# ANALYSIS OF AUTOMOBILE RADIATOR USING COMPUTATIONAL FLUID DYNAMICS

A Project report submitted

in partial fulfillment of the requirement for the award of the degree of

# **BACHELOR OF ENGINEERING**

In

# MECHANICAL ENGINEERING

By

| K KARTHIK PREETHAM | 318126520148 |
|--------------------|--------------|
| KANDI HARISH       | 318126520146 |
| ARAJALLA SOMANADH  | 318126520118 |
| B YESHWANT BALVADA | 318126520119 |
| GANGARAPU MANJIT   | 318126520137 |

Under the guidance of

Mr. B G CHANDRA SEKHAR M.Tech(Ph.D)

Assistant Professor

DEPARTMENT OF MECHANICAL ENGINEERING



ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY AND SCIENCES

Autonomous status accorded by UGC and Andhra University (Approved by AICTE, Permanently Affiliated to A.U., & Accredited by NBA, NAAC) Sangivalasa, Bheemunipatnam Mandal Visakhapatnam(District)-531162

2022

# ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY AND SCIENCES

Autonomous status accorded by UGC and Andhra University (Approved by AICTE, Permanently Affiliated to A.U., & Accredited by NBA, NAAC) Sangivalasa, Bheemunipatnam Mandal Visakhapatnam(District)-531162



# CERTIFICATE

This is to certify that the Project Report entitled "ANALYSIS OF AUTOMOBILE RADIATOR USING COMPUTATIONAL FLUID DYNAMICS" has been conducted by K KARTHIK PREETHAM (318126520148), KANDI HARISH (318126520146), ARAJALLA SOMANADH (318126520118), BYESHWANT BALVADA (318126520119), GANGARAPU MANJIT (318126520137) in the partial fulfilment of the requirements for the award of the Degree of Bachelor of Technology in Mechanical Engineering. It is the work of bonafide, carried out under the guidance and supervision of Mr. B G CHANDRA SEKHAR M.Tech (Ph.D), Assistant Professor, Department of Mechanical Engineering during the academic year of 2018-2022.

A G. W. Supt

PROJECT GUIDE Mr. B G CHANDRA SEKHAR M.Tech (Ph.D) Assistant Professor Dept. of Mechanical Eng. ANITS, Sangivalasa Visakhapatnam.

R.n.u - . .

HEAD OF THE DEPARTMENT Dr. B. Naga Raju Professor Dept. of Mechanical Eng. ANITS, Sangivalasa Visakhapatnam.

PROFESSOR & HEAD Department of Mechanical Engineering ANK NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCE Sangivalaşa 531 162 VISAKHAPATNAM Disi A F

# THIS PROJECT WORK IS APPROVED BY THE FOLLOWING BOARD OF EXAMINERS

INTERNAL EXAMINER.

24.1.1 2

PROFESSOR & HEAD Department of Mechanical Engineering New NEERUX ONDA INSTITUTE OF FEEINOLOGY & SCIENCE Sangivalasa 531 162 VISJEHZPATNAM Dist A F

EXTERNAL EXAMINER.

Shund Profiler

# ACKNOWLEDGEMENT

We express immensely our deep sense of gratitude to **Mr. B G CHANDRA SEKHAR**, Assistant Professor Department of Mechanical Engineering, Anil Neerukonda Institute of Technology & Sciences, Sangivalasa, Bheemunipatnam (Mandal), Visakhapatnam (District) for his valuable guidance and encouragement at every stage of the work for the successful fulfilment of students.

We are here thankful to **Prof. T.V Hanumantha Rao**, Principal and **Prof. B.Nagaraju**, Head of the Department, Department of Mechanical Engineering, Anil Neerukonda Institute of Technology & Sciences for their valuable suggestions.

We express our sincere thanks to the non-teaching staff of Mechanical Engineering for their kind co-operation and support to continue work.

Last but not least, we like to convey our thanks to all who have contributed either directly or indirectly for the completion of our work.

| K KARTHIK PREETHAM  | (318126520148) |
|---------------------|----------------|
| KANDI HARISH        | (318126520146) |
| ARAJALLA SOMANADH   | (318126520118) |
| B YESHWANT BALAVADA | (318126520119) |
| GANGARAPU MANJIT    | (318126520137) |

# ABSTRACT

Radiators are a type of heat exchangers used to transfer thermal energy from one medium to another for the purpose of cooling and heating. Upwards of 33% of the energy generated by the engine through combustion is lost in heat. Insufficient heat dissipation can result in the overheating of the engine, which leads to the breakdown of the lubricating oil, metal weakening of engine parts, and significant wear between engine parts. To minimize the stress on the engine because of heat generation, automotive radiators must be redesigned to be more compact while still maintaining an elevated level of heat transfer components. This led to the increased demand for power-packed radiators, which can dissipate the maximum amount of heat or any given space. This project aims to do the analysis of a straight tube radiator for different velocities. The modeling is done using Creo Parametric, fluid flow analysis is done by using Ansys Fluent.

Keywords: ANSYS, CFD, Velocity, Heat Exchanger, Fluent, Car Radiator

CONTENTS

# **TABLE OF CONTENTS**

| 1 INTRODUCTION  | 2  |
|---|--|
| 1.1 DEFINITIONS   | 2  |
| 1.1.1 HEAT EXCHANGER  | 2  |
| 1.1.2 RADIATOR  | 2  |
| 1.2 RADIATOR TERMINOLOGY  | 3  |
| 1.3 HISTORY   | 4  |
| 1.4 TYPES OF HEAT EXCHANGERS  | 5  |
| 1.4.1 DOUBLE PIPE HEAT EXCHANGER  | 5  |
| 1.4.2 SHELL TUBE HEAT EXCHANGER   | 5  |
| 1.4.3 PLATE HEAT EXCHANGER  | 5  |
| 1.4.4 CONDENSERS AND BOILERS AS HEAT EXCHANGERS   | 6  |
| 1.5 CLASSIFICATION OF RADIATOR  | 6  |
| 1.5.1 ACCORDING TO THE RADIATOR CORE STRUCTURE  | 6  |
| 1.5.2 ACCORDING TO THE DIRECTION OF FLOW OF MOVEMENT  | 8  |
| 1.6 WORKING PRINCIPLE   | 9  |
| 1.7 APPLICATIONS OF RADIATOR  | 9  |
|   |  |
| 2 LITERATURE REVIEW   |  |
| 2 LITERATURE REVIEW   | 11<br>   |
| 2 LITERATURE REVIEW   | <b>11</b><br><b>19</b><br>19   |
| 2 LITERATURE REVIEW   | <b>11</b><br><b>19</b><br>19<br>20   |
| 2 LITERATURE REVIEW<br>3 INTRODUCTION TO SOFTWARE PACKAGES<br>3.1 INTRODUCTION TO CREO PARAMETRIC<br>3.2 INTRODUCTION TO ANSYS<br>3.3 INTRODUCTION TO COMPUTATIONAL FLUID DYNAMICS (CFD)  | <b>11</b><br><b>19</b><br>20<br>21   |
| 2 LITERATURE REVIEW<br>3 INTRODUCTION TO SOFTWARE PACKAGES<br>3.1 INTRODUCTION TO CREO PARAMETRIC<br>3.2 INTRODUCTION TO ANSYS<br>3.3 INTRODUCTION TO COMPUTATIONAL FLUID DYNAMICS (CFD)<br>4 MODELING PROCEDURE  | <b>11</b><br><b>19</b><br>20<br>21<br><b>27</b>  |
| 2 LITERATURE REVIEW<br>3 INTRODUCTION TO SOFTWARE PACKAGES<br>3.1 INTRODUCTION TO CREO PARAMETRIC<br>3.2 INTRODUCTION TO ANSYS<br>3.3 INTRODUCTION TO COMPUTATIONAL FLUID DYNAMICS (CFD)<br>4 MODELING PROCEDURE<br>4.1 GENERATION OF RADIATOR SHAPE USING CREO PARAMETRIC  |  |
| 2 LITERATURE REVIEW<br>3 INTRODUCTION TO SOFTWARE PACKAGES<br>3.1 INTRODUCTION TO CREO PARAMETRIC<br>3.2 INTRODUCTION TO ANSYS<br>3.3 INTRODUCTION TO COMPUTATIONAL FLUID DYNAMICS (CFD)<br>4 MODELING PROCEDURE<br>4.1 GENERATION OF RADIATOR SHAPE USING CREO PARAMETRIC<br>4.2 STEPS INVOLVED IN THE ANALYSIS AND SOLUTION   | <b>11</b><br><b>19</b><br>20<br>21<br><b>27</b><br><b>27</b><br>27   |
| 2 LITERATURE REVIEW<br>3 INTRODUCTION TO SOFTWARE PACKAGES<br>3.1 INTRODUCTION TO CREO PARAMETRIC<br>3.2 INTRODUCTION TO CREO PARAMETRIC<br>3.3 INTRODUCTION TO COMPUTATIONAL FLUID DYNAMICS (CFD)<br>4 MODELING PROCEDURE<br>4.1 GENERATION OF RADIATOR SHAPE USING CREO PARAMETRIC<br>4.2 STEPS INVOLVED IN THE ANALYSIS AND SOLUTION<br>4.2.1 ANSYS  | <b>11</b><br><b>19</b><br>20<br>21<br><b>27</b><br>27<br>27<br>27  |
| 2 LITERATURE REVIEW   | 11<br>19<br>20<br>21<br>27<br>27<br>27<br>27<br>27<br>27<br>27<br>28   |
| 2 LITERATURE REVIEW<br>3 INTRODUCTION TO SOFTWARE PACKAGES<br>3.1 INTRODUCTION TO CREO PARAMETRIC<br>3.2 INTRODUCTION TO CNEO PARAMETRIC<br>3.3 INTRODUCTION TO COMPUTATIONAL FLUID DYNAMICS (CFD)<br>4 MODELING PROCEDURE<br>4.1 GENERATION OF RADIATOR SHAPE USING CREO PARAMETRIC<br>4.2 STEPS INVOLVED IN THE ANALYSIS AND SOLUTION<br>4.2.1 ANSYS<br>4.2.2 GEOMETRY<br>4.2.3 MESH  |  |
| 2 LITERATURE REVIEW   | 11<br>19<br>20<br>21<br>27<br>27<br>27<br>27<br>27<br>27<br>27<br>27<br>27<br>27<br>28<br>28<br>30   |
| 2 LITERATURE REVIEW   | <b>11</b><br><b>19</b><br><b>19</b><br><b>20</b><br><b>21</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>28</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b>  |
| 2 LITERATURE REVIEW<br>3 INTRODUCTION TO SOFTWARE PACKAGES<br>3.1 INTRODUCTION TO CREO PARAMETRIC<br>3.2 INTRODUCTION TO CNPUTATIONAL FLUID DYNAMICS (CFD)<br>3.3 INTRODUCTION TO COMPUTATIONAL FLUID DYNAMICS (CFD)<br>4 MODELING PROCEDURE<br>4.1 GENERATION OF RADIATOR SHAPE USING CREO PARAMETRIC<br>4.2 STEPS INVOLVED IN THE ANALYSIS AND SOLUTION<br>4.2.1 ANSYS<br>4.2.2 GEOMETRY<br>4.2.3 MESH<br>4.2.4 SETUP<br>4.2.5 SOLUTION<br>4.2.6 RESULTS. | <b>11</b><br><b>19</b><br><b>2</b> 0<br><b>2</b> 1<br><b><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>27</b><br/><b>28</b><br/><b>30</b><br/><b>30</b><br/><b>30</b></b>   |
| 2 LITERATURE REVIEW   | <b>11</b><br><b>19</b><br><b>1</b> 9<br><b>20</b><br><b>21</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>27</b><br><b>28</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b><br><b>30</b> |

| 7 DEFEDENCES                                     | 67 |
|--|----|
| 6 CONCLUSIONS                                    | 65 |
| 5.6 TEMPERATURE OUTLET PLOT                      | 59 |
| 5.5 SCALED RESIDUALS                             | 54 |
| 5.4 THE TEMPERATURE CONTOURS OF THE CAR RADIATOR |    |
| 5.3 TEMPERATURE OUTLET PLOT                      | 43 |
| 5.2 SCALED RESIDUALS                             |    |
| 5.1 THE TEMPERATURE CONTOURS OF THE CAR RADIATOR |    |

# LIST OF FIGURES

| Fig 1.1.1 Car Radiator   | 4  |
|--|----|
| Fig 1.1.2 Cellular Radiator  | 7  |
| Fig 1.1.3 Tubular Radiator   | 7  |
| Fig 1.1.4 Cross flow Radiator  | 8  |
| Fig 1.1.5 Down flow Radiator   | 8  |
| Fig 1.1.1 CFD Model applications and their simulations                   | 22 |
| Fig 4.2.1 Car Radiator Design in Ansys                                   | 27 |
| Fig 4.2.2 Car Radiator Fins  | 28 |
| Fig 4.2.3 Values of Edges, faces of a Car Radiator Design in ANSYS       | 29 |
| Fig 4.2.4 Values of nodes and elements of a Car Radiator Design in ANSYS | 29 |
| Fig 4.2.5 Temperature contour of a Car Radiator Design in ANSYS          | 30 |
| Fig 5.1.1 Temperature contour for the radiator at 1m/s for aluminium     | 33 |
| Fig 5.1.2 Temperature contour for the radiator at 2m/s for aluminium     | 33 |
| Fig 5.1.3 Temperature contour for the radiator at 3m/s for aluminium     | 34 |
| Fig 5.1.4 Temperature contour for the radiator at 4m/s for aluminium     | 34 |
| Fig 5.1.5 Temperature contour for the radiator at 5m/s for aluminium     | 35 |
| Fig 5.1.6 Temperature contour for the radiator at 6m/s for aluminium     | 35 |
| Fig 5.1.7 Temperature contour for the radiator at 7m/s for aluminium     | 36 |
| Fig 5.1.8 Temperature contour for the radiator at 8m/s for aluminium     | 36 |
| Fig 5.1.9 Temperature contour for the radiator at 9m/s for aluminium     | 37 |
| Fig 5.1.10 Temperature contour for the radiator at 10m/s for aluminium   | 37 |
| Fig 5.2.1 Scaled residuals for the radiator at 1m/s for aluminium        |    |
| Fig 5.2.2 Scaled residuals for the radiator at 2m/s for aluminium        |    |
| Fig 5.2.3 Scaled residuals for the radiator at 3m/s for aluminium        |    |
| Fig 5.2.4 Scaled residuals for the radiator at 4m/s for aluminium        | 39 |
| Fig 5.2.5 Scaled residuals for the radiator at 5m/s for aluminium        | 40 |
| Fig 5.2.6 Scaled residuals for the radiator at 6m/s for aluminium        | 40 |
| Fig 5.2.7 Scaled residuals for the radiator at 7m/s for aluminium        | 41 |

