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DESIGN AND ANALYSIS OF CYLINDER HEAD GASKET

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***Abstract**: Cylinder head gasket is used to improve the efficiency of automobile engines sealing the combustion gases and to avoid coolant or engine oil leaking into the cylinders. The cylinder head gasket should be designed in such a way that it creates sealing to the cylinder engine which should withstand the temperature generated by each combustion inside the cylinder at different loading conditions. The gas should not be escaped as the contact stresses subjected to the gasket should be analyzed depending on the size and shape of the cylindrical head. The gasket may fail due to overheating, abrupt change in temperature, incorrect installation, detonation, which may vary depends on material.*

In this research, we will design and model a single cylinder IC engine head gasket using Solid works, according to the specifications and size of a cylinder. The major approach of this dissertation is to conduct thermal analysis on the cylinder head gasket with different composite materials such as Copper and Asbestos, Steel and Asbestos, epoxy carbon and copper. Model is created in solid works and different temperatures analysis will be carried out through ANSYS using certain thermal loads (i.e.213^{0}c, 3130c and 413^{0}c). The results will be taken out and the area which experiences the maximum load will be shown, the analysis will be performed and compared between different materials as described, where the optimal performance of materials can be known.

Tools: Solid Works, Ansys

I. INTRODUCTION

Engine block

The internal combustion engine is an engine in which the combustion of a fuel (normally a fossil fuel) occurs with an oxidizer (usually air) in a combustion chamber. In an internal combustion engine, the expansion of the high-temperature and -pressure gases produced by combustion applies direct force to some component of

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the engine, such as pistons, turbine blades, or a nozzle. This force moves the component over a distance, generating useful mechanical energy.

An engine block is the structure which contains the cylinders, and other parts, of an internal combustion engine. In an early automotive engine, the engine block consisted of just the cylinder block, to which a separate crankcase was attached. Modern engine blocks typically have the crankcase integrated with the cylinder block as a single component. Engine blocks often also include elements such as coolant passages and oil galleries.

The term "cylinder block" is often used interchangeably with engine block, although technically the block of a modern engine (i.e. multiple cylinders in a single component) would be classified as a monopoly. Another common term for an engine block is simply "block".

Engine block components

The main structure of an engine (i.e. the long block, excluding any moving parts) typically consists of the cylinders, coolant passages, oil galleries, crankcase and cylinder head(s). The first production engines of the 1880s to 1920s usually used separate components for each of these elements, which were bolted together during engine assembly. Modern engines, however, often combine many of these elements into a single component, in order to reduce production costs.

The evolution from separate components to an engine block integrating several elements (a monopoly engine) has been a gradual progression throughout the history of internal combustion engines. The integration of elements has relied on the development of foundry and machining techniques. For example, a practical low-cost V8 engine was not feasible until Ford developed the techniques used to build the Ford flathead V8 engine. These techniques were then applied to other engines and manufacturers.

Cylinder blocks

Cylinders cast in a single block of six, with integrated crankcase (turbocharger in background)

A cylinder block is the structure which contains the cylinder, plus any cylinder sleeves and coolant passages. In the earliest decades of internal combustion engine development, cylinders were usually cast individually, so cylinder blocks were usually produced individually for each cylinder. Following that, engines began to combine two or three cylinders into a single cylinder block, with an engine combining several of these cylinder blocks combined together.

In early engines with multiple cylinder banks — such as a V6, V8 or flat-6 engine — each bank was typically a separate

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cylinder block (or multiple blocks per bank). Since the 1930s, mass production methods have developed to allow both banks of cylinders to be integrated into the same cylinder block.

Cylinder liners

Wet liner cylinder blocks use cylinder walls that are entirely removable, which fit into the block by means of special gaskets. They are referred to as "wet liners" because their outer sides come in direct contact with the engine's coolant. In other words, the liner is the entire wall, rather than being merely a sleeve.

Advantages of wet liners are a lower mass, reduced space requirement and that the coolant liquid is heated faster from a cold start, which reduces start-up fuel consumption and provides heating for the car cabin sooner.

