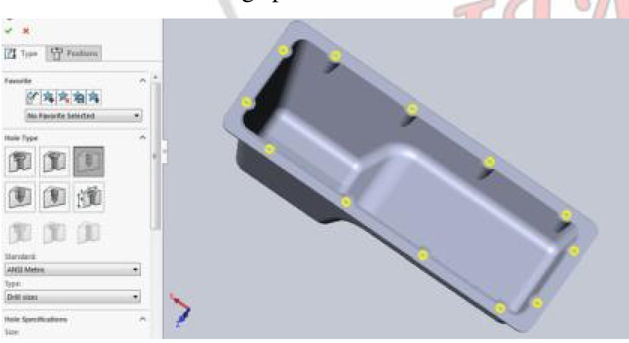
Cut extrude



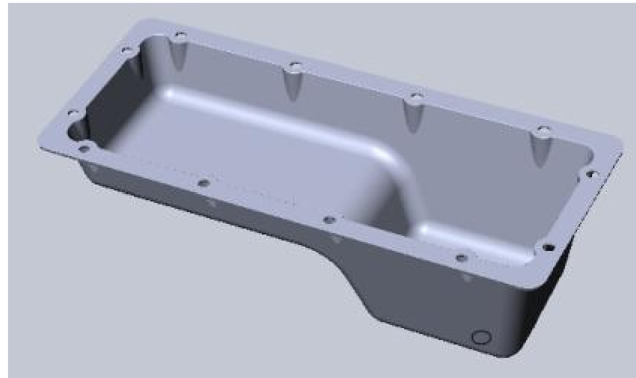
Provide shell to make part hollow

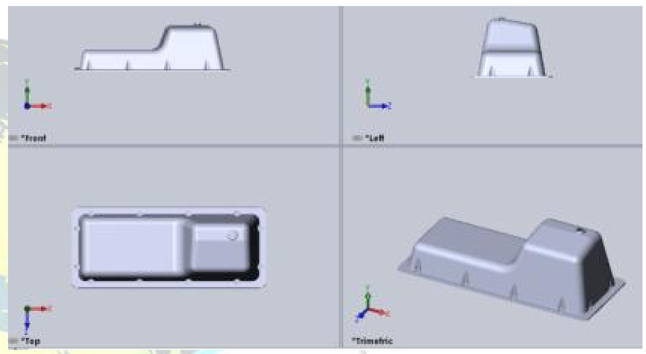


Provide holes according specs



Final view





Four different views

Basic Concepts of FEM

The software uses the Finite Element Method (FEM). FEM is a numerical technique for analyzing engineering designs. FEM is accepted as the standard analysis method due to its generality and suitability for computer implementation. FEM divides the model into many small pieces of simple shapes called elements effectively replacing a complex problem by many simple problems that need to be solved simultaneously.

Fig .CAD model of a part

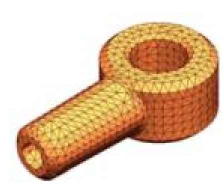


Fig Model subdivided into small pieces (elements)

Elements share common points called nodes. The process of dividing the model into small pieces is called meshing.

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ANSYS

ANSYS delivers innovative, dramatic simulation technology advances in every major Physics discipline, along with improvements in computing speed and enhancements to enabling technologies such as geometry handling, meshing and post-processing. These advancements alone represent a major step ahead on the path forward in Simulation Driven Product Development.

Thermal Stress Analysis

Changes in temperature can induce substantial deformations, strains, and stresses. Thermal stress analysis refers to static analysis that includes the effect of temperature.

Perform thermal stress analysis using one of the following options:

- Using a uniform rise or drop in temperature for the whole model.
- Using a temperature profile resulting from a steady state or transient thermal analysis.
- Using a temperature profile from Flow Simulation.

Material Properties

Aluminum Alloy

Properties of Outline Row 3: Aluminum Alloy

	A	B	C
1	Property	Value	Unit
2	Density	2770	kg m^-3
3	Isotropic Secant Coefficient of Thermal Expansion		
6	Isotropic Elasticity		
7	Derive from	Young's Modulus and Poisso...	
8	Young's Modulus	7.1E+10	Pa
9	Poisson's Ratio	0.33	
10	Bulk Modulus	6.9608E+10	Pa
11	Shear Modulus	2.6692E+10	Pa