| Fig 5.2.8 Scaled residuals for the radiator at 8m/s for aluminium     | 41 |
|---|----|
| Fig 5.2.9 Scaled residuals for the radiator at 9m/s for aluminium     | 42 |
| Fig 5.2.10 Scaled residuals for the radiator at 10m/s for aluminium   | 42 |
| Fig 5.3.1 Temperature outlet for the radiator at 1m/s for aluminium   | 43 |
| Fig 5.3.2 Temperature outlet for the radiator at 2m/s for aluminium   | 43 |
| Fig 5.3.3 Temperature outlet for the radiator at 3m/s for aluminium   | 44 |
| Fig 5.3.4 Temperature outlet for the radiator at 4m/s for aluminium   | 44 |
| Fig 5.3.5 Temperature outlet for the radiator at 5m/s for aluminium   | 45 |
| Fig 5.3.6 Temperature outlet for the radiator at 6m/s for aluminium   | 45 |
| Fig 5.3.7 Temperature outlet for the radiator at 7m/s for aluminium   | 46 |
| Fig 5.3.8 Temperature outlet for the radiator at 8m/s for aluminium   | 46 |
| Fig 5.3.9 Temperature outlet for the radiator at 9m/s for aluminium   | 47 |
| Fig 5.3.10 Temperature outlet for the radiator at 10m/s for aluminium | 47 |
| Fig 5.4.1 Temperature contour for the radiator at 1m/s for copper     | 49 |
| Fig 5.4.2 Temperature contour for the radiator at 2m/s for copper     | 49 |
| Fig 5.4.3 Temperature contour for the radiator at 3m/s for copper     | 50 |
| Fig 5.4.4 Temperature contour for the radiator at 4m/s for copper     | 50 |
| Fig 5.4.5 Temperature contour for the radiator at 5m/s for copper     | 51 |
| Fig 5.4.6 Temperature contour for the radiator at 6m/s for copper     | 51 |
| Fig 5.4.7 Temperature contour for the radiator at 7m/s for copper     | 52 |
| Fig 5.4.8 Temperature contour for the radiator at 8m/s for copper     | 52 |
| Fig 5.4.9 Temperature contour for the radiator at 9m/s for copper     | 53 |
| Fig 5.4.10 Temperature contour for the radiator at 10m/s for copper   | 53 |
| Fig 5.4.1 Scaled residuals for the radiator at 1m/s for copper        | 54 |
| Fig 5.5.2 Scaled residuals for the radiator at 2m/s for copper        | 54 |
| Fig 5.5.3 Scaled residuals for the radiator at 3m/s for copper        | 55 |
| Fig 5.5.4 Scaled residuals for the radiator at 4m/s for copper        | 55 |
| Fig 5.5.5 Scaled residuals for the radiator at 5m/s for copper        | 56 |
| Fig 5.5.6 Scaled residuals for the radiator at 6m/s for copper        | 56 |
| Fig 5.5.7 Scaled residuals for the radiator at 7m/s for copper        | 57 |
| Fig 5.5.8 Scaled residuals for the radiator at 8m/s for copper        | 57 |
| Fig 5.5.9 Scaled residuals for the radiator at 9m/s for copper        | 58 |
| Fig 5.5.10 Scaled residuals for the radiator at 10m/s for copper      | 58 |
| Fig 5.6.1 Temperature outlet for the radiator at 1m/s for copper      | 59 |

| Fig 5.6.2 Temperature outlet for the radiator at 2m/s for copper   | 59 |
|--|----|
| Fig 5.6.3 Temperature outlet for the radiator at 3m/s for copper   | 60 |
| Fig 5.6.4 Temperature outlet for the radiator at 4m/s for copper   | 60 |
| Fig 5.6.5 Temperature outlet for the radiator at 5m/s for copper   | 61 |
| Fig 5.6.6 Temperature outlet for the radiator at 6m/s for copper   | 61 |
| Fig 5.6.7 Temperature outlet for the radiator at 7m/s for copper   | 62 |
| Fig 5.6.8 Temperature outlet for the radiator at 8m/s for copper   | 62 |
| Fig 5.6.9 Temperature outlet for the radiator at 9m/s for copper   | 63 |
| Fig 5.6.10 Temperature outlet for the radiator at 10m/s for copper | 63 |

# LIST OF TABLES

| Table 3.1 Comparison of Experiment and Simulation  | 23 |
|--|----|
| Table 3.2 General Comparisons  | 23 |
| Table 4.1 Dimensions table of the car radiator   | 28 |
| Table 5.1 Table of Outlet temperature corresponding to the inlet velocity of the coolant     | 32 |
| Table 5.2 Table of Outlet temperature corresponding to the inlet velocity of the coolant for |    |
| copper   | 48 |

# CHAPTER-1

**INTRODUCTION** 

# **1** INTRODUCTION

### **1.1 DEFINITIONS:**

### **1.1.1 HEAT EXCHANGER:**

A heat exchanger is a system used to transfer heat between two or more fluids. Heat exchangers are used in both cooling and heating processes. The fluids may be separated by a solid wall to prevent mixing, or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, and sewage treatment. The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air. Another example is the heat sink, which is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant. There are three primary classifications of heat exchangers according to their flow arrangement. In parallel-flow heat exchangers, the two fluids enter the exchanger at the same end, and travel in parallel to one another to the other side. In counterflow heat exchangers the fluids enter the exchanger from opposite ends. The counter current design is the most efficient, in that it can transfer the most heat from the heat (transfer) medium per unit mass due to the fact that the average temperature difference along any unit length is higher. For efficiency, heat exchangers are designed to maximize the surface area of the wall between the two fluids, while minimizing resistance to fluid flow through the exchanger.

### **1.1.2 RADIATOR:**

The radiators are heat exchangers that are used to transfer thermal energy from one medium to another for the purpose of cooling and heating. A radiator is a device consisting of a large amount of cooling surface which contains enormous amounts of air so that it spreads through the water to cool efficiently. The radiator has a wide range of applications in automobile industries there are used to cool the internal combustion engine. They also used in piston-engine aircraft, railways, locomotives, motorcycles, stationary generating plants and other places where such engines are used. Radiators are usually made of copper and brass because of their high heat conductivity. The various sections of the radiators are joined by soldering. The radiator will do the cooling purposes because the temperature of the burning gases in the engine cylinder reaches up to 1500°C to 2000°C. Radiators are classified according to the direction of the water flow through them. In some, the water flows from top to bottom-down flow type radiator.

## **1.2 RADIATOR TERMINOLOGY:**

Radiators transfer most of their heat via convection rather than thermal radiation. If there are large temperature differences, it can cause distortion of the engine components. Its composition, there are water room, water chamber, and the radiator core of the three parts. The coolant is flowing in the radiator core, and the air is outside the radiator, and through the coolant, the stifling air into chilly air, so as to achieve the purpose of absorbing heat and cooling.

**Upper tank:** Due to absorbing heat from the engine coolant get hot, the liquid expands and creates pressure in the radiator additionally. The pressure causes the coolant to get higher than the pressure cap, in order to prevent leakage excess coolant needs to be captured somewhere the excess fluid flows into the pipe and goes into the overflow tank.

**Lower tank:** just after it has passed through the heat radiating tubes and fins in the body of the radiator the bottom tank receives the cooling water.

**Tubes:** On its way to the opposite tank, as the coolant passes through the radiator tubes, it transfers heat to the tubes that transfer the heat to the fins that are attached between the rows. The fins head the heat flow to the ambient air.

**Filler cap**: Since the coolant expands the high coolant temperature leads to an increase in pressure in the cooling system. Coolant is press in the tank that will increase the pressure in the tank.

**Fins**: Fins are surfaces that are used to increase the rate of heat transfer to or from the environment and they extend from the surface by increasing convection. Fins increase the surface area and can be an economical solution to heat transfer problems.

**Fan:** The fan is mounted behind the radiator on the water pump shaft. When the engine is running at the low speed it certainly insufficient to produce the desired cooling from nature. Here the fan serves the purpose.

**Thermostat**: Now what the thermostat does is as you have got coolant running through engine it looks at the temperature of it. Once the temperature gets too high and your engine is warmed up then thermostat detects and will pass the coolant back through the radiator and then the coolant will come cool through the radiator.

**Water Pump:** The water pump is used to increase the velocity of the circulating water. When a low-temperature coolant passes through the water pump it pumps the coolant back into the engine.

### **1.3 HISTORY:**

The heating radiator was invented by Franz San Galli in 1855, a Kingdom of Prussiaborn Russian businessman living in St. Petersburg. In the late 1800s, companies, such as the American Radiator Company, promoted cast iron radiators over previous fabricated steel designs in order to lower costs and expand the market. Car radiators grew with the invention of cars. In the history of the world's automobile development, the German engineer Karl Benz made the first gasoline-powered tricycle. The car uses a two-stroke gasoline engine and has some basic features of modern cars, including a water-cooling system. But there is no radiator, relying on a long and curved pipe to circulate water to ensure the cooling of the internal combustion engine. This type of coiled radiator has low efficiency, consumes a lot of water, and requires a bulky cooling circuit, which is far from satisfying the demand.

The first real car radiator in the world was the honeycomb radiator invented by Wilhelm Maybach in 1901. He was a German engine designer and industrialist who designed the first honeycomb radiator for the Mercedes 35hp. Later, he improved the design and changed the square tube into a round tube. The two ends of the tube were pierced into a hexagon, and the ends of the hexagon were welded together by soldering. Save copper wire. However, the internal water flow speed of the honeycomb radiator is slow, which is easy to accumulate; the welding seam is long, which is easy to leak; and the cost is high, and the maintenance is complicated. Therefore, it was later replaced by a tube-fin radiator.

At present there are two, one is aluminium, used in the general passenger car; the second is copper material, used in large commercial vehicles.



Fig 1.1.1 Car Radiator

# 1.4 TYPES OF HEAT EXCHANGERS: 1.4.1 DOUBLE PIPE HEAT EXCHANGER:

Double-pipe heat exchangers are devices that provide the transfer of thermal energy between two fluids at different temperatures. The major use of these heat exchangers is the sensible heating or cooling process of fluids where small heat transfer areas are required. The oil cooler is an example of these processes. In this study, fouled finned, clean finned, fouled unfinned, and clean unfinned double-pipe heat exchangers used as an oil cooler in ships have been compared. In thermal design, suggested different Nusselt number equations have been used, and the results of these equations have been shown in tables and figures. As a result, it is evaluated that using fouled finned double-pipe heat exchanger as oil cooler in ships is the most appropriate selection.

### **1.4.2 SHELL TUBE HEAT EXCHANGER:**

A shell and tube heat exchanger are a class of heat exchanger designs. It is the most common type of heat exchanger in oil refineries and other large chemical processes and is suited for higher-pressure applications. As its name implies, this type of heat exchanger consists of a shell (a large pressure vessel) with a bundle of tubes inside it. One fluid runs through the tubes, and another fluid flows over the tubes (through the shell) to transfer heat between the two fluids. The set of tubes is called a tube bundle, and may be composed of several types of tubes: plain, longitudinally finned, etc.

## **1.4.3 PLATE HEAT EXCHANGER:**

A plate heat exchanger is a type of heat exchanger that uses metal plates to transfer heat between two fluids. This has a major advantage over a conventional heat exchanger in that the fluids are exposed to a much larger surface area because the fluids are spread out over the plates. This facilitates the transfer of heat, and greatly increases the speed of the temperature change. Plate heat exchangers are now common and very small brazed versions are used in the hot-water sections of millions of combination boilers. The high heat transfer efficiency for such a small physical size has increased the domestic hot water (DHW) flowrate of combination boilers. The small plate heat exchanger has made a significant impact in domestic heating and hot water. Larger commercial versions use gaskets between the plates, whereas smaller versions tend to be brazed.

## **1.4.4 CONDENSERS AND BOILERS AS HEAT EXCHANGERS:**

A condenser is a heat exchanger used to condense a gaseous substance into a liquid state through cooling. In so doing, the latent heat is released by the substance and transferred to the surrounding environment. Condensers are used for efficient heat rejection in many industrial systems. Condensers can be made according to numerous designs and come in many sizes ranging from small (hand-held) to exceptionally large (industrial-scale units used in plant processes). For example, a refrigerator uses a condenser to get rid of heat extracted from the interior of the unit to the outside air.

Condensers are used in air conditioning, industrial chemical processes such as distillation, steam power plants and other heat-exchange systems. Use of cooling water or surrounding air as the coolant is common in many condensers.

In a boiler heat exchanger, heat is transferred from the hot gases of a combustion process to water moving through the exchanger's internal piping system. As a result, the water heats up as the gas cools down. Other appliances that utilize a heat exchanger include refrigerators and air conditioners, though the direction of heat transfer in these systems is reverse to that of a boiler.

### **1.5 CLASSIFICATION OF RADIATOR:**

### ACCORDING TO THE RADIATOR CORE STRUCTURE:

- CELLULAR RADIATOR
- TUBULAR RADIATOR

## ACCORDING TO THE DIRECTION OF FLOW OF MOVEMENT:

- CROSS FLOW
- DOWN FLOW

# **1.5.1 ACCORDING TO THE RADIATOR CORE STRUCTURE: 1.5.1.1 CELLULAR RADIATOR:**

The core is composed of many individual air cells which are surrounded by water. Because of its appearance, the cellular type usually is known as a honeycomb radiator, especially when the cells in front are hexagonal in form. In a cellular. radiator, the clogging of any passage results in a loss but of a small part of the total cooling surface. Air passes through the tubes and the water flows in the spaces between them in cellular type core. The core contains a large number of air cells that are surrounded by the radiator. It is known as a honeycomb radiator because of its appearance as the cells in front are hexagonal in form.



Fig 1.1.2 Cellular Radiator

# **1.5.1.2 TUBULAR RADIATOR:**

In tubular type core, the upper and lower tanks are connected by a series of tubes through which water passes. Fins are placed around the tubes to improve heat transfer. Air passes around the outside of the tubes, between the fins, absorbing heat from the water in passing. In a tubular radiator, because the water passes through all the tubes, if one tube becomes clogged, the cooling effect of the entire tube is lost. In a cellular. radiator, the clogging of any passage results in a loss but of a small part of the total cooling surface.



Fig 1.1.3 Tubular Radiator

# **1.5.2 ACCORDING TO THE DIRECTION OF FLOW OF MOVEMENT: 1.5.2.1 CROSS FLOW RADIATOR:**

A cross flow radiator is a radiator that has its tanks on the sides of the radiator core. The coolant moves across the core from the right side to the left side. This type of radiator is a good option for cars with a low hood line or a modern smaller car.



### **Crossflow Radiator**

Fig 1.1.4 Cross flow Radiator

## **1.5.2.2 DOWN FLOW RADIATOR:**

In a down-flow radiator you have a tank attached to the top and bottom of the radiator core. The coolant enters the top tank and flows down to the bottom tank. As you have guessed by now, a crossflow radiator has tanks on the left and right side. Coolant enters one side and flows across to the other.



Fig 1.1.5 Down flow Radiator

## **1.6 WORKING PRINCIPLE:**

The radiator is simple device. Nowadays most modern cars use aluminium radiators. Radiators usually have a tank on each side, and inside the tank is a transmission. In this type of radiator, we are going to have an aluminum mesh. In this aluminum/copper device, it consists of one inlet and one outlet. Inside the radiator, there are tubes mounted in a parallel arrangement. And the aluminum/copper fins are attached to all the tubes. The Radiator working is quite simple. In the radiator, the coolant flows from the inlet to the outlet through many tubes mounted in a parallel arrangement. The hot water enters the radiator through the inlet port. And a fan is attached behind the radiator to cool down the hot water in the tubes. The fan blows the air and cools down the water. So, the water is going to come out cooler than it entered before and then go back to the engine. we have come to see the great purpose of a radiator in the automobile engine cooling system. Well, working is less complex and easy to understand. In a radiator, there is a tank on each side, and inside contained a transmission cooler. There are inlet and outlet ports, which from the inlet port coolant flows to the tubes where they are exposed to cooling. The tubes are in a parallel arrangement, where they come in contact with cooling fins to draw away heat from the core.