Dry liner cylinder blocks use either the block's material or a discrete liner inserted into the block to form the backbone of the cylinder wall. Additional sleeves are inserted within, which remain "dry" on their outside, surrounded by the block's material.

For either wet or dry liner designs, the liners (or sleeves) can be replaced, potentially allowing overhaul or rebuild without replacement of the block itself, although this is often not a practical repair option.

Coolant passages

Môn blocs

An engine where all the cylinders share a common block is called a monopoly engine. Most modern engines (including cars, trucks, buses and tractors) use a monoblock design of some type, therefore few modern engines have a separate block for each cylinder. This has led to the term "engine block" usually implying a monopoly design and the term monopoly itself is rarely used.

In the early years of the internal combustion engine, casting technology could produce either large castings, or castings with complex internal cores to allow for water jackets, but not both simultaneously. Most early engines, particularly those with more than four cylinders, had their cylinders cast as pairs or triplets of cylinders, then bolted to a single crankcase.

Up until the 1930s, most V engines retained a separate block casting for each cylinder bank, with both bolted onto a common crankcase (itself a separate casting). For economy, some engines were designed to use identical castings for each bank, left and right.[2](p120) A rare exception is the Lance 22½° narrow-angle V12 of 1919, which used a single block casting combining both banks.(pp50-53) The Ford flathead V-8 — introduced in 1932 — represented a significant development in the production of

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affordable V engines. It was the first V8 engine with a single engine block casting, putting a V8 into an affordable car for the first time.

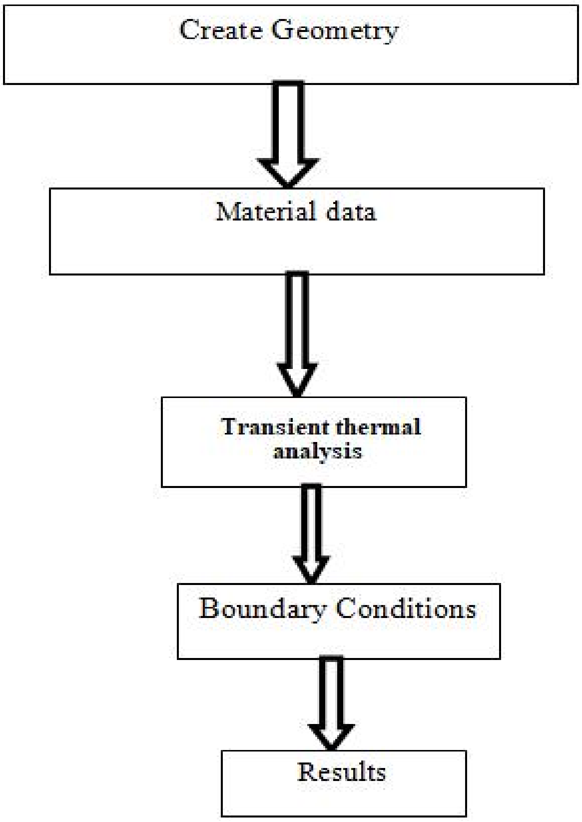
II. LITERATURE SURVEY

1. V.Arjun, Mr. V.V. Ramakrishna, Mr. S. Rajasekhar, al. [2015], Thermal Analysis of an Engine Gasket At Different Operating Temperatures, Gasket sits between the engine block and cylinder head in an engine. Its purpose is to seal the cylinders to ensure maximum compression and avoid leakage of coolant or engine oil into the cylinders. From our project, we would like to modify the material and design of the gasket of four cylinder engine. MLS or Multiple Layers Steel (These typically consist of three layers of steel) and asbestos – Most modern head engines are produced with MLS gaskets. The contact faces are usually coated with a rubber-like coating such as Viton that adheres to the cylinder block and cylinder head while the thicker center layer is left bare. Because of the health risk of fine asbestos fibers, gasket manufacturers are forced to look for alternatives to asbestos.

