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Experimental Analysis of I.C. Engine Components and Improvisation of the Radiator Design

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1. SCOPE OF THE RESEARCH:

The automobile consists of various systems as explained earlier. All these systems occupy their significance in the operation of the automobile. The I.C. engine system is considered to be the heart of the automobile, as it produces the required motive power. In this the Piston, Connecting rod and the crank-shaft form the essential kinematic linkage that that aides in producing the power. And also, the cooling system assumes significance as it is responsible for the dissipation of the heat generated by the combustion process. For achieving this a radiator plays a crucial role.

Here, in this project we explore the design considerations of the above components of the Maruti Suzuki Alto VX as stated and analyze their failure criterion, if any. Due to the non availability of the designs for the parts under consideration, we have followed a manual approach for the determination of the nominal dimensions of these part and then preparing their drafts. There after we intend to model these parts in CATIA V5® and analyze them in PRO-E® MECHANICA®. A comparative study is taken up by considering different materials for these components.

The systems of the automobile include:

Cooling and Heating Systems:

Combustion inside an engine produces temperatures high enough to melt cast iron. A cooling system conducts this heat away from the engine's cylinders and radiates it into the air. In most automobiles, a liquid coolant circulates through the engine. A pump sends the coolant from the engine to a radiator, which transfers heat from the coolant to the air. In early engines, the coolant was water.

In most automobiles today, the coolant is a chemical solution called antifreeze that has a higher boiling point and lower freezing point than water, making it effective in temperature extremes. Some engines are air cooled, that is, they are designed so a flow of air can reach metal fins that conduct heat away from the cylinders.A second, smaller radiator is fitted to all modern cars. This unit uses engine heat to warm the interior of the passenger compartment and supply heat to the windshield defroster.

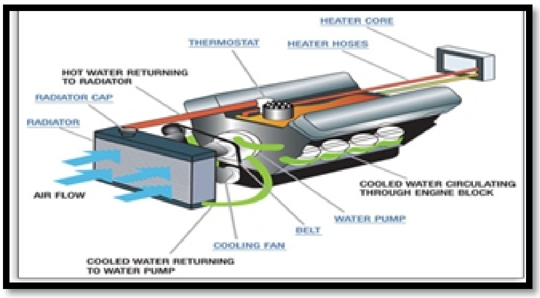

FIG.1 : Layout of the Cooling System of a typical automobile

1.1: Components of a Cooling system:

The essential components that make up the cooling system are as follows:

1. Radiator:The function of a radiator is to ensure the close contact of the hot coolant exiting the engine with the low temperature atmospheric air. A radiator consists of an upper (or header) tank, core and the lower (or collector) tank. Besides, am overflow valve is also provided on the header and a drain valve on the collector tank. The coolant is collected in the collector tank at the bottom of the radiator, from where it is recirculated to the engine for cooling. There are basically two types of radiator cores, namely: tubular and cellular type.

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In the tubular type core, the water flows through the tubes and air is made to pass around these tubing. Whereas in the cellular type the air flows through the tubing and the the coolant flows through the spaces provided in between them. Of these, the tubular type of cores are more popular and are further classified depending upon the shape of the fins around them. These are:

a. Tubular cores with serpentine fins

b. Tubular cores with spiral fins

c. Tubular cores with plate fins

4. Frontal Fan:

The fan is an essential component of the cooling system as the radiator. It maintains the essential draft of the air over the radiatior, especially at lower speeds of the vehicle. It is mounted behind the radiator on the same shaft on which the water pump is mounted. It may have four to seven blades depending on the requirement. It is generally made up of sheet metal.

The major reasons which lead to the deterioration of the engine performance are as follows:

1.The ignition process not being spontaneous in nature, but instead being gradual.

2. Loss of heat to the cylinder walls.

3.Loss due to the early opening of the exhaust valve.

4.Loss of work for inducting fresh charge into the combustion chamber.

5.Due to the occurrence of incomplete combustion.

6.Existence of friction between the moving parts which causes wearing.