## **1.7 APPLICATIONS OF RADIATOR:**

- To cool motor oil or power steering fluid.
- Automatic transmission fluid.
- Air conditioner and Automobiles.
- Cooling internal combustion engines.
- Piston-engine aircrafts.
- Railway locomotives where heat engines are used

# CHAPTER-2

# LITERATURE REVIEW

# **2** LITERATURE REVIEW

**1** Adnan M. Hussain studied the forced convection heat transfer enhancement by TiO2 and SiO2 suspended in water as a base fluid inside the flat copper tubes of an automotive cooling system . Maximum Nusselt number enhancements of up to 11% and 22.5% were obtained for TiO2 and SiO2 nanoparticles, respectively, in water. The experimental results showed that the Nusselt number behaviours of the nanofluids highly depended on the volume flow rate, inlet temperature and nanofluid volume concentration. The results showed that the SiO2 nanofluid produces a higher heat transfer enhancement than the TiO2 nanofluid; likewise, TiO2 nanofluid enhanced heat transfer more than pure water. The results also proved that TiO2 and SiO2 nanofluid have a high potential for heat transfer enhancement and are highly appropriate for industrial and practical applications. The study succeeded in analysing the importance of nanofluid which in fact proves to be beneficial in many of the other industrial application.

**2 A.H. Mamun, K.Y. Leong, S.N. Kazi, and R. Saidur:** This paper outlines the effect on cooling capacity while using nanofluid based coolant in engine cooling system. Through this, it was discovered that nano-fluid increases heat transfer which has higher thermal conductivity than base coolant which blends of 50%/50% ethylene glycol and water. When same heat transfer occurs compared to base one of the radiator, its core area can be reduced. Ethylene glycol as a coolant in the radiator when used compared to the nanofluid, the thermal performance of a radiator is raised by increasing power of pumping.

**3 Alhassan S. Tijani** conducted research work with a goal to replace conventional coolants in radiators . For that he used Al2O3/CuO based nanofluid with water and ethylene glycol as base fluid . He conducted his experimental work to determine the thermos-physical properties and heat transfer characteristics of the used nanofluid. He also simulated the model using ANSYS Fluent software. The heat transfer characteristics were measured in terms of thermal conductivity , heat transfer coefficient ,Nusselt number and rate of heat transfer. Density plays an especially key role in determining the thermo-physical behaviour of nanofluids due to its influence on Reynolds number, Nusselt number and thermal diffusivity. As described in the paper the lowest thermal conductivity of the coolant is at 0.415 W/m K for the base fluid which is in fact conventionally used and the highest thermal conductivity observed is at 1.287 W/m K for 0.3% concentration of Al2O3 nanofluid. The nanofluids have a tremendous increase in thermal conductivity as compared with the base fluid and this is expected to increase heat transfer enhancement in the radiator. As

the concentration of nanoparticles added to the nanofluid increases from0.05% to 0.3%, the thermal conductivity for both nano fluids increase as well. Comparing both nanofluids, CuO nanofluid had lower thermal conductivity than that of Al2O3, with thermal conductivity of 1.241 W/m K and 1.287 W/m K for CuO and Al2O3nanofluidrespectively.

**4 A. Sing** Nano fluid is the suspensions of nano particle in base fluid. Nano fluids are the unique feature which is different from conventional liquid solid mixture in which nm or  $\mu$ m sized particle are added in the base fluid to enhance the heat transfer rate. Most system/process whose performance is affected by the heat transfer disceptation nano fluid provides especially key role in such case. It is evident that the effects of viscosity and thermal conductivity should be considered together.

**5 Chavan & Tasgaonkar:** Low-lying areas and high-temperature areas (regions with low heat transfer areas) are identified in the corners. We see that the velocity increases with the rpm of the radiator fan. For optimal performance, it eliminates corners and improves the radius of the Circular mode. The low power consumption of the fan works well because the cost savings of the equipment is 24%, the cost savings on the production of large scale will be about 20% when the operation is done. Chavan et al., Hydraulic actuators such as pumps and motors were selected to obtain the required force of gravity. The calculation and temperature of the same temperature are calculated. To eliminate temperature growth, a cooling radiator is performed using the standard LMTD method. The wings have been shown solely to give a sense of proportion. The design has been successfully adapted to the available environment. Radiator analysis was performed using CFD in ANSYS Fluent.

**6 Devireddy Sandhya** conducted work for improving the performance of radiator with ethylene glycol water based TiO2 nanofluids . The paper focuses on measuring the overall heat transfer coefficient of the two working fluids that include 40:60% EG/W and 40:60% EG/W and mixed with TiO2 nanofluid which when worked experimentally is found that the presence of TiO2 enhances the heat transfer rate. They varied various concentrations of the nanofluid to research optimum condition for obtaining the maximum performance of the radiator. It was found that at 0.5% concentration the heat transfer rate is enhanced to about 35% of the normal base fluid . The paper also concludes that on the increasing the flow rate of nanofluids through the radiator tubes increases the heat transfer coefficient.

**7 D.H. Lee, L.D. Tijing, B.C. Pak and B.J. Baek:** By the utilization of twisted and straight internal fin inserts the heat transfer enhancement was researched under this article and the pressure drop and characteristics of heat transfer results on horizontal two tubes with coil-wire insert were concluded. The hot and cold-water mass flow rates effect directly the heat transfer rate and coefficient of heat transfer. It is seen that as Re raises the coil-wire insert effect on the magnification of heat transfer leads to reduce.

**8 Hardik Kumar Patel & Deepu Dinesen:** Using CFD were identified by comparing the heat transfer and pressure reduction of the heat exchanger with different performance parameters. Reduction of Vishwa Deepak Dwivedi and Ranjeet Rai in the cooling capacity of the incoming air temperature while the cooling capacity rises with the rise of the incoming cooling temperature. Decreased pressure also increases with increasing air pressure and with a decrease in the ratio of weight to the radiator. Approximately 6% increase in cooling capacity using a hot-duty louver fin with Nanofluid compared to a standard cooler with the same model.

**9 Jama et al.:** The air flow distribution and non-uniformity across the radiator of full-size Australian made ford falcon was evaluated in industrial wind tunnel. The cooling air intake of the vehicle were shielded by a quarter, one half and three quarter and fully blocked. The best method to shield front end is to employ horizontal method. This shielding method produces the more uniform cooling airflow distribution compared to other methods. Non uniformity index increased significantly as the front-end air intake area was shielded. It is reduced the cooling capacity of the vehicle. These shielding methods also produced higher average velocity across the radiator which is analogous to better cooling.

**10 John Vetrovec:** By use of passive heat load accumulator which normalizes out peak heat loads of the engine cooling system with heat load averaging capacity was evaluated through this paper. During reduced heat load condition, the phase change material will store the heat generated during peak which is called heat load accumulator. During a cold engine start the reduced emissions of harmful pollutants and faster engine warm-up was done by translating heat load to a smaller coolant inventory which by averaging allows relaxation of cooling system and substantial reduction of system size and weight, which was done by losing phase change of PCM (Phase Change Material) from liquid to solid or vice versa, which would result in same heat rejection and reduction in load on cooling system for compact heat exchanger. The accumulator can be adjusted

to replace a portion of ECS (Engine Cooling System) coolant lines, when faster warmups and high transient loads at cold engine start was handled by the system which results in concept of down-sizing of ECS volume and weight when 1) handling of high-transient loads by surpassing a full-size ECS. 2) Under typical heat load conditions, comparable to a full-size ECS offering a heat load-handling performance.

**11 JP Yadav and Bharat Raj Singh:** This article reviews the variation of parameters like inlet coolant temperature, its mass flow rate; etc. and installation of the radiator into a test-setup to review a differential analysis between different coolants. The coolant used here is composed of water and propylene glycol in a ratio of 40:60 and other is water alone. It resulted that due to the corrosiveness of water and containment of dissolved salts decreased the quality of coolant flow passage and its limitation occurs to water independent of its results in the best coolant. From the tests that have been followed in this paper, it is concluded that: one. The cooling capacity and effectiveness will raise with raise in the rate of coolant flow in radiator more for water than the mixture. 2. Cooling Capacity and Output Temperature is more for water and mixture respectively for given Input Temperature of Radiator for both with and without Fan.

### 12 Komalangan Krishnakumar, Navid Bozorgan and Nariman Bozorgan:

A numerical study on coolant i.e., CuO-water nanofluid with a given pumping power and heat exchange of copper oxide water capacity was described in this article. Under turbulent flow conditions, the overall convective local coefficients of heat transfer of nanofluid at distinct volume fractions (2% to 0.1%) and effects of speed of automobile on the radiator's efficiency were researched. The nanofluid's total coefficient of heat transfer is much better than the coefficient of heat transfer of water was described in the numerical analysis. Here and hence, it is concluded that the total area of heat transfer of the radiator can be decreased.

### 13 M. Seifi Jamnani, S.M. Peyghambarzadeh, S.M. Hoseini and S.H. Hashem

**Abadi:** This paper research about the experimental comparison of heat transfer by forced convection of Nano-fluid which is water based to that of pure water in the radiator of the automobile. Where on the addition of Al2O3 nanoparticles into the water, five distinct level of quantity magnitude of Nano-fluids in the domain of 0.2-1 vol. % was made, where the sample functional liquid goes into the radiator consisting of 34 vertical tubes which have the elliptical cross-section and with constant speed inside the tube bank the air creates a cross flow. To have the

fully turbulent regime the flow rate of the liquid has been modified in the domain of 2- 5 lit/min. On the other hand, by fluctuating the temperature in the domain of 37-490oC the effect of fluids inlet temperature to that of radiator on coefficient of heat transfer has been studied, which results the improvement in heat transfer effectiveness by increasing the circulating rate of fluid while the inlet temperatures of fluid to that of radiator has adverse effects. In correspondence with pure water, the efficiency of heat transfer can be enhanced by the application of Nano-fluid at low concentrations, up to 45%.

**14 N. Galanis, G. Roy, C.T. Nguyen, and C. Gauthier:** Here the magnification of heat transfer delivered by a specific nanofluid i.e., water and Al2O3 composition have been experimentally studied for the cooling of microprocessors and other heated electronic components which is the work of water closed system. The use of Nanofluid was addressed to be advantageous from the data obtained for Nano-fluid and distilled water with various component concentrations about 2.2% and 0.95%. with respect to distilled water, the heat transfer improvement was observed for a 4.5% concentration.

**15** Nor AzwadiCheSidik studied various experimental projects carried out regarding various nanofluids and the recent technological advancements of nano fluids in engine cooling system. He studied the works of Vajja et al., Eastman et al., Liu et al. and derived the summary regarding various use of nanofluids as coolants in automobile system their preparation methods, their influence on the efficiency of the system , various stabilizing agents, and also respective thermal conductivities of various nanofluids. The research paper helped in recognizing the performance of each nanofluid including the accurate experimental results that can be used for further experimental validation.

**16 Oliet et al.** Studied varied factors which influences the radiator performance. It includes air, fin density, coolant flow and air inlet temperature. The radiator performance depends upon air and coolant mass flow rate. When air and coolant flow rates increase the efficiency of radiator also increases. When inlet air temperature increases the cooling capacity decreases. Smaller fin spacing and greater louver fin angle have higher heat transfer. Fin density may be increased till it blocks the air flow and heat transfer rate reduced.

**17 Sadik Kakac, et al** In his literature survey showed that nanofluids significantly improve the heat transfer capability of conventional heat transfer fluids such as oil or water by suspending nanoparticles in these base liquids. The understanding of the fundamentals of heat transfer and wall friction is prime importance for developing nanofluids for a wide range of heat transfer application. He concluded that although there are recent developments in the study of heat transfer with nanofluids, more experimental results and the theoretical understanding of the mechanisms of the particle movements are needed to understand heat transfer and fluid flow behaviour of nanofluids.

**18 S. Cheong, Y. Kwon, Y. Hwang, D. Kim, and Y. Cho (2009):** A straightforward circular tube which is having turbulent and laminar flow with a constant heat flux of convective heat transfer coefficient was studied, whose performances are affected by nanofluids in this paper. The coefficient of heat transfer by convection of alumina nanofluid is improved in correspondence to base sample fluid by 20% & 15% in turbulent and laminar flow correspondingly. Through their research, they also saw that in turbulent flow, thermal conductivity plays a key role and in the laminar flow, the thermal boundary layer plays a key role. There is no enhancement in the coefficient of heat transfer by convection for amorphous molecules of nanofluids.

**19 S. Heris** They study the effect of water ethylene glycol mixture base nanofluid in a car radiator. Significant enhancements in heat transfer rate are observed using this mixture. The highest Nu number enhancement up to 55% was obtained in 0.8% volume concentration of CuO and water ethylene glycol mixture. As increase in inlet temperature the Nu number is increased.

**20 Siraj Ali Ahmed** too carried out work on use of nanofluids in radiator which too gives brief idea about the use of TiO2 nanofluid in radiator and helps us in reducing the focus of our work to the use of TiO2. The team concluded that overall heat transfer coefficient of TiO2 nanofluid can be experimentally used for measuring as a function of concentration and temperature. The paper concludes heat transfer coefficient improves for 0.2% nanoparticle concentration as compared to pure water which happens due to TiO2's grater thermal conductivity, aspect ratio, lower specific gravity, thermal resistance and thermal resistance, geometry of particles and larger specific area as to compared to pure water.

**21 Yiding Cao et al.:** They introduce application of heat pipe in automobile industry. In this application heat pipe is introduced in the automotive radiator to enhance heat transfer. The use of heat pipe increases the automobile radiator efficiency and reduces cooling fan power consumption. Heat pipes are wickless heat pipes and two- phase closed thermosyphons. The working fluids inside the heat pipe are different than the engine coolant. The effectiveness of heat pipe are hundred times higher than the copper. The gravity is used to assist the return fluid. Air is evocated from container and container is sealed. Heat was applied to the evaporator section, which causes the liquid to vaporize. The vapor then flows from the hotter section due to the higher vapor pressure to the colder section of the heat pipe, where it was condensed. The liquid condensate then returns to the evaporator section from the condenser section under the assistance of gravity.

# CHAPTER-3

# **INTRODUCTION TO SOFTWARE PACKAGES**

# **3 INTRODUCTION TO SOFTWARE PACKAGES**

## **3.1 INTRODUCTION TO CREO PARAMETRIC:**

PTC's developers created Creo Parametric as a sound foundation software that allows users the ability to expand deeper functionality with each component. As your products become more complex in its engineering, Creo offers expanded capabilities to meet your requirements. Every product isn't made equal, and your 3D CAD solution shouldn't be either.

Creo Parametric provides the broadest range of powerful yet flexible CAD 3D modeling software capabilities to accelerate the design of parts and assemblies. With Creo and its extensions, you'll have access to technologies such as:

- Generative design
- Real-time simulation
- Additive manufacturing
- Augmented reality

Creo Parametric is what most people think of when they think of "Creo". It's the standard solution for scalable 3D CAD design and is the direct descendent of Pro/Engineer Wildfire. Creo Direct is a separate application that allows users to make edits to 2D and 3D parametric designs in a direct modelling environment.

### PART MODELLING:

In Part Modelling you can create apart from a conceptual sketch through solid featurebased modelling, as well as build and modify parts through direct and intuitive graphical manipulation.