2. M.Srikanth1 B.M.Balakrishnan2, al. [2015], Cylinder Head Gasket Analysis to Improve its Thermal Characteristics Using Advanced Fem Tool, Gasket sits between the engine block and cylinder head in an engine. Its purpose is to seal the cylinders to ensure maximum compression and avoid leakage of coolant or engine oil into the cylinders. From our project, we would like to modify the material and design of the gasket of four cylinder engine. MLS or Multiple Layers Steel (These typically consist of three layers of steel)and asbestos – Most modern head engines are produced with MLS gaskets. The contact faces are usually coated with a rubber-like coating such as viton that adheres to the cylinder block and cylinder head while the thicker center layer is left bare. Because of the health risk of fine asbestos fibers, gasket manufacturers are forced to look for alternatives to asbestos. Various possibilities of substituting asbestos in cylinder head gaskets are characterized by different problems of development. Elastomer-bonded soft materials, i.e. combinations of Kevlar fibers, carbon fibre, pyrosic ceramic glass fiber materials.

3. Jerry e. Kashmerick, al (1991) in this Different cylinder head gasket materials are in use today, primarily due to the elimination of the standard asbestos millboard, new engine designs, requirements on compressed thickness, and increasing durability and sealing standards. The history of small engine cylinder head gaskets is reviewed. Current and future head gasket requirements and gasket material and types are outlined. The affect of these materials on heat transfer is summarized. Design considerations directed to attaining and maintaining clamp loads and clamp load loss are addressed. Static and dynamic testing to improve and verify the suitability of designs is explained. A smooth transition from a tested prototype to production product requires attention to clamp load related details.

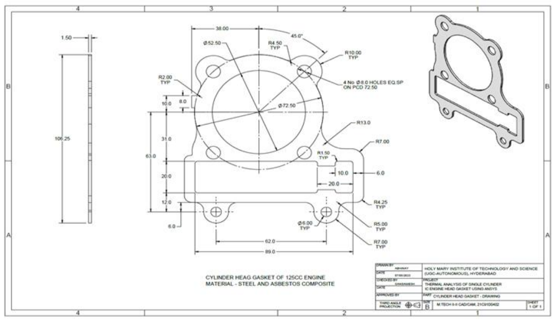
III METHODOLOGY

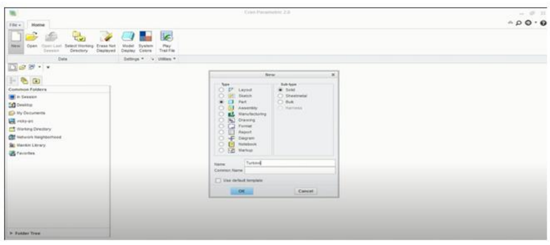


SOLIDWORK SOFTWARE

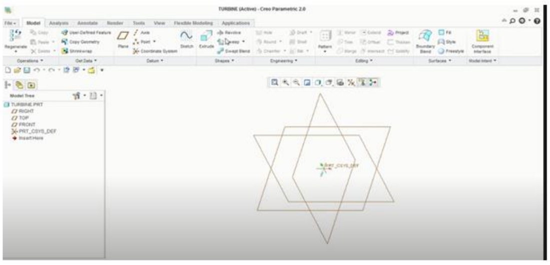
SolidWorks is a 3D parametric design tool used to create a wide range of items, including toys, hoover cleaners, cell phones, furniture, electrical assemblies, marine equipment, aeroplane components, autos, marine equipment, furniture, and electrical assemblies. Designing mechanically functional assemblies with fewer than 200 pieces commonly uses SolidWorks. So we created a non-pneumatic tyre with the aid of this Solid Works software.

MODELLING OF CYLINDER HEAD GASKET





Solid works modules



part module

IV MODELLING AND ANALYSIS

INTRODUCTION TO FEA

Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variation calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by M. J. Turner, R. W. Clough, H. C. Martin, and L. J. Top established a broader definition of numerical analysis. The paper cantered on the "stiffness and deflection of complex structures".