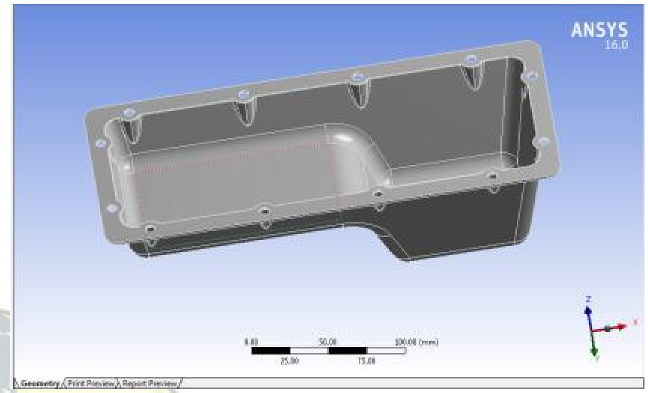
Magnesium Alloy

Properties of Outline Row 4: Magnesium Alloy

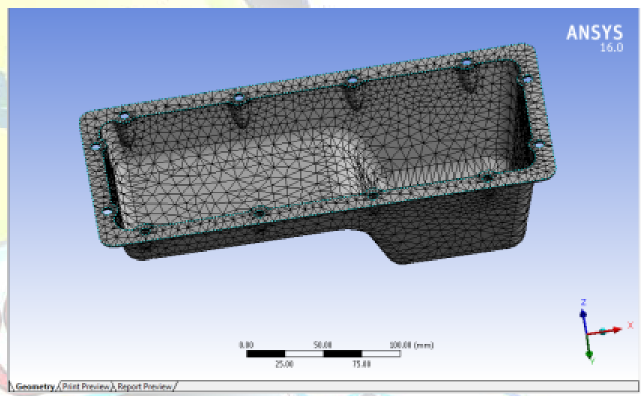
	A	B	C
1	Property	Value	Unit
2	Density	1800	kg m^-3
3	Isotropic Secant Coefficient of Thermal Expansion		
6	Isotropic Elasticity		
7	Derive from	Young's Modulus and Poisso...	
8	Young's Modulus	4.5E+10	Pa
9	Poisson's Ratio	0.35	
10	Bulk Modulus	5E+10	Pa
11	Shear Modulus	1.6667E+10	Pa

ANALYSIS

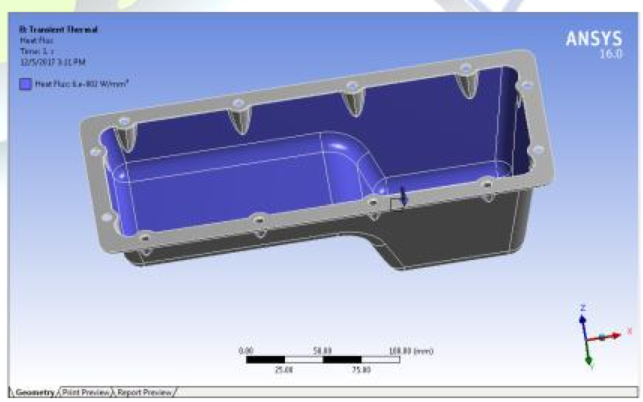
Transient Thermal Analysis



Mesh



Heat flux applied



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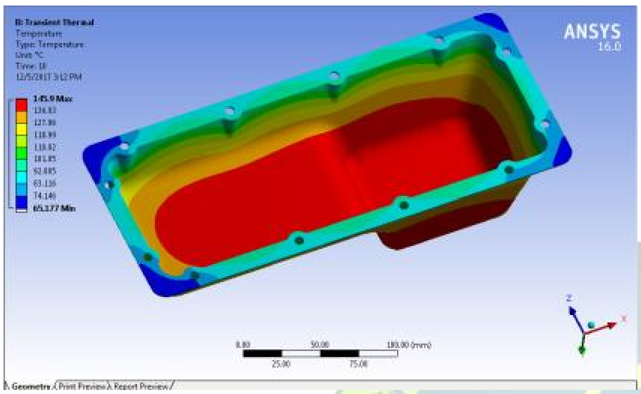
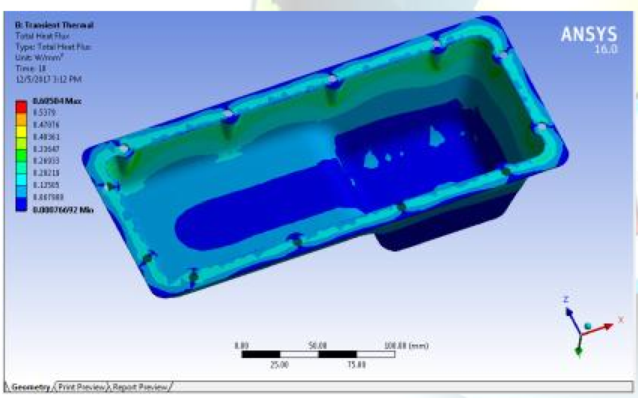
RESULTS