The various characteristics on which the performance of an engine depends are as follows:

2.TECHNICAL SPECIFICATIONS OF MARUTI ALTO VX AND PERFORMANCE CALCULATIONS

2.1 Technical Specifications of ALTO VX:

Table 1: Technical Specifications of ALTO VX

ENGINE DATA

Specification	Description
Engine Type	4-cylinder in-line petrol; Trnsverse, Iron block and alloy head
Bore	68.5 mm
Stroke	72 mm
Displacement	1061 mm
Compression Ratio	9.4 or 9.2 mm
Max. Power	46.2 kW (62 BHP) at 6000 rpm
Max. Torque	81.4 N-m (83 kgm) at 4500 rpm
Power to Weight ratio	81.5 HP/tonne
Torque to Weight ratio	10.9 kgm/tonne
Specific Output	58.4 BHP/litre
Max. Range	560 km
Firing order	1-3-4-2
Piston Material	Alluminium alloy with cavity
Gudgeo pin connection	Floating
No. of main bearings	4
No. of Camshaft bearings	4
Valve type	Poppet
Valve gear	4 valves per cylinder, SOHC
Valve seat angle	450

FUEL INJECTION & SUPPLY SYSTEM

Fuel injection type	Multi-point Fuel Injection (MPFI)
Fuel pump type	Mechanical
Carburettor type	Solex-Mikuni 24-30 DIDS
Fuel tank capacity	35 litres
COOLING SYSTEM	
Type	Water cooling; sealed type
Coolant capacity	3.6 liters
Thermostat	Wax pallet type; starts to open at 870C, fully open at 950C
Fan blades	4 no.'s

LUBRICATION SYSTEM

Type	Wet sump; pressure type
Oil pump	Internal gear type
Oil pressure	340-400 at 3000 rpm
Oil filter	Full flow; Cartridge type

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IGNITION SYSTEM

Type Battery
Ignition coil Suzuki
Distributor type Suzuki
Contact breaker gap 0.4-0.5 mm
Type of automatic ignition type Centrifugal and vacuum
Centrifugal advance 200 – 240
Spark plug NGK BP 5 ES
Spark plug gap 0.7 – 0.8 mm

BATTERY SYSTEM

Battery type NS-405; 30 Amp-hr @ 20 hour rating
Generator type Alternator
Regulator type Vibrating voltage type

3. DETERMINATION OF NOMINAL DIMENSIONS OF THE PARTS UNDER CONSIDERATION

Nominal Dimensions are the essential dimensions which are required in the Part Drawing of the component. These are also known as the Functional Dimensions. Nominal dominance assumes significance due to the fact that they are very much required in the functioning of the components. It is with these that the basic geometrical shape of the components is inferred.

Here, in this project we are required to perform structural and thermal analyses on the components under consideration for which precise 3-D models of these components are required.

To prepare the models of the components the parts drawings of the components are required. Due to the non-availability of these part drawings, we followed a manual approach to determine the nominal dimensions of the components We utilized metrological instruments like Vernier Callipers, Screw gauge, Ruler etc. to find the required dimensions of the components.

3.1 Construction details of Fin and tubular radiator:

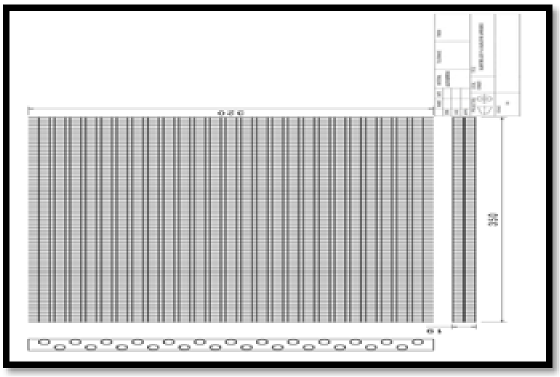

FIG.3.1 : Radiator Fin

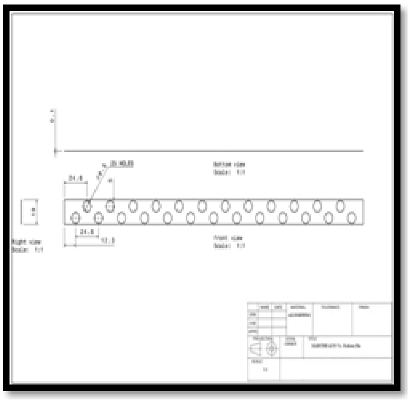

FIG.3.2 : Existing Radiator Assembly

4.MODELLING OF THE PARTS UNDER CONSIDERATION USING

4.1 Radiator Assembly:

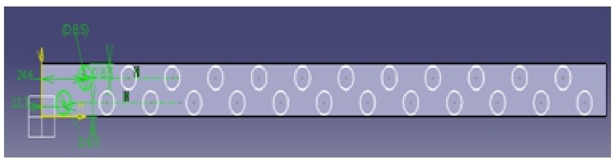

FIG.4.1.1: The Sketcher profile of the Radiator fin

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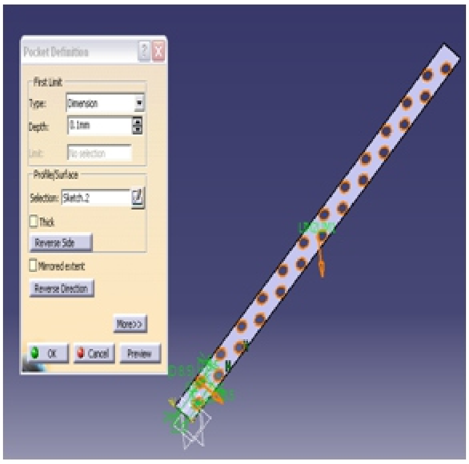