By the early 70's, FEA was limited to expensive mainframe computers generally owned by the aeronautics, automotive, defence, and nuclear industries. Since the rapid decline in the cost of computers and the phenomenal increase in computing power, FEA has been developed to an incredible precision. Present day supercomputers are now able to produce accurate results for all kinds of parameters.

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

There are generally two types of analysis that are used in industry: 2-D modelling, and 3-D modelling. While 2-D modelling conserves simplicity and allows the analysis to be run on a relatively normal computer, it tends to yield less accurate results. 3-D modelling, however, produces more accurate results while sacrificing the ability to run on all but the fastest computers effectively. Within each of these modelling schemes, the programmer can insert numerous algorithms (functions) which may make the system behave linearly or non-linearly. Linear systems are far less complex and generally do not take into account plastic deformation. Non-linear systems do account for plastic deformation, and many also are capable of testing a material all the way to fracture.

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FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress. Points of interest may consist of: fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors is what carries the material properties to the object, creating many elements.

A wide range of objective functions (variables within the system) are available for minimization or maximization:

- Mass, volume, temperature
- Strain energy, stress strain
- Force, displacement, velocity, acceleration
- Synthetic (User defined)

There are multiple loading conditions which may be applied to a system. Some examples are shown:

- Point, pressure, thermal, gravity, and centrifugal static loads
- Thermal loads from solution of heat transfer analysis
- Enforced displacements
- Heat flux and convection
- Point, pressure and gravity dynamic loads

Each FEA program may come with an element library, or one is constructed over time. Some sample elements are:

- Rod elements
- Beam elements
- Plate/Shell/Composite elements
- Shear panel
- Solid elements
- Spring elements
- Mass elements
- Rigid elements
- Viscous damping elements

Many FEA programs also are equipped with the capability to use multiple materials within the structure such as:

- Isotropic, identical throughout
- Orthotropic, identical at 90 degrees
- General anisotropic, different throughout

Types of Engineering Analysis

Structural analysis consists of linear and non-linear models. Linear models use simple parameters and assume that the material is not plastically deformed. Non-linear models consist of stressing the material past its elastic capabilities. The stresses in the material then vary with the amount of deformation as in.

Vibration analysis is used to test a material against random vibrations, shock, and impact. Each of these incidences may act on the natural vibration frequency of the material which, in turn, may cause resonance and subsequent failure.

Fatigue analysis helps designers to predict the life of a material or structure by showing the effects of cyclic loading on the specimen. Such analysis can show the areas where crack propagation is most likely to occur. Failure due to fatigue may also show the damage tolerance of the material.

Heat Transfer analysis models the conductivity or thermal fluid dynamics of the material or structure. This may consist of a steady-state or transient transfer. Steady-state transfer refers to constant thermo properties in the material that yield linear heat diffusion.

Results of Finite Element Analysis

FEA has become a solution to the task of predicting failure due to unknown stresses by showing problem areas in a material and allowing designers to see all of the theoretical stresses within. This method of product design and testing is far superior to the manufacturing costs which would accrue if each sample was actually built and tested.

Pre-processing: The user constructs a model of the part to be analyzed in which the geometry is divided into a number of discrete sub regions, or elements," connected at discrete points called nodes." Certain of these nodes will have fixed displacements, and others will have prescribed loads. These models can be extremely time consuming to prepare, and commercial codes vie with one another to have the most user-friendly graphical “pre-processor" to assist in this rather tedious chore. Some of these pre-processors can overlay a mesh on a pre-existing CAD file, so that finite element analysis can be done conveniently as part of the computerized drafting-and-design process.

Analysis: The dataset prepared by the pre-processor is used as input to the finite element Code itself, which constructs and solves a system of linear or nonlinear algebraic equations

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$$Kijuj = f$$

Where u and f are the displacements and externally applied forces at the nodal points. The formation of the K matrix is dependent on the type of problem being attacked, and this

Module will outline the approach for truss and linear elastic stress analyses. Commercial codes may have very large element libraries, with elements appropriate to a wide range of problem types. One of FEA's principal advantages is that many problem types can be addressed with the same code, merely by specifying the appropriate element types from the library.