The Part Modelling Help introduces you to the terminology, basic design concepts, and procedures that you must know before you start building a part. Part Modelling shows you how to draft a 2D conceptual layout, create precise geometry using basic geometric entities, and dimension and constrain your geometry. You can learn how to build a 3D parametric part from a 2D sketch by combining basic and advanced features, such as extrusions, sweeps, cuts, holes, slots, and rounds. Finally, the Part Modelling Help provides procedures for modifying part features and resolving failures.

### **PART MODELLING MODULES:**

- Part Modelling
- Sketcher
- Feature Recognition Tool
- Creo Flexible Modelling

### **ASSEMBLY DESIGN:**

The Assembly Help describes the processes you use to manage assemblies, their features, and their components. The Help for Assembly area is divided into four high-level sections covering general assembly functionality, configuring assemblies, using top-down design, and managing large assemblies.

Use the Assembly Help to learn how to create, manipulate, redefine, analyse, and reorient your assembly.

#### **ASSEMBLY DESIGN MODULES:**

- Assembly
- Creo Intelligent Fastener
- Assembly Process Planning

#### **MODEL ANALYSIS:**

Model analysis lets you perform four different types of model evaluation: behavioural modelling, model checking, tolerance analysis, and design editing. Behaviour modelling enables you to perform a wide variety of analyses on a model and incorporate the results into the model. Model checking runs transparently within Creo Parametric, making sure your model complies with company design standards and best modelling practices. Design editing provides you with a list of the major design steps and model parameters that you can use to create a program that changes the model according to new design specifications.

### **3.2 INTRODUCTION TO ANSYS:**

ANSYS, Inc. is an American Computer-aided engineering software developer headquartered south of Pittsburgh in Cecil Township, Pennsylvania, and United States. ANSYS publishes engineering analysis software across a range of disciplines including finite element analysis, analysis, computational, explicit and implicit methods, and heat transfer.

### **STRUCTURAL ANALYSIS:**

#### **ANSYS AUTODYN:**

ANSYS Autodyn is computer simulation tool for simulating the response of materials to short duration severe loadings from impact, high pressure or explosions.

### **ANSYS MECHANICAL:**

ANSYS Mechanical is a finite element analysis tool for structural analysis, including linear, nonlinear and dynamic studies. This computer simulation product provides finite elements to model behaviour, and supports material models and equation solvers for a wide range of mechanical design problems. ANSYS Mechanical also includes thermal analysis and coupled-physics capabilities involving acoustics, piezoelectric, thermal–structural and thermo-electric analysis.

### **FLUID DYNAMICS:**

#### **ANSYS Fluent, CFD, CFX:**

ANSYS Fluent, CFD, CFX, and related software are Computational Fluid Dynamics software tools used by engineers for design and analysis. These tools can simulate fluid flows in a virtual environment — for example, the fluid dynamics of ship hulls; gas turbine engines (including the compressors, combustion chamber, turbines and afterburners); aircraft aerodynamics; pumps, fans, HVAC systems, mixing vessels, hydro cyclones, vacuum cleaners, etc.

## **3.3 INTRODUCTION TO COMPUTATIONAL FLUID DYNAMICS (CFD):**

Fluid (gas and liquid) flows are governed by partial differential equations which represent conservation laws for the mass, momentum, and energy. Computational Fluid Dynamics (CFD) is the art of replacing such PDE systems by a set of algebraic equations which can be solved using digital computers. Computational Fluid Dynamics (CFD) provides a qualitative (and sometimes even quantitative) prediction of fluid flows.

By means of

- Mathematical modelling (partial differential equations)
- Numerical methods (discretization and solution techniques)
- Software tools (solvers, pre- and post-processing utilities)

CFD enables scientists and engineers to perform 'numerical experiments' (i.e., computer simulations) in a 'virtual flow laboratory'.

## **ADVANTAGES OF CFD:**

Numerical simulations of fluid flow (will) enable

- Architects to design comfortable and safe living environments
- Designers of vehicles to improve the aerodynamic characteristics
- Chemical engineers to maximize the yield from their equipment
- Petroleum engineers to devise optimal oil recovery strategies
- Surgeons to cure arterial diseases (computational hemo dynamics)
- Meteorologists to forecast the weather and warn of natural disasters
- Safety experts to reduce health risks from radiation and other hazards
- Military organizations to develop weapons and estimate the damage
- CFD practitioners to make big bucks by selling colourful pictures



Fig 1.1.1 CFD Model applications and their simulations

## **EXPERIMENT VS SIMULATION:**

CFD gives an insight into flow patterns that are difficult, expensive, or impossible to study using traditional (experimental) techniques.

| Experiment                                 | Simulation                                |
|--|---|
| Quantitative description of flow phenomena | Quantitative prediction of flow phenomena |
| using measurements                         | using CFD software                        |
| • For one quantity at a time               | • For all desired quantities              |
| • At a limited number of points            | • with high resolution in                 |
| and time instants                          | space and time                            |
| • For a laboratory-scale model             | • For the actual flow domain              |
| • For a limited range of problems          | • For any problem and                     |
| and operating conditions                   | realistic operating conditions            |
| Error sources: measurement errors flow     | Error sources: modelling, discretization  |
| disturbances by the probes                 | implementation                            |

| Table 3.1 | Comparison | of Experiment | and Simulation |
|-----------|------------|---------------|----------------|
|-----------|------------|---------------|----------------|

As a rule, CFD does not replace the measurements completely but the amount of experimentation and the overall cost can be significantly reduced.

## **Table 3.2 General Comparisons**

| Experiments    | Simulations        |
|----------------|--------------------|
| • Expensive    | • Cheaper          |
| • Slow         | • Faster           |
| • Sequential   | • Parallel         |
| Single purpose | • Multiple purpose |
|                |                    |

Equipment and personnel are difficult to transport CFD software is portable, easy to use and modify

The results of a CFD simulation are never 100% reliable because

- The input data may involve too much guessing or imprecision
- The mathematical model of the problem at hand may be inadequate

### **CFD ANALYSIS PROCESS:**

| 1. Problem statement    | information about the flow      |
|-------------------------|---------------------------------|
| 2. Mathematical model   | IBVP = PDE + IC + BC            |
| 3. Mesh generation      | nodes/cells, time instants      |
| 4. Space discretization | coupled ODE/DAE systems         |
| 5. Time discretization  | algebraic system Ax = b         |
| 6. Iterative solver     | discrete function values        |
| 7. CFD software         | implementation, debugging       |
| 8. Simulation run       | parameters, stopping criteria   |
| 9. Postprocessing       | visualization, analysis of data |
| 10. Verification model  | validation / adjustment         |

## **MATHEMATICAL MODEL:**

- Choose a suitable flow model (viewpoint) and reference frame.
- Identify the forces which cause and influence the fluid motion.
- Define the computational domain in which to solve the problem.
- Formulate conservation laws for the mass, momentum, and energy.
- Simplify the governing equations to reduce the computational effort:
  - Use available information about the prevailing flow regime
  - Check for symmetries and predominant flow directions (1D/2D)
  - Neglect the terms which have little or no influence on the results
  - Model the effect of small-scale fluctuations that cannot be captured
  - incorporate a priori knowledge (measurement data, CFD results)
- Add constitutive relations and specify initial/boundary conditions.

## **DISCRETISIZATION PROCESS:**

The PDE system is transformed into a set of algebraic equations

- Mesh generation (decomposition into cells/elements)
  - Structured or unstructured, triangular or quadrilateral?
  - CAD tools + grid generators (Delaunay, advancing front)
  - mesh size, adaptive refinement in 'interesting' flow regions
- Space discretization (approximation of spatial derivatives)
  - Finite differences/volumes/elements
- High- vs. low-order approximations
- Time discretization (approximation of temporal derivatives)
  - Explicit vs. implicit schemes, stability constraints
  - Local time-stepping, adaptive time step control

#### **CFD SIMULATIONS:**

The computing times for a flow simulation depend on

- The choice of numerical algorithms and data structures
- Linear algebra tools, stopping criteria for iterative solvers
- Discretization parameters (mesh quality, mesh size, time step)
- Cost per time step and convergence rates for outer iterations
- Programming language (most CFD codes are written in FORTRAN)
- Many other things (hardware, vectorization, parallelization etc.)

The quality of simulation results depends on

- The mathematical model and underlying assumptions
- Approximation type, stability of the numerical scheme
- Mesh, time step, error indicators, stopping criteria

#### POST PROCESSING AND ANALYSIS:

Post processing of the simulation results is performed in order to Extract the desired information from the computed flow field

- Calculation of derived quantities (stream function, vortices)
- Calculation of integral parameters (lift, drag, total mass)
- Visualization (representation of numbers as images)
  - 1D data: function values connected by straight lines
  - 2D data: streamlines, contour levels, colour diagrams
  - 3D data: cutlines, cut planes, iso surfaces, iso volumes
  - Arrow plots, particle tracing, animations
- Systematic data analysis by means of statistical tools
- Debugging, verification, and validation of the CFD model

## **CHAPTER-4**

**MODELING PROCEDURE** 

## **4 MODELING PROCEDURE**

### 4.1 GENERATION OF RADIATOR SHAPE USING CREO PARAMETRIC:

- Save the Radiator shape in 'igs' or 'stp' format.
- Start the sketch by drawing a end fin with the required dimensions and then mirror it to the end after creating the holes to insert the tubes.
- Now draw a tube with the required dimension and the tubes are replicated.
- Addition fins are added and the inlet and outlet is extended.

### 4.2 STEPS INVOLVED IN THE ANALYSIS AND SOLUTION:

### 4.2.1 ANSYS:

- Open the ANSYS workbench, open the tool box and then select the fluid flow (fluent) from the analysis system .
- Now import the 'igs' or 'stp' file into the ANSYS work bench.



Fig 4.2.1 Car Radiator Design in Ansys

### **4.2.2 GEOMETRY:**

|                                  | Units (mm) |
|----------------------------------|------------|
| Length of Fin plate              | 210        |
| Width of Fin plate               | 44         |
| Length of the tube               | 292        |
| Diameter of each tube            | 5          |
| Total no of Tubes                | 16         |
| Inlet Diameter of Radiator tube  | 10         |
| Outlet Diameter of Radiator tube | 10         |

### Table 4.1 Dimensions table of the car radiator



Fig 4.2.2 Car Radiator Fins

### 4.2.3 MESH:

- After the required profile is generated, enter the required data like body size and face size. Select the entities required for meshing.
- Now enter the number of divisions and element size.
- Now by using the inflation select the bodies and number of layers.

- The above-mentioned meshing structure has been accomplished by considering mapped meshing and applying various edge sizing criteria to carry out the task.
- The generated mesh have number of nodes is 58,882 and the number of elements is 1,97,973.



Fig 4.2.3 Values of Edges, faces of a Car Radiator Design in ANSYS



Fig 4.2.4 Values of nodes and elements of a Car Radiator Design in ANSYS

### 4.2.4 SETUP:

- Enter the boundary conditions and type of fluid flow.
- The atmospheric temperature is taken to be 373K and is fixed throughout the experiment.
- Select the type of material and enter the reference values.

### 4.2.5 SOLUTION:

• Enter the number of iterations value.

### **4.2.6 RESULTS:**

• The Temperature contours are obtained for different velocities.



Fig 4.2.5 Temperature contour of a Car Radiator Design in ANSYS

### 4.3 CALCULATION:

Coolant (C): Water

Velocity (V): 1m/s

Diameter of the cross section (d): 10mm = 0.01m

Area (A):  $\pi d^2/4 = (3.14^*(0.01^2))/4 = 7.85^*10^{-5}m^2$ 

Discharge (Q): Q=AV m<sup>3</sup>/sec =  $(7.85*10^{-5}) * 1 = 7.85*10^{-5} m^{3}/sec = 7.85*10^{-2} lit/sec$ 

Density of water ( $\rho$ ): kg/m<sup>3</sup> = 997 kg/m<sup>3</sup>

Mass Flow rate (M):  $\rho Q = (7.85*10^{-5}) * 997 = 0.078 \text{ kg/s}$ 

## CHAPTER 5 RESULTS AND DISCUSSIONS

## **5 RESULTS AND DISCUSSIONS**

### FOR ALUMINIUM:

### 5.1 THE TEMPERATURE CONTOURS OF THE CAR RADIATOR:

# Table 5.1 Table of Outlet temperature corresponding to the inlet velocity of the coolant for aluminium

| VELOCITY (m/s) | OUTLET TEMPERATURE (K) |
|----------------|------------------------|
| 1              | 366.834                |
| 2              | 369.318                |
| 3              | 370.360                |
| 4              | 370.962                |
| 5              | 371.312                |
| 6              | 371.582                |
| 7              | 371.777                |
| 8              | 371.914                |
| 9              | 372.033                |
| 10             | 372.101                |

| The That How (Puert) - O/D-Rut             |   | - n ×  |
|--|---|--------|
| The Liter Marrier Scinice Sourt York inter |   |        |
| 1-1-1-1-1- Dames - 48                      | BARG FFISTE SABLUE ORFICE   |        |
| balles variables harmonie Orbiteles        | 14 5 SOARA # D- 5   |        |
| Nau a Canadatar                            | View 8 Th   |        |
| A sense Caluter                            | Temperature   | Ansys  |
|  | 3.726+102<br>3.7050+102<br>3.6528+102<br>3.6528+102<br>3.6528+102<br>3.5561+102<br>3.5561+102<br>3.5561+102<br>3.5561+102<br>3.5508+102 | ULCONT |
| Autorities Colculator                      | - 3484-102<br>3460-102<br>3460-102  |        |
| Fuettos atunta                             | 3 411e+02<br>3 387e+02  |        |
| Laster adel                                | 3 3530+02 C 4 1 4 1 4 1 4 1 4 1 4 1 4 1 4 1 4 1 4   |        |
| Case                                       | 2.3346+02   |        |
| Variable Temperature                       | 3290e+02  |        |
| annolari ince 🔹 🐑                          |   |        |
| and Contain 1                              | 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1   |        |
| Insula                                     |   |        |
| Area Average of Temperature on outlet      |   |        |
| man etin (b)                               |   | ť      |
| These processing radiable are collected as | a 116   |        |
| D shee equivalet assesses                  | 5275 5229   |        |
| Okama Mana Dana                            |   |        |
|  | 20 Yearson Talko Yearson alliad Values Committed Values Depart Values   |        |

Fig 5.1.1 Temperature contour for the radiator at 1m/s



Fig 5.1.2 Temperature contour for the radiator at 2m/s



Fig 5.1.3 Temperature contour for the radiator at 3m/s



Fig 5.1.4 Temperature contour for the radiator at 4m/s

| tautee       | le 23 mb 17 fr Standon + 42 18 18 1<br>random Agentaum Catalaters 1, P. | 10 年末型的年代 米田田田公園 O目本人自己的主义   |       |
|--------------|---|--|-------|
| E Main       | Calinater<br>Coloniologi<br>ety Calinater                               |  | Ansys |
|              |   | Conduct 1<br>3.7256+02<br>3.6752+02<br>3.6752+02<br>3.6752+02<br>3.6752+02<br>3.6752+02<br>3.6752+02<br>3.6752+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5566+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02<br>3.5556+02 |       |
| Fairtfas Cal | kalutor :   | 3.008e+02<br>3.460e+02<br>3.460e+02  |       |
| Posta        | suata +   | 3.411e+02<br>3.337e+02   |       |
| Lecotery     | 544 · · ·   | 3.3636+02  |       |
| Care         | -   | 3.314e+02  |       |
| dimention of | Ana - 11  |  |       |
| that         | Ak Panin 14   | NOSG36050560502  |       |
| Sec. 1       |   |  |       |
| Amu Avera    | go of Imagoratare on eader  | 142342342342342342   |       |
| maiz(s)      |   |  | ť     |
| Com pose     | nos made or orbides   | 1 EM 💙   | A.    |
| 11 months    | and a separate  | 1415 1.225   |       |