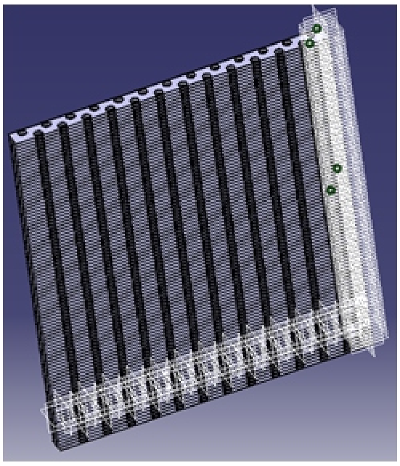


FIG.4.2: Obtaining the holes by the Pocket option
FIG.4.3: Existing Radiator Assembly in the Assembly module.

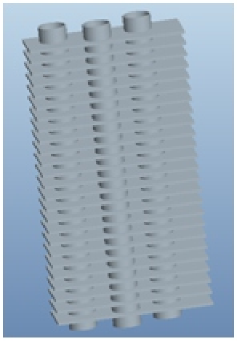
5. ASSUMPTIONS MADE BEFORE PROCEEDING TO ANALYSIS

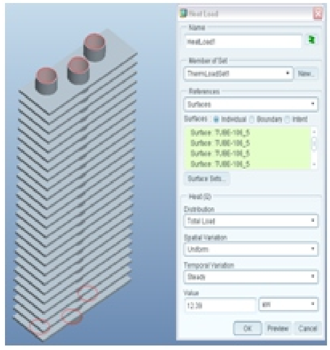
The following are the assumptions made before proceeding to the analysis phase of the project:

1.The analysis is Linear in nature.
2.The properties of the materials considered are Isotropic in nature.
3.The deformations occurring in the components are elastic in nature only.
4.The pressure distribution on the top of the piston during the expansion or power stroke is uniformly distributed.
5.The car is assumed to be moving at a speed of 36 KMPH or 10 m/s.
6.Temperature of the surrounding (T ω) is 35 o C.
7.The only mode of heat transfer to the Radiator parts is by Convection only (i.e. the conduction and radiation effects are neglected).
8.The flow rate of water in the Cooling system is assumed to be 500 kg/s.
9.The flow of water in the radiator tubing is assumed to be Uniform in nature.

6. DESCRIPTION OF ANALYSES OF THE PARTS UNDER CONSIDERATION

6.1 Analysis of the Radiator (Thermal- Steady State):





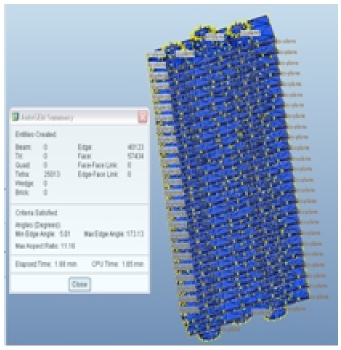


FIG.6.1 FIG.6.2 FIG.6.3
FIG.6.1: Model of the radiator imported into MECHANICA
FIG.6.2: Schematic representation of the heat load applied on the section considered of the radiator core
FIG. 6.3: Meshed structure of the Radiator core considered

7. RADIATOR PERFORMANCE:

7.1 Determination of the surface area of the Radiator Core:
7.2 Determination of Reynold's Number:
7.3 Determination of Nusselt's Number:

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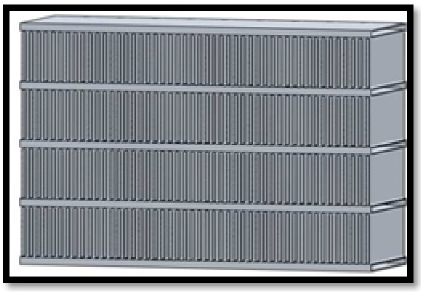
7.4 Determination of convective heat transfer coefficient:
7.5 Determination of the Overall heat transfer coefficient:
7.6 Determination of the Effectiveness:

8. IMPROVISATION OF THE RADIATOR DESIGN

8.1 Introduction to Serpentine radiator cores:



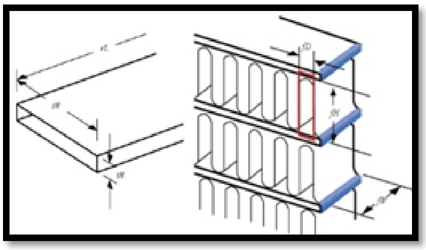


FIG.8.1: A radiator core of serpentine core type.