Post processing: In the earlier days of finite element analysis, the user would pore through reams of numbers generated by the code, listing displacements and stresses at discrete positions within the model. It is easy to miss important trends and hot spots this way, and modern codes use graphical displays to assist in visualizing the results. Typical postprocessor display overlays collared contours representing stress levels on the model, showing a full field picture similar to that of photo elastic or moiré experimental results.

V ANALYSIS PROCEDURE

INTRODUCTION TO ANSYS

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

ANSYS is the standard FEA teaching tool within the Mechanical Engineering Department at many colleges. ANSYS is also used in Civil and Electrical Engineering, as well as the Physics and Chemistry departments.

ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping.

With virtual prototyping techniques, users can iterate various scenarios to optimize

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the product long before the manufacturing is started. This enables a reduction in the level of risk, and in the cost of ineffective designs. The multifaceted nature of ANSYS also provides a means to ensure that users are able to see the effect of a design on the whole behaviour of the product, be it electromagnetic, thermal, mechanical etc.

Steps involved in ANSYS:
In general, a finite element solution can be broken into the following these categories.

1. Pre-processing module: Defining the problem

The major steps in pre-processing are given below

- defining key points /lines/areas/volumes
- define element type and material /geometric/properties mesh lines/areas/volumes/are required

The amount of detail required will depend on the dimensionality of the analysis (i.e. 1D, 2D, axis, symmetric)

2. Solution processor module: assigning the loads, constraints and solving. Here we specify the loads (point or pressure), constraints (translation, rotational) and finally solve the resulting set of equations.

3. Post processing module: further processing and viewing of results

In this stage we can see:
List of nodal displacement
Elements forces and moments
Deflection nplots
Stress contour diagrams

Thermal

ANSYS is capable of both steady state and transient analysis of any solid with thermal boundary conditions. Steady-state thermal analyses calculate the effects of steady thermal loads on a system or component. Users often perform a steady-state analysis before doing a transient thermal analysis, to help establish initial conditions. A steady-state analysis also can be the last step of a transient thermal analysis; performed after all transient effects have diminished. ANSYS can be used to determine temperatures, thermal gradients, heat flow rates, and heat fluxes in an object that are caused by thermal loads that do not vary over time. Such loads include the following:

Convection

Radiation

Heat flow rates

Heat fluxes (heat flow per unit area)

Heat generation rates (heat flow per unit volume)

Constant temperature boundaries

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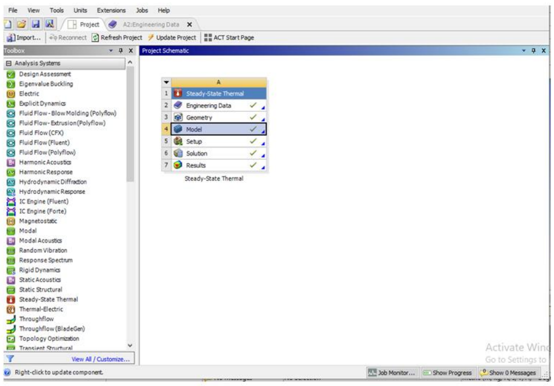
A steady-state thermal analysis may be either linear, with constant material properties; or nonlinear, with material properties that depend on temperature. The thermal properties of most material vary with temperature. This temperature dependency being appreciable, the analysis becomes nonlinear. Radiation boundary conditions also make the analysis nonlinear. Transient calculations are time dependent and ANSYS can both solve distributions as well as create video for time incremental displays of models.