For aluminum alloy

Temperature

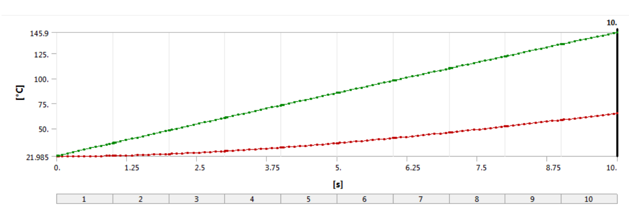


Heat flux



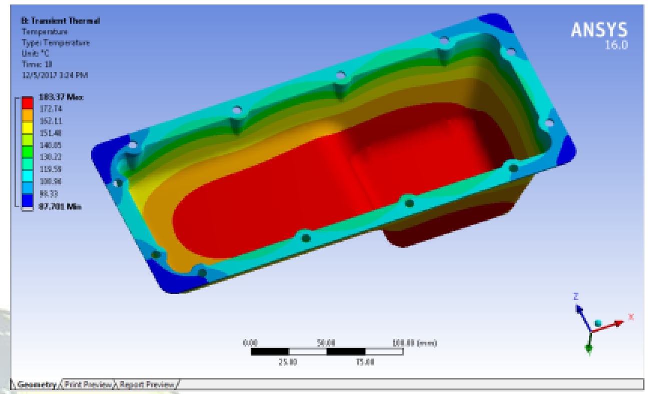
Graph

Temperature & heat flux vs. time

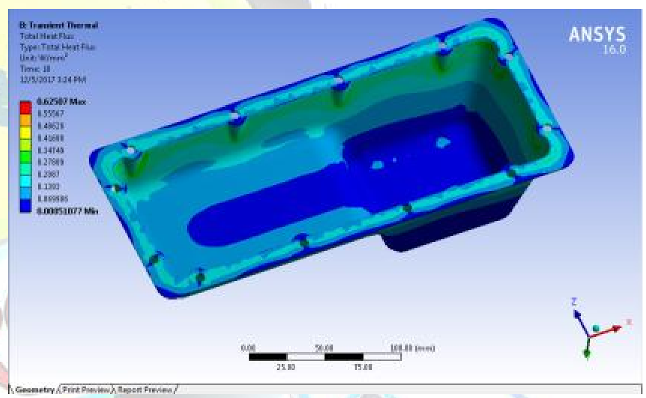


For magnesium alloy

Temperature

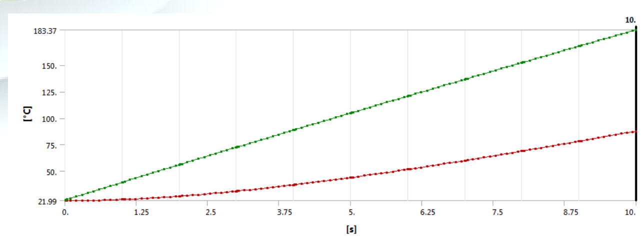


Heat flux



Graph

Temperature & heat flux vs. time



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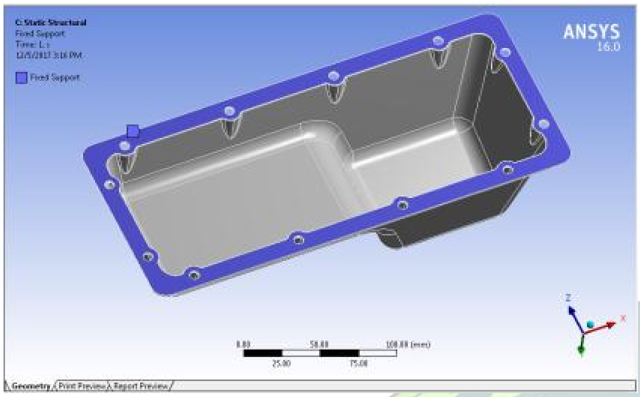
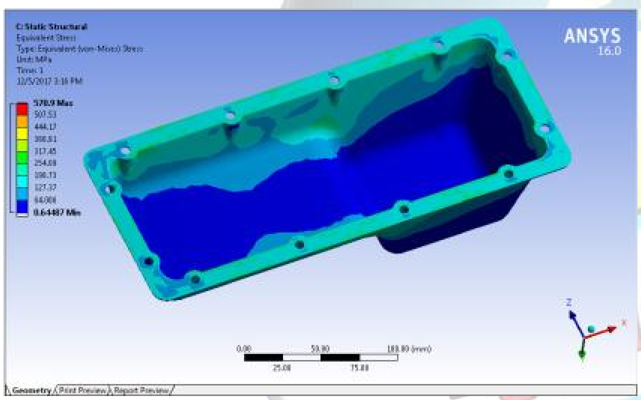
THERMAL STRESS ANALYSIS