Fig 5.1.5 Temperature contour for the radiator at 5m/s



Fig 5.1.6 Temperature contour for the radiator at 6m/s



Fig 5.1.7 Temperature contour for the radiator at 7m/s



Fig 5.1.8 Temperature contour for the radiator at 8m/s

| E S S                | al 20 10 10 10 10 10 10 10 10 10 10 10 10 10   | C 10 (11 20) | **************************************  |       |
|----------------------|--|--------------|---|-------|
| E fand               | c.McMalaitar<br>an Calculatur  |              |   | Ansys |
|                      |  |              | Temperature<br>Contour 1  |       |
|                      |  |              | 3.728e+02<br>3.7728e+02<br>3.7728e+02<br>3.853e+02<br>3.8558e+02<br>3.5558e+02<br>3.558e+02<br>3.558e+02<br>3.558e+02<br>3.558e+02<br>3.558e+02 |       |
| familie fai          | Labolar  |              | 3.460e+02<br>3.435e+02  |       |
| Function             | anatus   | 1.4          | 3.411e+02<br>3.387c+02  | m     |
| Localization.        | salet.   | 1.1          | 3.383e+02   |       |
| Com                  | Care -   |              | 3.3366+02<br>3.314e+02  | M/ D  |
| Variable.            | Feripacakin  | 11-          | 3.290e+02   |       |
| Contract of Contract | And Street, St |              |   |       |
|                      |  |              | T423054354360   |       |
| Area Gerra           | on of Transmission on oider.   |              | 142342342342342   |       |
| 191-430 DK           |  |              |   |       |
| -                    |  |              |   |       |
| a con pe             | AND INCOMES IN CONCERNMENT   |              |   |       |

Fig 5.1.9 Temperature contour for the radiator at 9m/s



Fig 5.1.10 Temperature contour for the radiator at 10m/s

## 5.2 SCALED RESIDUALS:



Fig 5.2.1 Scaled residuals for the radiator at 1m/s



Fig 5.2.2 Scaled residuals for the radiator at 2m/s



Fig 5.2.3 Scaled residuals for the radiator at 3m/s



Fig 5.2.4 Scaled residuals for the radiator at 4m/s



Fig 5.2.5 Scaled residuals for the radiator at 5m/s

| Design Constant Autor of   | anna Va    |  | and incide   |                                       |   |            |            |                   |       |
|--|------------|--|--|---------------------------------------|---|------------|------------|-------------------|-------|
| Hank Control of Control<br>Control of Control of Cont | Chapterd . | benefaces<br>Mash.<br>El Install   | Heads Marchale<br>Concerner Market<br>Concerner Market<br>Market Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Market<br>Ma | Terbe Hahl<br>Deen<br>C tube Terrings | nation<br>F <sub>10</sub> Instant, S10 res<br>X tomation, <u>16</u> res | andic      | *          |                   |       |
|  |            |  | dendry.  | × 20                                  | Nakel North   | e 3        | ( <b>1</b> | tomp_softer rplot |       |
|  |            | International In | 1000   |                                       |   |            |            |                   | Ansy  |
| - Fand Salary Inco. [10] Sublast Stands Street,  | 000 - 74   | locity   | 1870   | 1                                     |   |            |            |                   | STUDE |
| Westly Spectrumer Herbodi Magnitum, Narrial to Ananimy   |            | ec fy  | 10-0   | 1                                     |   |            |            |                   |       |
| Reference France, Apalitate  |            |  |  | 1                                     |   |            |            |                   |       |
| Vehality Hugolude (In/V) +   | - 404      | ker.   | 10-03  | ZAL                                   |   |            |            |                   |       |
| ermin, tribal Sange Presidan (Fe) a  | 1.         |  |  | 11                                    |   |            |            |                   |       |
| Participante   |            |  | 10-0   |                                       |   |            |            |                   | -     |
| Spicification minified, internaly and traceouty family   | 1.4.1      |  |  | / DF                                  |   |            |            |                   |       |
| Turbulent Internate (SK2 5   |            |  | Te-0   | < - 1 \ \ \ F = 1                     |   |            |            |                   |       |
| Terfeduar Hassaily flater (1)  |            |  |  | 111-                                  |   |            |            |                   |       |
| Fairly theme (map)   |            |  | Te-0   |                                       |   |            |            |                   | =     |
| Sayor Dehilton   | TE .       |  | te-0   |                                       |   |            |            |                   | -     |
| h Munders  |            |  |  |                                       |   |            |            |                   |       |
| CARepare   | 6          |  | 18-0   | 0 100                                 | 2007 2002   | ano ano a  | 100        | 000 000           | inno  |
| window   | 2.         |  |  | - w - 346                             | 200   | 10.000     | in com     |                   |       |
| Celosene America   |            |  |  |                                       |   | Iterations |            |                   |       |
| 2. Karl Calculationy   |            |  |  |                                       |   |            |            |                   |       |
| Thereas .  |            |  |  |                                       |   |            |            | 2012              |       |
| (angles)   | -          |  |  |                                       |   |            |            |                   |       |
| No. of Concession, Name of Con<br>Name of Concession, Name of Concess                  |            |  |  |                                       |   |            |            |                   |       |

Fig 5.2.6 Scaled residuals for the radiator at 6m/s

40



Fig 5.2.7 Scaled residuals for the radiator at 7m/s

|   |   |                               | ad panage    |             |  |                             | 0         | Column Traversh (Chevrol) | 0.6                    |
|---|---|-------------------------------|--------------|-------------|--|-----------------------------|-----------|---------------------------|------------------------|
| Mark Deen<br>We. Solution - Soluti   | Pagent +                                      | anatana<br>El mat.<br>El mat. | Healt Hotels | Turbo Nadat | Adapt<br>Fightmannel Top Andre<br>King and Adapt<br>King and Adapt | nete. # Crues<br>ip # Manap | 4         |                           |                        |
| work wet  |   | -                             |              | ×           | Scaled Building  | • 3                         | < 8       | hang, surfact right       | and the set of the set |
|   |   | emikkaeli<br>Yaafiy<br>Sofiy  | far=00       |             |  |                             |           |                           | Ansy                   |
| the New Local Diff. Contact States .  | - y-vel                                       | ocity.                        |              | A           |  |                             |           |                           | STUDEN                 |
| satisfy Specification Method, respiration, montal to Reundary   |   | 909Y<br>14                    | 10-01        | 1           |  |                             |           |                           |                        |
| Robertone Promer, Abasticate  |   |                               |              | 11          |  |                             |           |                           |                        |
| Velocity Meginicult (m/s) a   | - 1 1019                                      | ga                            | 1. 19-50     | 11          |  |                             |           |                           |                        |
| poisson; lintual Gauge Prelament (Pin) <sub>Al</sub>  | S-11  |                               | 31.022       | 11          |  |                             |           |                           |                        |
| Turbalware  | -   |                               | 18-03        | T           |  |                             |           |                           | -                      |
| Turbalant Blandy (%) a  | 21.   |                               |              |             |  |                             |           |                           |                        |
| Turbulerd Viscotty Rater 11   |   |                               | 10.00        | INE         |  |                             |           |                           |                        |
| II DAVISINGUITE   |   |                               | 10.00        | 1 H         |  |                             |           |                           |                        |
| Augusta Channel ( Market  |   |                               | 18-00        | 16          |  |                             |           |                           |                        |
| Contra Co  |   |                               | Ye-00        | 1           |  |                             |           |                           | -                      |
|   | 12 I  |                               |              | 1           |  |                             |           |                           |                        |
| C Fegurt Johnson  | ( <u>e</u> )                                  |                               | 18-07        | 0 101       | 2001 300 4   | NR 1000                     | 2001 2001 | 404. 004.                 | in a                   |
| C Agent Delinion<br>A. Moder:<br>Michigani  |   |                               |              |             | 1000   | Harations                   |           | And a second second       |                        |
| D Separt Johnson<br>R. Molecur<br>D Collegation<br>Status del Mert adaption   | 天;  |                               |              |             |  |                             |           |                           |                        |
| © Angung Talananan<br>Banaharan<br>∰ cat kunganan<br>Banaharanan kunganan<br>Banaharanan kunganan<br>Banaharanan kungan   | <u>, , , , , , , , , , , , , , , , , , , </u> |                               |              |             |  | nerations                   |           |                           |                        |
| © Report 244000000<br>Ø carterganes<br>(analysis)<br>© statuted type adaption<br>© statuted<br>© st | <u>*.</u>                                     |                               |              |             |  | nerations                   |           |                           |                        |
| U Agang Jaholinen<br>Antoning:<br>E alternagiste<br>E antoning:<br>E antoning Verit adaption<br>Canada Antoning<br>Canada Antoning<br>Data Canadamin<br>E antoning  | ж,  |                               |              |             |  | nerations                   |           | 1 select                  | e 4.                   |

Fig 5.2.8 Scaled residuals for the radiator at 8m/s

| Design Complex Constrained Address   |   | ter te                     | and and   |             |  |                                    | CONTRACT STATE     |                 |
|--|---|----------------------------|---|-------------|--|------------------------------------|--------------------|-----------------|
| Hand Deep<br>Arman,<br>→ Q Deels Deel (Control of Control o | C Appendi<br>C Appendi<br>C Appendi<br>C Appendi<br>C Appendi | · 田市                       | Mouth Module<br>Dynamic Health,<br>Sig Morry Hann,<br>Sig Morry Hann, | Tarbo Hadal | Adapt<br>Fightmood To Assends<br>K cantolik (in Manap-   | Burtack<br># Oxfill +<br>in Macap- |                    |                 |
| warmy isle   | 2.5.8   |                            | -   | × 8         | Solid Buildails  | × 8                                | trang. solid       | rpin            |
| Terre  |   | Smitteh<br>distiy<br>ekciy | ta=D  |             |  |                                    |                    | Ansy:<br>acal A |
| the Sea Lines, here , 27 Linese rate main.   |   | NUCRY                      |   | 1           |  |                                    |                    | STUDEN          |
| WARRY Spectromer Method: Magintule, Harvari Is Boundary  |   | elacity<br>elav            | 10-0  | 1 1         |  |                                    |                    |                 |
| Balanesee Franke, Journale   | -   |                            |   | 1           |  |                                    |                    |                 |
| Velocity Registrate (In/C)-  |   | 9601                       | 1. 194  | 14          |  |                                    |                    |                 |
| personalation and the second sec   | 1.1   |                            |   | 11          |  |                                    |                    |                 |
| Tableto -  | -   |                            | 18-0  |             |  |                                    |                    | mannet.         |
| Turks new Discosts (%/) a  |   |                            |   | 111 1       |  |                                    |                    |                 |
| Terminer Presently Nation 18   | - 1   |                            | 14.9  | 1/11        |  |                                    |                    |                 |
|  |   |                            | 10-0  | TH is       |  |                                    |                    |                 |
| And Over Stdr  |   |                            |   |             | Concernences of the second sec | and the second data                |                    |                 |
| 3/2004   |   |                            | 78-0  |             |  |                                    |                    |                 |
| fagert Johnson   | -   |                            |   | 1           |  |                                    |                    |                 |
| C Another  | (A)   |                            | te-D  | /           |  |                                    | Tana Canada Canada | - Charles       |
| To semilati Verit adeptint   | 1.  |                            |   | 0 300       | 200 300 400  | 500 000                            | .000               | 1000            |
| R. statutes  |   |                            |   |             | 1  | erations                           |                    |                 |
| Concernent Activities  |   |                            |   |             |  |                                    |                    |                 |
| ada a  |   |                            |   |             |  |                                    |                    | induction all   |
| a second   | Common Stationer  | 2                          |   |             |  |                                    |                    | Arts Taxall     |
|  |   |                            |   |             |  |                                    |                    |                 |

Fig 5.2.9 Scaled residuals for the radiator at 9m/s

| Benefit Taplan Good Meldine .  |              | e 444                                 | -  |   |  |   | Q         | d lime & (Dearly   | 0.0   |
|--|--------------|---------------------------------------|--|---|--|---|-----------|--------------------|-------|
| Mark Control of Contro | Pagenti +    | atortana<br>∰rank.<br>∭rank.          | Houth Houtub<br>Dynamic Hault<br>Moreg Planes<br>Cap Mecht | Terbo Healed<br>Kopie<br>Ø Terbo Tapalage -<br>O Terbo Desete | Adapt<br>Fig. Hannel, Till Action<br>K Cartholin, Jill Maria | Ar_ A Charles<br>Ar_ A Charles<br>Ar_ A Manape. |           |                    |       |
| nucle and  |              | 1004                                  |  | × 🗱   | Sealed Residents   | ж   | N         | manp, notice spice |       |
| -  |              | inn kit kundit<br>Krantily<br>Koczity | ter-00   | -   |  |   |           |                    | Ansy  |
| an band hanter have not where have been  |              | ucey.                                 |  | 1   |  |   |           |                    | STUDE |
| service spectrumer Method Augustude, Normal to Normalies   | - 24         | boby.                                 | 1e-01  |   |  |   |           |                    |       |
| Reference Forms. Absolute  |              | er.                                   |  | 1   |  |   |           |                    |       |
| which we have the second  | * 0014       | ian .                                 | 10-00  | 144   |  |   |           |                    |       |
| electricitatial large treasure (inc)_a   |              |                                       |  | 11  |  |   |           |                    |       |
| fathalance   | 5.04 L       |                                       | 18-00  | 11/   |  |   |           |                    |       |
| Specification Medical Segregary and Varianty Relation  |              |                                       |  | 101   |  |   |           |                    | -     |
| Terminent Internety (%2 g  |              |                                       | 14-04  |   |  |   |           |                    |       |
| Turbuland Viscosity Ratio: 11  | 3 <b>2</b> 1 |                                       |  | 111   |  |   |           |                    |       |
|  |              |                                       | 1=-05  | 11/   |  |   |           |                    |       |
| August Change   Mada   |              |                                       |  | 1/10  |  | -   | - Andrews |                    | -     |
|  |              |                                       | 10-00  | $\sim$  |  |   |           |                    |       |
| Carbon   | 103-1        |                                       |  |   |  |   |           |                    | S     |
| Approximation  |              |                                       | 16.00  | Second parts  | parente a post   | 2020100   |           | 100111112          | -     |
| 2 cat megidem  | 1.2          |                                       | 19-11  | 0 100   | 200 300 400  | 500 800   | mn i      | 900 1              | 000   |
| Antonian Area Adaption   | - A.         |                                       |  |   |  | Horations                                       |           |                    |       |
| a millionaram  |              |                                       |  |   |  | neradona  |           |                    |       |
| But Debuterer  |              |                                       |  |   |  |   |           |                    |       |
|  |              |                                       |  |   |  |   |           | i picto            | ( # ) |
|  |              |                                       |  |   |  |   |           |                    |       |
| Sufficient Country   | (market)     |                                       |  |   |  |   |           |                    |       |