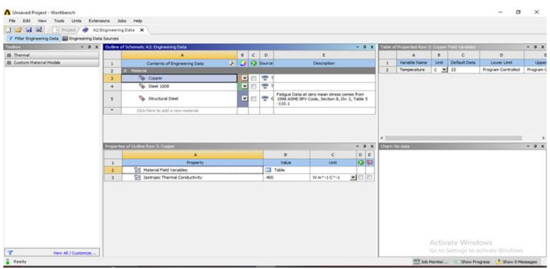
VI RESULTS

Material copper

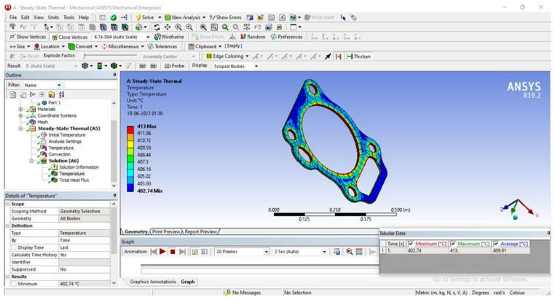
Applying temperature 213^{0}c



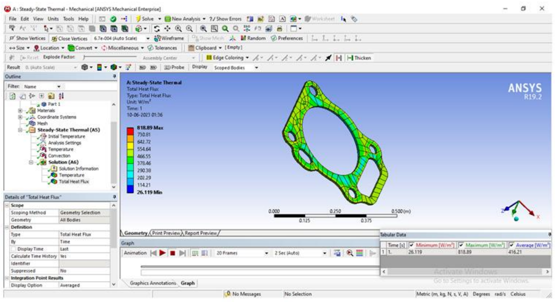
Material properties



Temperature distribution



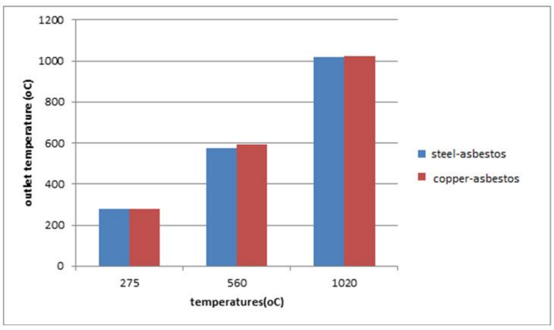
Heat flux



RESULT TABLE

material	input temperature (^{0} c)	Temperature distribution (^{0} c)	Heat flux (W/mm^2)
Copper	213	213	370.5
	313	313	564.48
	413	413	758.46
Epoxy carbon	213	213	400.02
	313	313	609.46
	413	413	818.89
Steel- asbestos	213	213	516.19
	313	313	786.46
	413	413	1056.6
Copper- asbestos	213	213	516.2
	313	313	786.38
	413	413	1056.7

GRAPHS



Graph: inlet temperatures versus outlet temperature

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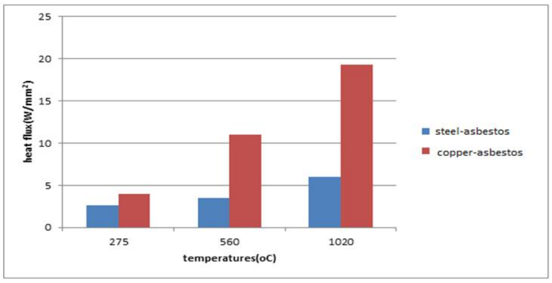

VII CONCLUSION

The major approach of this dissertation is to conduct thermal analysis on the cylinder head gasket with different composite materials such as Copper and Asbestos, Steel and Asbestos, epoxy carbon and copper. Model is created in solid works and different temperatures analysis will be carried out through ANSYS using certain thermal loads (i.e.213^{0}c, 3130c and 413^{0}c). The results will be taken out and the area which experiences the maximum load will be shown, the analysis will be performed and compared between different materials as described, where the optimal performance of materials can be known.

By observing thermal analysis copper – asbestos is having more heat flux compare to the steel-asbestos, copper alloy and carbon fiber material

So we conclude that copper- asbestos composite is suitable for cylinder head gasket compare to the steel-asbestos, copper alloy and carbon fiber material

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