Fixed support

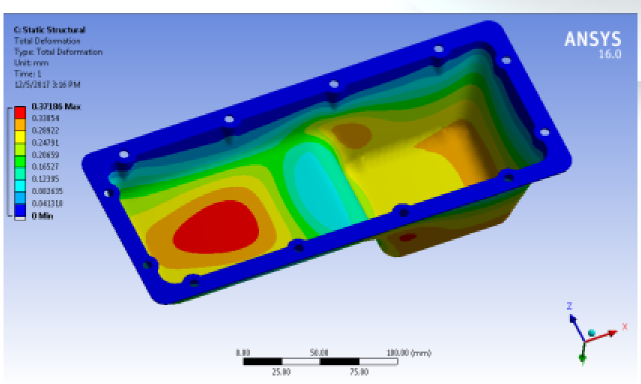


For aluminum alloy

Stress



Deformation

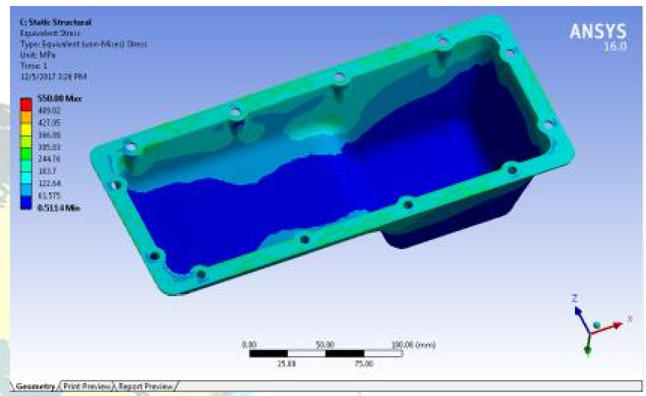


Mass

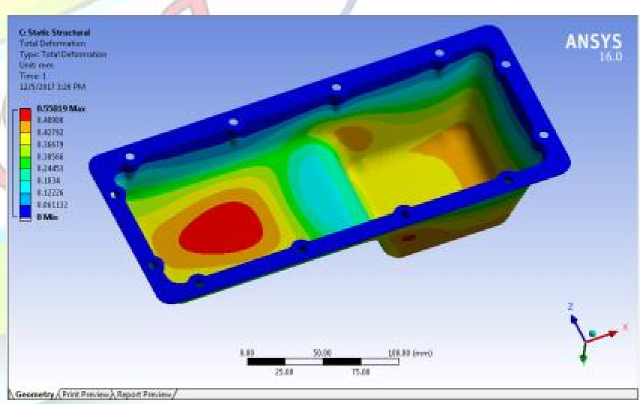
Properties	
Volume	1.4159e+005 mm³
Mass	0.39222 kg

For magnesium alloy

Stress



Deformation



Mass

Properties	
Volume	1.4159e+005 mm³
Mass	0.25487 kg

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Transient thermal analysis

Material	Temp (min) cent	Temp (min) cent	Heat Flux W/mm2
Al alloy	145.90	65.177	0.60504
Mg alloy	183.37	87.701	0.62507

Thermal Stress Analysis

Material	Max Stress (mpa)	Max Deformation (mm)	Mass (kg)
Al alloy	570.90	0.37186	0.39222
Mg alloy	550.08	0.55019	0.25487

Conclusion

- Design and analysis of oil pan or oil sump is done.
- Model of oil pan is made by using solidworks 2016 software by using different commands and tools.
- Solidwork modal file is transferred to ansys software by converting solidworks file to IGES file.
- Transient's thermal analysis is carried out on oil pan for max time duration of 5sec.
- Two different materials are used for analysis on oil pump such as Aluminum alloy and magnesium alloy.
- We will get Temperature, and heat flux as the result of transient thermal analysis, which are noted and tabulated.
- Transient thermal analysis is transferred to static structural analysis to study its thermal stress due to heat generated.
- After assigning boundary conditions and thermal condition we will get stress and deformation as the result of static structural analysis because of thermal load.
- Stress, deformation and mass of each material are noted and tabulated.
- According to thermal stress analysis table magnesium alloy is showing less stress compare to aluminum alloy.
- Mean while magnesium alloy also showing less weight compare to aluminum alloy.
- Hence we can conclude that magnesium alloy is the best material for oil pan because of its good strength to weight ratio.

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