Fig 5.2.10 Scaled residuals for the radiator at 10m/s

## 5.3 TEMPERATURE OUTLET PLOT:



Fig 5.3.1 Temperature outlet for the radiator at 1m/s

| to Deside Physics man induced definition in   | india i  |                      | -  |  |  |                                   | Q and and price   | - 68 <b>m</b> - 1            |
|---|--|----------------------|--|--|--|-----------------------------------|-------------------|------------------------------|
| tant term<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>terms<br>term | D Append<br>Right Appendix Mar<br>Distription (San | - 100000000          | Micele Machelle<br>Character Machelle<br>Character Machelle<br>Micele Machelle | Barbo Hold<br>Dutte<br>Of Tures Tepings -<br>Turbo Tures | Adapt<br>Fig. month. To screenin.<br>Controls. At monge. | Serlare<br>+ Creste -<br>Minsept_ |                   |                              |
|   | Ē  | - ara, adat          | 373.00   | × <b>=</b>   | Nobel Sepherik   | × 8                               | teng, salist rptd |                              |
| Wenty Spectration Went Magnitude, normal to Bandary<br>Reference Present Associatio<br>Wenty Magnitude (nrs) 2  |  |                      | 372.00   | × -  |  |                                   |                   |                              |
| Signification (Section (Sectio  | -  |                      | 371.00   | × -  |  |                                   |                   |                              |
| Tapel Planton Personal Insuranty and Vescovity Adda<br>Particularit Descript (PA) (s.   |  | Area-Weight<br>Avera | ed 3/0.00<br>ge  | x0 -]  |  |                                   |                   |                              |
| Tarbalant massade thele 18  | -  | temperati            | of<br>116 309.00   | ×  |  |                                   |                   |                              |
| Table (then) (weap)   |  |                      | 368.00   | 0  |  |                                   |                   |                              |
| Contraction     Contraction     Contraction     Contraction     Contraction     Contraction     Contraction     Contraction     Contraction   | 10 m   |                      | 307.00   |  | 200 300 400<br>Ite                                       | sao ooo                           | 750 600 900       |                              |
| Canadator Activitas<br>Chan Labolature<br>Institute   |  |                      |  |  |  |                                   | 0 44478           | 4.4                          |
|   | (Income of Case                                    |                      |  |  |  |                                   | 1                 | and the second second second |

Fig 5.3.2 Temperature outlet for the radiator at 2m/s



Fig 5.3.3 Temperature outlet for the radiator at 3m/s

| through the second second in the second seco | -                           |            | alled the state    |   |  |            |                               | Q,   |               | 0         |
|--|-----------------------------|------------|--------------------|---|--|------------|-------------------------------|------|---------------|-----------|
| Mark         Own           •         000         000         0000 <th>C. Append<br/>Register Head.</th> <th>· El Non.</th> <th>Hack Moduls</th> <th>Forthe Hacked<br/>English<br/>Of Tache Teppings</th> <th>Adap<br/>Paj Monati, 1<br/>X Cartonic, 1</th> <th>H<br/>Maria</th> <th>Serface<br/>+ Date +<br/>Marage</th> <th></th> <th></th> <th></th>   | C. Append<br>Register Head. | · El Non.  | Hack Moduls        | Forthe Hacked<br>English<br>Of Tache Teppings | Adap<br>Paj Monati, 1<br>X Cartonic, 1 | H<br>Maria | Serface<br>+ Date +<br>Marage |      |               |           |
| unity Vint<br>M  |                             | en orien   |                    | *   | Scaled IA                              | and the de | ×                             | •    | temp_oddet-tp |           |
| In Tarent Sector Description Sector Sector   | 7)                          |            | 372,5006           | 4   |  |            |                               |      |               | STUDEN    |
| Balanana Matala Jawalah<br>Malanta Masalah Secul -   | <u>a</u> 1                  |            | 172 0000           | 1   |  |            |                               |      |               |           |
| reprise brind Gauge Presson (Frid )  | 4                           |            | 272.000            |   |  |            |                               |      |               |           |
| farfadered   |                             |            | 371.5000           | 4   |  |            |                               |      |               |           |
| Specification Method, beautity and Vacuate Asia  | - A                         | rea-Weight | ed                 | 4   |  |            |                               |      |               |           |
| Tachalend Internetty [Fis] (p  |                             | Avera      | <b>99</b> 371,0000 |   |  |            |                               |      |               | -         |
| Tubled Vessely Relicing  | 5 I I I                     | temperatu  | or                 | 1/  |  |            |                               |      |               |           |
| Apply (store) (weight)   | -1                          |            | K] 370 5000        | 1   |  |            |                               |      |               |           |
| 2002   | 179                         |            | 170.0000           | -   |  |            |                               |      |               |           |
| Appert Databases   |                             |            |                    | 1   |  |            |                               |      |               |           |
| L Manimur<br>E (all Popolen<br>autoration Mark Adaption  | 1                           |            | 363 5000           | α 100   | 200 300                                | 400 Itera  | ations                        | raia | 800 966       | 1000      |
| Caluation Advices  |                             |            |                    |   |  |            |                               |      |               |           |
| Net CELLERS  |                             |            |                    |   |  |            |                               |      |               | Hand with |
| Sector 1   |                             |            |                    |   |  |            |                               |      |               |           |

Fig 5.3.4 Temperature outlet for the radiator at 4m/s

44

| Design the birth addies  | nandra sa        |                    | ullet bestige   | i II       |   |                                    | . Q.)  | Same (Chine)          | 0.6            |
|--|------------------|--------------------|---|------------|---|------------------------------------|--------|-----------------------|----------------|
| New Control of Control | Appent -         | Biofect            | Michillionala<br>Constantion<br>Constantion<br>Constantion<br>Constantion | Date Hadd  | Adapt<br>Fig.Honord. Sig.honor<br>M.Control. M. Honor | erta e<br>e. Artes e<br>e. Artes e |        |                       |                |
|  |                  | 1                  | 373.000   | × <b>8</b> | tratel Asykhait                                       | ×                                  |        | Trongs_stable( system | Ansy<br>2021 S |
| monty teacharan Helball Hagenade, tearner to bandery<br>Adverse Farrer Alaskate<br>Instany Hagetake (1911) y   |                  |                    | 372,5000  | -          |   |                                    |        |                       |                |
| executional large Pressue (Pa) g   |                  |                    | 372.0000  | -          |   |                                    |        |                       |                |
| Tarihakeun<br>Igan Soliki Method, Maaraky and Vounany Kala<br>Tarihakeu kessedig Phij. g   | A                | ea-Weight<br>Avera | ed 371.500  | -          |   |                                    |        |                       |                |
| Turnland Vacanda Ranni ya  | -                | temperatu          | of<br>me 371.0000<br>[K]  | 1          |   |                                    |        |                       |                |
| Cover  |                  |                    | 370 5000  | 1          |   |                                    |        |                       |                |
| n - segar Labolanni<br>8 de labola :<br>2 de tragisteri<br>2 de tragisteri   | <b>年</b> 人       |                    | 370.0000  | 0 100      | 200 300 40  | see eee<br>Iterations              | 700 80 | 0 900                 | 1000           |
| Capadron Actives D for Caluation   |                  |                    |   |            |   |                                    |        | i select              | e se           |
| (Braphine)   | Constant Collins |                    |   |            |   |                                    |        |                       |                |

Fig 5.3.5 Temperature outlet for the radiator at 5m/s

| And a second   | Research of                  | the Pa      | anded denty  |            |                            |                              |                   | Q.0 | he (Calence    | 0 💼              |
|--|------------------------------|-------------|--|------------|----------------------------|------------------------------|-------------------|-----|----------------|------------------|
| Next Data<br>Control (2000) - Control (200 | Pagent<br>Pagent<br>Pages In | · El mat.   | Mode Hadde<br>Devene Hade.<br>12 Mong Plane.<br>10 Ley Martel. | Torto Hodd | Adapt<br>Fig. Annual. 50 A | darige. Just<br>Seage. J. To | AR<br>FS +<br>Apr |     |                |                  |
| xity have  | ×                            | 199. 984    | Herek<br>  | × N        | Stated Aug                 | tudi.                        | * 8               | 100 | a juddet tyled | Ansy             |
| · Type Salari late  17 mater tand them   | CHEL                         |             | 372.750  | 1          |                            |                              |                   |     |                | STUDEN           |
| Educate States Control Indicate States in Strength   |                              |             |  | . 1        |                            |                              |                   |     |                |                  |
| Vedening Manufacture (MVV)   | 7.0                          |             | 372.000  | ° 1        |                            |                              |                   |     |                |                  |
|  |                              |             | 372.250  | 0          |                            |                              |                   |     |                |                  |
| and the second sec   |                              |             | and and  |            |                            |                              |                   |     |                |                  |
| Description Medical Assessment and Insuranty Rates   |                              | dria W.eard | 3/9.90   | 83         |                            |                              |                   |     |                |                  |
| Tarkalet Diseale (N) a   |                              | Avera       | de 321.750   | 6          |                            |                              |                   |     |                |                  |
| Technical Manualy Battle 12  |                              |             | of   |            |                            |                              |                   |     |                |                  |
| Towners on press.  |                              | temperat    | ure: 371.900   | 10         |                            |                              |                   |     |                |                  |
| August Channel Horige  |                              |             | [K] 371.250  | 0          |                            |                              |                   |     |                |                  |
| Spot Island  |                              |             | 3/1.000  | . 1        |                            |                              |                   |     |                |                  |
| Multip)  |                              |             |  | . 1        |                            |                              |                   |     |                |                  |
| Call Registers   | -                            |             | 300.750  | 0 100      | 100 100                    | 400 500                      | 000 110           |     | 000            | 1000             |
| Malazzi  | A.,                          |             |  | 100        | 2001                       | Marca King                   |                   |     |                | 1000             |
| and the state  |                              |             |  |            |                            | neration                     | в                 |     |                |                  |
| Apr December   |                              |             |  |            |                            |                              |                   |     |                |                  |
| tufan  |                              |             |  |            |                            |                              |                   |     | 8 interior     | 14.44            |
| Refer  | CONTRACTOR OF                |             |  |            |                            |                              |                   |     |                | A REAL PROPERTY. |
| Science  | 8.00.10                      | 22-8        |  |            |                            |                              |                   |     |                |                  |

Fig 5.3.6 Temperature outlet for the radiator at 6m/s

| Note  | Pression Pageton Sound Stations No.   |           | kan Pad                          | and dentes  |   |  |                                  | Contract (Second (Second )) | 0.0      |
|---|---|-----------|----------------------------------|---|---|--|----------------------------------|-----------------------------|----------|
| Image   | men.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>proc.<br>pr | Appendi - | annian<br>Eran.<br>El            | Heads Module<br>Construct Heads<br>(1) Marry Planet<br>(1) Cap Modul                            | Tarbo Hadd<br>Dobs<br>Of Tarbs Technology -<br>Of Tarbs Doorte. | Adapt<br>Fig.manual To America<br>X cantale in Manage- | Burtens<br># Overs +<br># Manage |                             |          |
| Wind         Wind         Max         Max </td <td>ver og bler<br/>Mens</td> <td></td> <td>9.599</td> <td>373 000</td> <td>*</td> <td>Scaled Reality</td> <td>× 84</td> <td>tang, sullet splat</td> <td>Ansy</td> | ver og bler<br>Mens   |           | 9.599                            | 373 000   | *   | Scaled Reality   | × 84                             | tang, sullet splat          | Ansy     |
| Autom         The full below         371 2000         370 200         360 400         100 900 900         10000         1000         1000   | micch (an-ficker) Method (magnetic), Named is bandaley<br>Beforevite (Magnetic) (44) -<br>Weeks (Magnetic) (44) -<br>Magnetic-Vital (magn Fyrmer 916) -<br>Factorization<br>Reporting (1997) -<br>Taribalant (Manual (1997) -<br>Taribalant (Manual (1997) -<br>Taribalant (Manual (1997) -   | A         | ea-Weight<br>Averaj<br>temperatu | 312.600<br>3172.600<br>372.600<br>372.600<br>372.600<br>ed 3172.600<br>of 311.600<br>Fe 311.600 |   |  |                                  |                             | -        |
|   | Annual Links<br>Constant<br>Constant<br>Register<br>Androse Veril Advances<br>Register<br>Androse Veril Advances<br>Conductor Network<br>Register<br>Conductor Network  | inin k    |                                  | 371.400<br>371.200<br>371.000   |   | 200 300 400<br>Ite                                     | so eee<br>erations               | mo eoo eoo y                | 7<br>000 |

Fig 5.3.7 Temperature outlet for the radiator at 7m/s

| Bernard Standard States States and   | Address No.  |  | e                   | and and   | 1 G.   |                     |            | Quere lawers (1944)     | 0 6                 |
|--|--|--|---------------------|---|--|---------------------|------------|-------------------------|---------------------|
| Norm.  | breas<br>a - cl bran.<br>b - cl branticht.<br>rep. cl branticht. | Append -   | Martino<br>El rest. | Mode Headshi<br>Conserve Heads<br>12 Marcy Phases<br>III Cay Marcal | Tartin Hadd<br>Date:<br>Color:<br>Color Tartin Tarrings. | Adapt<br>Pg: Manual | P Crets +  |                         |                     |
| Weathy Yout  | -  |  | x.544               | 3/5 000   | × <b>n</b>   | Scaled Asphalis     | × <b>N</b> | ting: sollet yks        | Ansy<br>2021 STUDEN |
| saroly (perfector father) regulate, sortal to incodes<br>Microsoftense Autom   |  |  |                     | 377.800   |  |                     |            |                         |                     |
| Methoday Meganitude (mr. 10 g  |  | 1  |                     |   |  |                     |            |                         |                     |
| gerson; bind Gege Present PtCo   |  | ÷ ()   |                     | 372.490   | 61   |                     |            |                         |                     |
| tarbalance   |  |  |                     | 372 200   | 1  |                     |            |                         |                     |
| Specification Motival' assessing and lossing italian   |  | - An   | ea-Weight           | ed  | 24   |                     |            |                         |                     |
| Tachateat Intercepty [%] w   |  | 1000   | Avera               | ge 372.000  | -  |                     |            | Versen in second second | E.                  |
| Rubbing Vennity Kells (1)  |  |  | termerati           | OF NTLAN  | 1  |                     |            |                         | -                   |
|  |  |  | restignetatio       | [K]   | 11   |                     |            |                         |                     |
| Apply [these   tests ]   |  | 1.51   |                     | 371.000   |  |                     |            |                         |                     |
|  |  |  |                     | 371.400   | 1  |                     |            |                         |                     |
| The Report Eastername  |  | 111  |                     |   |  |                     |            |                         |                     |
| D, Munderer  |  | (0)  |                     | 371,200   | 2 -1+  | ····                |            | 2                       | 1                   |
| Coll Registers   |  | 1  |                     |   | 0 100  | 200 200 400         | 500 000    | 700 000 000 1           | 000                 |
| f. stateter  |  | C  |                     |   |  | 11                  | erations   |                         |                     |
| Calculative activities   |  |  |                     |   |  |                     |            |                         |                     |
| da   |  |  |                     |   |  |                     |            | V.22                    | 1                   |
| Ø sutient  |  | -  |                     |   |  |                     |            | 1 1000                  | 2 M                 |
| 2 Kint   |  | and the second s |                     |   |  |                     |            |                         |                     |
| 3 Same   |  | 876_1027-  |                     |   |  |                     |            |                         |                     |
| Astrophysics   |  | 2.00 ·   |                     |   |  |                     |            |                         |                     |
| and the second s | 101  | Hitriania pos  | plate               |   |  |                     |            |                         |                     |