FIG. 8.1:General description of the profile of serpentine type radiator core

8.2 Construction details of Serpentine radiator core:

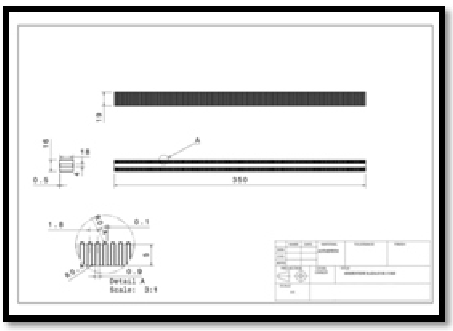
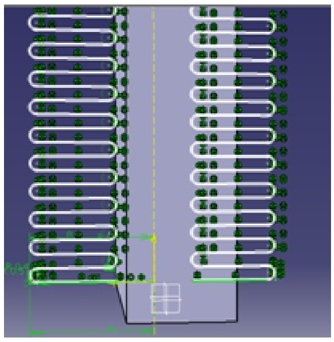
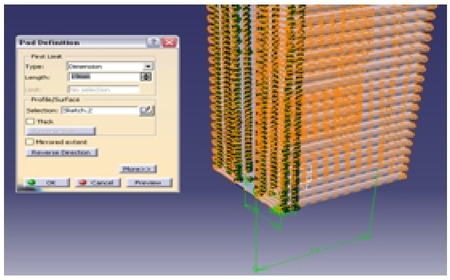


FIG. 8.2.1: Part drawing of the Serpentine coil in radiator core



8.2.2: Profile of the Serpentine radiator the Sketcher

8.3 Modelling of Serpentine coil in CATIA V5:



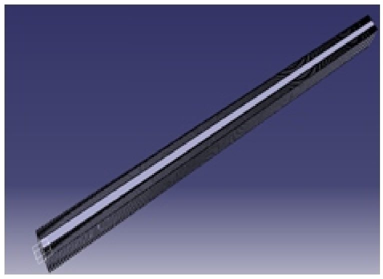


FIG.8.3.1: Padded profile of the coil Serpentine radiator core

FIG8.3.2: Final isometric view of the Serpentine radiator

8.4 Determination of effectiveness:
8.4.1 Determination of the surface area of the Radiator Core:
8.4.2 Determination of the Effectiveness:
8.4.3 Comparison of the results with the existing radiator:

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Table 2: Comparison of effectiveness

Name	Effectiveness
Existing-Tubular and Fin	53.10%
Improvise-Serpentine	71.69%

Therefore, the increase in the effectiveness of the radiator by employing the Serpentine radiator core is 18.59 %.

9.RESULTS OBTAINED IN PRO E MECHANICA®:

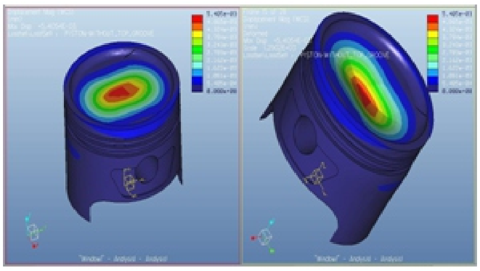


FIG.9.1: Nodal displacements of the Piston.

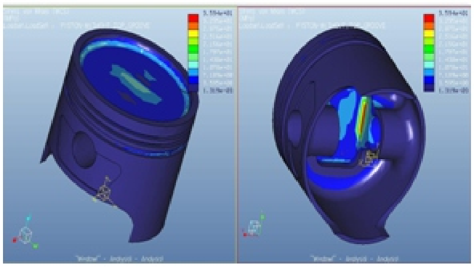
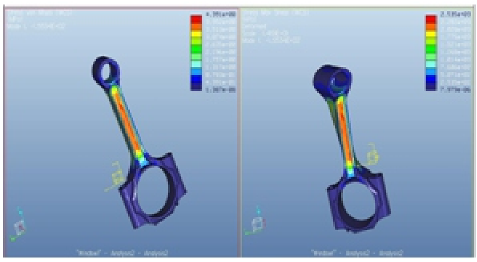