Fig 5.3.8 Temperature outlet for the radiator at 8m/s

46

|   |                      |                                     |   |  |   |                               | CONTRACTOR INCOME        |                          |
|---|----------------------|-------------------------------------|---|--|---|-------------------------------|--------------------------|--------------------------|
| Insure         Design (1)         Data (1)         Design (1) <thdesign (1)<="" t<="" th=""><th>Calegoria -</th><th>Martuna<br/>El Martun<br/>El Installo</th><th>House Models</th><th>Sarka Hadad<br/>Data<br/>Of Tarka Tapakaya<br/>Tarka Tapakaya</th><th>Ange<br/>Nganana, Nganaman,<br/>Kanana, Kanapa,</th><th>Surface<br/>+ Data +<br/>Manage</th><th>CO, Land Course (Clarity</th><th></th></thdesign>  | Calegoria -          | Martuna<br>El Martun<br>El Installo | House Models  | Sarka Hadad<br>Data<br>Of Tarka Tapakaya<br>Tarka Tapakaya | Ange<br>Nganana, Nganaman,<br>Kanana, Kanapa, | Surface<br>+ Data +<br>Manage | CO, Land Course (Clarity |                          |
| entere en   |                      | ng jadai                            | 3/3 0000  | ]  | Soded Beakask                                 | × <b>N</b>                    | tang_addet splat         | Ansy<br>acone<br>student |
| Relations in State (Specific<br>Versions Hoperson 1-yrs) (S<br>Derived Hoperson 1 |                      |                                     | 372 8000  |  |   |                               |                          |                          |
| Specification Healthof association and Vaccianty Healtho<br>Network Secondly Park (14) (2)<br>Turbusky Secondly Park (14)   | A/                   | ea-Weighte<br>Averag<br>temperatu   | ed 372 2000<br>ge<br>of 372 0000<br>re<br>K] 1/1 0000 | -  | **  | ·····                         |                          | •                        |
| Carlos ( 1999)  |                      |                                     | 371.6000  | 1  |   |                               |                          | -                        |
| Coll Register:     Advances Mark Adaptive     Advances     Advances     Colorization     Colorization     Colorization  |                      |                                     |   | 0 100  | 200 200 400<br>Ite                            | see eee<br>rations            | 700 800 100 10           | 000                      |
| C Advert  | 1                    |                                     |   |  |   |                               | y internet               |                          |
| A men   | 9/8_3430<br>9/8_3430 | 7                                   |   |  |   |                               |                          |                          |

Fig 5.3.9 Temperature outlet for the radiator at 9m/s

| Second States and Andrew States   | Reads.                |                                 | inter inter  |  |                    |             | Q Quel General (U.S. 1) | 10 <b>m</b>   |
|---|-----------------------|---------------------------------|--|--|--------------------|-------------|-------------------------|---------------|
| Hank Denne<br>→ Overla- Janeiro - Jan | E-taped<br>- Bighted  | a Briantycan<br>Mask.<br>Jone - | Rack Hocks<br>Clarowsc Holl,<br>75 Mary Taras,<br>Taras Taras, | Table Maker<br>Discle<br>Control Transmission<br>Control Control | Adapt<br>Se Manual | - Dools -   |                         |               |
| digram (  | 100                   | 8                               | Month  | × 8  | Scaled Rosalinski  | × 👪         | tomp, particl, right    | id<br>nazavez |
|   |                       | inter, salar                    | 3/3 00   | 00 T   |                    |             |                         | Ansys         |
|   | 1                     |                                 | 10000  |  |                    |             |                         |               |
| Balanana Frenzi, Alaska   |                       |                                 | Sec. a.  | <u>%</u> ]   |                    |             |                         |               |
| March March (mil) up  |                       |                                 | 372.00   | 00   |                    |             |                         |               |
| nano(Stilled Sauge Pressers (Pol) a   |                       |                                 |  |  |                    |             |                         |               |
| Terfederer  |                       |                                 | 372.40   | 00 -   |                    |             |                         |               |
| Specification Nethod Jeanney and Vicensity Rote   |                       | Area-Weigh                      | ted  | · .  |                    |             |                         |               |
| Turnslent Intervery (%) g   |                       | Avera                           | ige 372.20   | 00 -   |                    |             |                         |               |
| Turbulevi Veccety Refit: 20   | 1.                    | temperat                        | of   | 10-  |                    |             | *                       | -             |
| Contraction (Contraction (Contraction))   | - 11                  | temperat                        | (K) 372.00   | 00 - /   |                    |             |                         |               |
| Acad Chara Heat   | 11                    |                                 | 100  | s1/  |                    |             |                         |               |
| Carrier   |                       |                                 | 374.00   | 00 -   |                    |             |                         |               |
| Report Definition   | 14                    |                                 |  |  |                    |             |                         |               |
| Tableton Control of Co  | 1. C                  |                                 | -377.00  | 00 + 100   | 156 500 400        | 100 mm mm   | AND 1999                | 1000          |
| Remotels: Migh Adjustor   | ٨.                    |                                 |  | . se   | 100 200 900        | 300 900 100 | 1. 300 State            | 25642         |
| Malater-  |                       |                                 |  |  | 100                | erations    |                         |               |
| No calculate  |                       |                                 |  |  |                    |             |                         |               |
| and the second se   |                       |                                 |  |  |                    |             | 5 amon                  | NE at         |
| Second V  | and the second second |                                 |  |  |                    |             |                         |               |

Fig 5.3.10 Temperature outlet for the radiator at 10m/s

### FOR COPPER:

## 5.4 THE TEMPERATURE CONTOURS OF THE CAR RADIATOR:

# Table 5.2 Table of Outlet temperature corresponding to the inlet velocity of the coolant for copper

| VELOCITY (m/s) | OUTLET TEMPERATURE (K) |
|----------------|------------------------|
| 1              | 366.684                |
| 2              | 369.243                |
| 3              | 370.295                |
| 4              | 370.893                |
| 5              | 371.261                |
| 6              | 371.582                |
| 7              | 371.742                |
| 8              | 371.892                |
| 9              | 372.006                |
| 10             | 372.086                |



Fig 5.4.1 Temperature contour for the radiator at 1m/s



Fig 5.4.2 Temperature contour for the radiator at 2m/s



Fig 5.4.3 Temperature contour for the radiator at 3m/s



Fig 5.4.4 Temperature contour for the radiator at 4m/s



Fig 5.4.5 Temperature contour for the radiator at 5m/s



Fig 5.4.6 Temperature contour for the radiator at 6m/s

| tutter 1                   | te si in the Co<br>Tarialise Augeneauxa<br>Callulater |                    | SCHARTER SCHARTER  |       |
|----------------------------|---|--------------------|--|-------|
| C Inch                     | tak palar<br>n- Gelulatar                             |                    | Temperature<br>Commer 1<br>3720e+U2<br>3702e+U2  | Ansys |
|                            |   |                    | 3.653a+122<br>3.655a+122<br>3.605a+102<br>3.5614+102<br>3.555a+102<br>3.550a+102<br>3.550a+102<br>3.550a+102 |       |
| function Cal               | Labolar   |                    | 3.460e+02<br>3.435e+02   |       |
| Fuention                   | 111111  | -                  | 3.411e+02<br>3.387e+02   | 22    |
| Contraction of Contraction | adec  |                    | 3.363e+02<br>3.338e+02   | 1     |
|                            | Terrestature.   |                    | 3314e+02 05009405405405405405  | 4     |
| (couldres                  |   | (*) (* *           |  | 450   |
| (Hold                      | ALC: NOT THE REPORT OF                                |                    | 74425475425425425425425425425425425425425425425  |       |
| market in                  |   |                    | 714/250/54/250/54/250/54/25  |       |
| Ano Avera<br>171.09.00     | ge of Tooperature as a                                | utiet.             |  |       |
|                            |   |                    |  | 😂 🗼   |
| Dest pres                  | kolet excession                                       |                    | 010  | 2x    |
| Calculate                  |   | eginal - Community | 0.613 £225<br>3) Valuer Tella Valuer Derl Valuer Dermet Valuer Ascart Valuer                                 |       |

Fig 5.4.7 Temperature contour for the radiator at 7m/s



Fig 5.4.8 Temperature contour for the radiator at 8m/s

![](_page_64_Picture_0.jpeg)

Fig 5.4.9 Temperature contour for the radiator at 9m/s

![](_page_64_Figure_2.jpeg)

Fig 5.4.10 Temperature contour for the radiator at 10m/s

## 5.5 SCALED RESIDUALS:

![](_page_65_Picture_1.jpeg)

Fig 5.4.1 Scaled residuals for the radiator at 1m/s

![](_page_65_Figure_3.jpeg)

Fig 5.5.2 Scaled residuals for the radiator at 2m/s

| - Deside Physics Boar Holland Bodyline B  | unado Mar   |   | nd Instan                 | 1. ÷         |   |                                 | Q, best hands ( ) prof | 0 =                         |
|---|-------------|---|---------------------------|--------------|---|---------------------------------|------------------------|-----------------------------|
| Anne Bank Control of States   | Chapteral . | Bertense<br>Entrette  | Mach Madek<br>Contract    | Turke Backet | Adapt<br>Fortunation fortunation<br>Contration of Manager | Notas<br>• Delle +<br>A Mangel. |                        |                             |
|   |             |   |                           | × N          | Scalad Feedback   | ( N B                           | trop. softer-roler     |                             |
| m<br>- Mendi mende men en in Administration de la |             | endadt<br>naðy<br>söðv<br>söðy<br>söðy<br>sviðy<br>sviðy<br>svi | 6473<br>140<br>140<br>140 |              |   |                                 |                        | Ansys<br>2021 RD<br>STUDENT |
| Easter<br>Specific Lines<br>Specific Lines<br>United  | 0.0         |   | 1+0<br>1+0                |              | 200 300 400   | 500 600 1                       | 100 800 560            | E                           |
| Auformatin March Anlagettern<br>Metallangetern<br>Caracterison Advison<br>D Aur Caracterison Advison  | 1           |   |                           |              | ite   | rations                         | 2 abets                |                             |
|   |             |   |                           |              |   |                                 | 0.0000100              | A 199 1 1                   |

Fig 5.5.3 Scaled residuals for the radiator at 3m/s

![](_page_66_Figure_2.jpeg)

Fig 5.5.4 Scaled residuals for the radiator at 4m/s

![](_page_67_Picture_0.jpeg)

Fig 5.5.5 Scaled residuals for the radiator at 5m/s

![](_page_67_Figure_2.jpeg)

Fig 5.5.6 Scaled residuals for the radiator at 6m/s

| Deads Papers Annotation Address An   | nite        |                              | * ***                                    |   |  |   | Quant Search (Caref) | 10 m     |
|--|-------------|------------------------------|--|---|--|---|----------------------|----------|
| Hank Dome. However, H | Co Agenti - | Atoricos<br>El ricet.        | Hash Hodels                              | Terbe Haad<br>Darke<br>C Tarte Tastoga<br>Tarte Tasto | Adapt<br>Technol. Technols.<br>Storate. A Merup. | Portan<br>+ Oann +<br>Micagi            |                      |          |
| many loss  |             |                              | terath .                                 | ×   | Build Stollarb                                   |   | trip_relifi opti     | i, ș     |
| PR   |             | kin altanlı<br>Yvaty<br>Vefa | 100                                      | 0   |  |   |                      | Ansy     |
| the ball them man on helper more works   |             | loc #y                       |  | 1   |  |   |                      | STUDEN   |
| West's Specification Method: Inspection, New of the Survey   | ·           | 005                          | 10-0                                     | 4   |  |   |                      |          |
| Reference Prove Aboutat  |             |                              | 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1 | 1   |  |   |                      |          |
| wwwy Magemak (rest) y  |             |                              | 50-0                                     | 14:   |  |   |                      |          |
| And an and a second sec | - 50        |                              |  | 11  |  |   |                      |          |
| Tuesdiamine Medical Internety and Verseyly Role  | 142         |                              | 19-0                                     |   |  |   |                      |          |
| Particles bignety (No. 5   |             |                              | 100                                      |   |  |   |                      |          |
| Turbulent Vesergine Ratio (1)  | 42          |                              | 10-0                                     | ///E*   |  |   |                      |          |
|  |             |                              | la d                                     | 191   |  |   |                      |          |
| August Once Febr   |             |                              |  |   |  |   |                      | -        |
| Faterens (was  | 120         |                              | 10-0                                     | a -   |  |   |                      | -        |
| , Reference Branker  | 14          |                              |  | 1   |  |   |                      |          |
|  |             |                              | 10-0                                     | 1 +   | ****   | +++++++++++++++++++++++++++++++++++++++ | (                    |          |
| Endland:   | A.          |                              |  | 0 100   | 200 380 400                                      | 500 600                                 | 700 800 900          | 1000     |
| Report Scholaro  |             |                              |  |   | Ite  | trations                                |                      |          |
| And Recenters  |             |                              |  |   |  |   |                      |          |
| Approvals Marill Adaptive  |             |                              |  |   |  |   | t sele               | that set |
|  |             |                              |  |   |  |   |                      |          |

Fig 5.5.7 Scaled residuals for the radiator at 7m/s

![](_page_68_Figure_2.jpeg)

Fig 5.5.8 Scaled residuals for the radiator at 8m/s

| Design Paper Annotation Address a  | andra (Ve  | e est               | ed engr                                 |  |                      |            | Q.       | No. of Concession, Space of Co | 0 -     |
|--|--|---------------------|---|--|----------------------|------------|----------|--|---------|
| Hank Down,<br>Charles Dally + 4 Marchalans (2 Approx, 2)<br>Marchall Dally + 4 Marchalans (2 Approx, 2)<br>Approx, 2)<br>Marchall Dally + 4 Marchalans (2 Approx, 2)<br>Approx, 2)<br>Marchall Dally + 4 Marchalans (2 Approx, 2)<br>Marchalans (2 Approx, 2)<br>March | Chapters -   | Barlans<br>El Surt. | Mart Hodes<br>Dynamic Hask<br>Marg Hask | farthe Hackel<br>Dates<br>Of Tartie Trainings. | Adapt<br>Fait Manuel | nça        |          |  |         |
| And Line   |  |                     | -                                       | × 🖬  | Businet Resultan     | 4 X        | <b>1</b> | tong paties spin   |         |
|  |  | incolumb            | 1                                       |  |                      |            |          |  | Ansy    |
|  |  | telly .             | Te+0                                    | 1.11   |                      |            |          |  | 2021 6  |
| and hand have been its three hand have   |  | ROCKY .             |   | 1  |                      |            |          |  | STUDIEN |
| tenning Spectrosow Nativel Inagetoos, Isernal to Standary  | - 2.44   | widy:               | Sec.                                    | - N  |                      |            |          |  |         |
| Reference Fischer Lawrence   | -  | 90 C                | 1 23                                    | 1  |                      |            |          |  |         |
| Valuety Magnitude Inviti a   | -  | ine.                | 1                                       |  |                      |            |          |  |         |
| anatomic Bartal Carace Pressure (Palla)  |  | 111                 | +c 10755                                |  |                      |            |          |  |         |
| Numbers .  |  |                     | 0.254                                   | 11   |                      |            |          |  |         |
| Spectromer Method immunity and Commits States  | 145  |                     | 199-02                                  |  |                      |            |          |  | +       |
| Purpaier starouty [94] a   |  |                     |   | 111  |                      |            |          |  |         |
| Turbury month fails on   |  |                     | 14-0                                    |  |                      |            |          |  |         |
| In a second second   |  |                     |   | 111  |                      |            |          |  |         |
| Provide Castral Castral  |  |                     | 5a-0                                    | 11/1   |                      |            |          |  |         |
| Apple Inc. Inc.  |  |                     |   |  |                      |            |          | and the second   | -       |
| Contraction of the second s  |  |                     | 19-08                                   | 1  |                      |            |          |  |         |
| C Assest Tableton  | 141  |                     |   |  |                      |            |          |  |         |
| Q. Montest   | 141  |                     | 9e-01                                   | t - +  | ******               |            |          |  |         |
| B Call Registers   | 181  |                     |   | 0 100  | 200 300 4            | 00 500 00  | 0 100    | 000 000  | 1000    |
| automatic Mask Adaptice  | 1  |                     |   |  |                      | Iterations |          |  |         |
| Calculation Anti-View  |  |                     |   |  |                      |            |          |  |         |
| See Calculation  |  |                     |   |  |                      |            |          |  |         |
| and a second sec   |  |                     |   |  |                      |            |          | t yeleta   | at at   |
|  | A REAL PROPERTY AND A REAL |                     |   |  |                      |            |          |  |         |
| (applies)  |  |                     |   |  |                      |            |          |  |         |