FIG.9.2: Von Mises stresses induced in the Piston



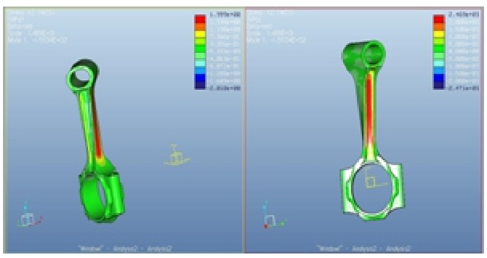


FIG. 9.4 FIG.9.4

FIG. A9.3: Von Mises stresses and Max. shear stress developed in the Connecting rod

FIG.9.4: Shear stresses developed in the XZ- and YZ-planesin Buckling analysis

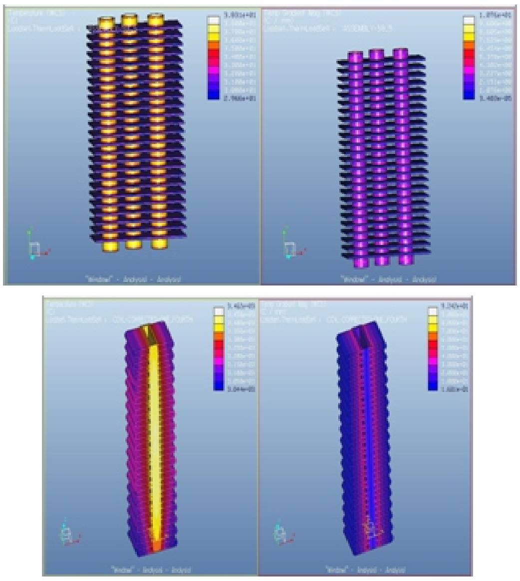


FIG. 9.5 FIG. 9.6

FIG. 9.5: Temperature distribution and Temperature gradient of the existing Maruti ALTO Vx radiator

FIG. 9.6: Temperature distribution and Temperature gradient of the improvised Maruti ALTO Vx radiator

10.CONCLUSION:

It is thereby concluded by this exhaustive study taken up that the Piston and Connecting Rod assembly are safe and do not undergo failure due to the compressive stresses set up in them due to the structural loads, as the values of these are below the Yield stress value of the Aluminium alloy Al 6061 (σy=276 M Pa) and Cast Iron (σy=1100 M Pa) . And the Factors of Safety obtained for the Piston and Connecting rod assembly are 7.67, 12.21 respectively, which are satisfactory. The components under consideration do not undergo failure due to compression and also due to shear.

Table 3: Results of the Structural analysis.

Component	Result	Mechanical-PRO E
Piston (Static)	Max. Nodal displacement (DMX) in mm	0.00540
	Max. vonMises stress (SMX) in MPa	35.94
	Max. Shear stress in MPa- XZ plane	10.51
	Max. Shear stress in MPa- YZ plane	78.18
Connecting Rod (Buckling)	Max. vonMises stress (SMX) in MPa	43.91
	Max. Shear stress in MPa- XY plane	1.99
	Max. Shear stress in MPa- YZ plane	2.46

And the existing radiator of the tubular and fin type has effectiveness of 53.1% and the temperature distribution obtained for it is 38.31oC and the thermal gradient obtained is 10.76 oC/mm. After the improvisation of its design by increasing the effective surface area of the radiator core by modifying the fin geometry to Serpentine type from Tubular and Fin type, the effectiveness has increased to 71.69%, the temperature distribution obtained is 34.62oC and the temperature gradient obtained is 92.42oC.

Table 4: Comparison of the thermal analysis

Name	Effective Surface area	NTU	Effectiveness	Temperature distribution
Existing-Tubular and Fin	2.48 m2	0.8	53.10%	1.076 °C/mm
Improvise-Serpentine	4.31 m2	1.398	71.69%	92.42 °C/mm

11.FUTURE STUDIES:

Since the results obtained in this study are based on the assumptions that the material properties are isotropic in nature and the analyses are linear in nature, further investigation can be carried out with the determination of the orthotropic material properties with respect to the geometry of the tooling and thus performing the analyses on a CAA (Computer-aided Analysis) software that is capable of performing a Non-linear analyses on these components. And further, a Computational Fluid Dynamic analysis can be taken up to establish the correct heat transfer from the radiator to the atmosphere. Thus, accomplishing more accurate and comprehensive results than those obtained in the present analyses.

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