Fig 5.5.9 Scaled residuals for the radiator at 9m/s

![](_page_69_Figure_2.jpeg)

Fig 5.5.10 Scaled residuals for the radiator at 10m/s

## 5.6 TEMPERATURE OUTLET PLOT:

| 8.8 × 7 8 8 2   |              |             |                              |                        |                    |                      |                           |         |
|---|--------------|-------------|------------------------------|------------------------|--------------------|----------------------|---------------------------|---------|
| Martin David Contact A  | Cireman .    | - Electron  | Abrah Musiek<br>Abrah Musiek | Taibu Model<br>Institu | Adapt<br>Televisia | Metlace<br>+ Desti - | A first transfer ( 7 ( 4) | USE     |
| hen - 😴 🦉 🔄 Treadour - Oj Septore - gj Bandwate.<br>1992 - Dank- Guelly - 🖕 Male Koywick - 🖒 Adjacens. gj Antonio.  | E Agino Nen. | - In terrat | Shang Reven                  | C firste homo -        | Norma. Streep.     | W Grap.              |                           |         |
| Would your  |              |             | ant .                        | × 11                   | Scaled Realition   | ×                    | teng setlet spin          | Ansys   |
| The second second second second second second   |              |             | 172.000                      |                        |                    |                      |                           | STUDENT |
| Subarana Parte Abustus  | 91           |             | 371.000                      |                        |                    |                      |                           |         |
| Spanners, brind Lange Presson (Per) a   | S-1          |             | 375,000                      |                        |                    |                      |                           |         |
| Tailainees<br>Epochanies Method Taineity and Taicong Italia<br>Tachalard Taineity (%) -   | - A          | rea-Weighte | ooo aac be                   |                        |                    |                      |                           |         |
| Subject values, talk an   | -            | temperatu   | of 367 000                   | 1                      |                    |                      |                           | -       |
| FALSTN (these) (stdgr)  |              | 1           | K] 300,000                   | 1                      |                    |                      |                           |         |
| R Reportations  | -            |             | 364.000                      |                        |                    |                      |                           |         |
| Post Register     Advance Andread   |              |             | M1 000                       | 0 100                  | 200 300 400<br>Ite | soo noo<br>rations   | 700 800 900 1             | 1000    |
| enald.<br>Ø Sarbeen<br># Grapten  |              |             |                              |                        |                    |                      | i wiete                   |         |
| An and a second | Name -       |             |                              |                        |                    |                      |                           | A       |

Fig 5.6.1 Temperature outlet for the radiator at 1m/s

| a Design (Barkis' (Bart Miller) Bakkas (B  | cada -                    | -                             | ralad Annua  | 1. 11 A   |                                 |                                   | Q, tool too to prove ( | 0 💼 🖌            |
|--|---------------------------|-------------------------------|--|---|---------------------------------|-----------------------------------|------------------------|------------------|
| Bank         Date         Date           Series         Image  | Colored<br>No Sector Inc. | a El Maria.<br>A. 19 Journal. | Breck Models<br>Deserve Plants<br>United Plants<br>Bring Plants<br>Bring Model | Tartie Haddel<br>Insen<br>Ef Tutte Tarrings<br>(1) Yoste Danies | Alley To Annual To Annual State | Antipati<br>A Contra -<br>M Manga |                        | ~                |
| energy inter-  |                           | nierą judei                   | 373.00   | × #   | Scaled Restitute                | * 8                               | tong_adds piter        | Ansys<br>attring |
| National Parallel International Internation Sciences (International International Inte | 3                         |                               | 172.00   | x -   |                                 |                                   |                        | STUDENT          |
| Ingenerate/Polisi Singer Prospers (Pol )   | 9                         |                               | 371.00   | xu -  |                                 |                                   |                        |                  |
| Rendelines<br>Rendelines Holical Interacts and Vessels factor<br>Technical Interacts [54] p  | 3                         | Area-Weigh<br>Avera           | ed ana ee  | x0 -  |                                 |                                   |                        |                  |
| Tachalant Hannaha Ratin <sub>10</sub>  | 2                         | temperat                      | of<br>ure 369.00<br>[K]  | × (   |                                 |                                   |                        | •                |
| ferfy [Diss.] (bdy.)   |                           |                               | 36.00  | 10  |                                 |                                   |                        |                  |
| The Super Contention     Content of the Super-Content of the Super-      | 1.0                       |                               | 207.00   | 0 100   | 300 300 400<br> t               | soo aoo vo<br>erations            | 10 1920 1900 1         | 000              |
| ( • Takutatio Artistia<br>O Are Laboration<br>and a<br>Contrast  |                           |                               |  |   |                                 |                                   | 1 artests              |                  |
| d trans  | Press of Lot              | 12.<br>12.                    |  |   |                                 |                                   |                        | 115              |

Fig 5.6.2 Temperature outlet for the radiator at 2m/s

![](_page_71_Picture_0.jpeg)

Fig 5.6.3 Temperature outlet for the radiator at 3m/s

| Density Physics may lithe at the   | Normality (1)          | -            | rafted density  | -   |  |                               | Q, mark hashed ("prof | 01      |
|--|------------------------|--------------|---|---|--|-------------------------------|-----------------------|---------|
| Anne Anne Anne Anne Anne Anne Anne Anne  | Departed Report Report | - Enertant   | Boch Hodds<br>Classes reas<br>U Hang Person<br>Et Lag Model | Tanka Haskit<br>Danis<br>Of Tana Teerings<br>(), Yang Danis | Adapt<br>To Noral To Advant<br>X Denni | Safan<br>• Data +<br>2 Maraja |                       |         |
| ung mai  |                        |              | Beek.   | × 🖬   | Scaled Revisionis                      | × 81                          | Triage and the spirit | 3       |
| •  | -                      |              |   | ۰ı  |  |                               |                       | Ansy    |
| Nody Spectration Hollod. Napoluda, Introd to Brandary  | -                      |              | 372.500   |   |  |                               |                       | 1040100 |
| Nefermini Traine, Souluta  |                        |              |   |   |  |                               |                       |         |
| resolution (Registration (196/10) 4  |                        |              | 372.000   | 6-  |  |                               |                       |         |
| runna/Indix/Sauge Provider (Pd) (  | 3.4                    |              |   |   |  |                               |                       |         |
| Tabalan  |                        |              | 371.500   | 0   |  |                               |                       |         |
| Specification field and provide and macropy Parce.   | - /                    | Irea-Weight  | ted   |   |  |                               |                       |         |
|  |                        | Avera        | ge 371.000  | 0.0   |  |                               |                       |         |
| -instant cases and 18  | 1.4                    | to manual to | 01  | 10  |  |                               |                       |         |
| Renty (Cheve) (Mede.)  |                        | temperati    | IK] 370.000   | •   |  |                               |                       |         |
| Andra B  | 10.00                  |              | 370.000   | 6 -   |  |                               |                       |         |
| 234430   | 1161                   |              |   | _N  |  |                               |                       |         |
| August Contention of Contentio |                        |              | 365.900   | e +   |  |                               |                       | 10      |
| Call Registers   | 1 dead                 |              |   | 0 100   | 200 200 400                            | 100 600 70                    | 0 000 000 0           | 000     |
| Aufornatio March Julighteen  | A.                     |              |   |   | It                                     | erations                      |                       |         |
| anatom Advites   |                        |              |   |   |  |                               |                       |         |
| Kie Cassenie   |                        |              |   |   |  |                               |                       |         |
| Setters  |                        |              |   |   |  |                               | 0 winets:             | Enders  |
| Carles.  | Concession in case     |              |   |   |  |                               |                       |         |

Fig 5.6.4 Temperature outlet for the radiator at 4m/s
| Do Down Hunto Darithmed Adden A   | and the     | t through t                                   | bongo +   |                                   |                                | Q, tool (see ) (1) | 0 1 |
|---|-------------|---|---|-----------------------------------|--------------------------------|--------------------|-----|
| Bank     Control     Date     Date       1 bink     (i)     (i) <t< th=""><th>Dy Append -</th><th>interfann. An<br/>田和山、田田<br/>田和山、田田<br/>田田<br/>田田</th><th>ni Madala Tantas Hastari<br/>nares Pasakan<br/>Ing Plananan<br/>I Madala (1) Tantas Tapringa<br/>I Madala (1) Tantas Tapringa</th><th>Alley Former To Annual Statements</th><th>fuelan<br/>• Data -<br/>Arthurp,</th><th></th><th></th></t<>  | Dy Append - | interfann. An<br>田和山、田田<br>田和山、田田<br>田田<br>田田 | ni Madala Tantas Hastari<br>nares Pasakan<br>Ing Plananan<br>I Madala (1) Tantas Tapringa<br>I Madala (1) Tantas Tapringa | Alley Former To Annual Statements | fuelan<br>• Data -<br>Arthurp, |                    |     |
| Contract of the second of | Are         | a-Weighted<br>Average<br>of                   | ×<br>373.0000<br>170.5000<br>   | Solid Rothum                      | * 8                            | long, acht abr     |     |
| Item     Item       Item <td>F B B</td> <td>PI</td> <td>370.5000<br/>370.0000<br/>0 100</td> <td>200 300 400<br/>Ite</td> <td>sao aoo voo<br/>arations</td> <td>800 100 1</td> <td>000</td>   | F B B       | PI  | 370.5000<br>370.0000<br>0 100   | 200 300 400<br>Ite                | sao aoo voo<br>arations        | 800 100 1          | 000 |

Fig 5.6.5 Temperature outlet for the radiator at 5m/s

| President State of St   |             | 10 ( Taria                               | Ant Decision   |   |   |   | <u> </u> |                 | 1000     |
|--|-------------|--|--|---|---|---|----------|-----------------|----------|
| Hank Jose<br>HTL-<br>N-<br>N-<br>N-<br>N-<br>N-<br>N-<br>N-<br>N-<br>N-<br>N   | C Augurit - | Seterfacea<br>Head                       | Most Midda<br>Sylamic Healt<br>Mang Planet<br>I Cay Mand           | Turbu Hudul<br>Cudis<br>C Turbu Turbu Turbuy-<br>C Turbu Quertu - | And<br>Televisian Televisian<br>X contration (A | Admigit. Befacti<br>Maragit. (Conto<br>Maragit. |          |                 |          |
| verset fan:  |             | -  | 3/3 0000   | × <b>N</b>  | Broket Rest                                     | fort (3   |          | tung suiki tyhi | Ansy     |
| Network     Name   | •           |  | 372 7680<br>372 3880<br>372 2580<br>372 9880                       |   |   |   |          |                 | FILDEN   |
| Transmission Conversion (1997)<br>Transmission Conversion (1997)<br>Transmission Conversion (1997)<br>Conversion ( | - A/        | ea-Weighte<br>Averag<br>temperatur<br>[? | ed 371,7566<br>of 371,5666<br>Q 371,2566<br>Q 371,2566<br>371,0000 |   |   |   |          |                 |          |
| Canadiana Canadi   |             |  | 370.5000   | 0 000   | 200 100   | 400 500 0<br>Iterations                         | 00 700   | 800 800         | <br>1000 |
| ○ Nai calatara<br>Afra   |             |  |  |   |   |   |          | 1 100           | 4        |

Fig 5.6.6 Temperature outlet for the radiator at 6m/s

61



Fig 5.6.8 Temperature outlet for the radiator at 7m/s

| transfer ( Physics ) have bellevel . Second re-  | aada in    | -             | alled decides   | 1                                      |                   |                                    | C. Bart Carrier (1984) | 0 6     |
|--|------------|---------------|---|--|-------------------|------------------------------------|------------------------|---------|
| Hank Dame<br>Proc. (Control of Control of Cont | Chapters - | beiterfaceas. | Head Module<br>Classon: Healt.<br>12 mang Planet<br>III Sep Heald | Satis Hold<br>Date<br>Of Tarls Tailog. | Adapt<br>Ng Namat | Surface<br>R., + Dece +<br>Manaph. |                        |         |
| Second and   | - 1        |               | kok-  | × 10                                   | Solid Institute   | × 🖬                                | tong_withrepid         |         |
| Alaria   |            | 1.141         |   |  |                   |                                    |                        | Ansys   |
| whith Samed Johnson Terror 700 Johnson - Joseph House -  | HT.        |               |   | °T                                     |                   |                                    |                        | STUDENT |
| Works Contractor Helford, Hagniada, Hartral Is Soundary  |            |               | 372 160   | 0 -                                    |                   |                                    |                        |         |
| Balanarias Prantas, Advantues  | +          |               | 372.000   | -                                      |                   |                                    |                        |         |
| Setteds Megalials Drift g  |            |               | 201   |  |                   |                                    |                        |         |
| persons; Terlal Gauge Pressors (Ted. g.  |            |               | 372.400   | 0 -                                    |                   |                                    |                        |         |
| Technican<br>Andrew Berlind Annual Annual Annual   | -          |               | 372 200   | 0 -                                    |                   |                                    |                        |         |
| Spectromer Avenue, and vacuumly same   | Ar         | ea-Weight     | ed  |  |                   |                                    |                        |         |
| Turbulet Venuely Table or  |            | Avera         | ge 372.000  | 8.1                                    |                   |                                    |                        |         |
|  | 1.1        | temperatu     | ire 371.800   | 0-1-                                   |                   |                                    |                        | -       |
| Apply them   Bully   |            | and a start   | K]  | . 1/                                   |                   |                                    |                        |         |
| Construction of the constr   | 1.14       |               | 377.000   | 1                                      |                   |                                    |                        |         |
| Care at  | 100        |               | 375.400   | 0 -                                    |                   |                                    |                        |         |
| Seguer Salemen   |            |               | 7/1.500   |  |                   |                                    |                        | 4       |
| B Of Pepters   |            |               |   | 0 100                                  | 200 200 400       | 500 000                            | 000 000 001            | 1000    |
| g Automatic Malifi Adaptice  | 1          |               |   |  |                   | Iterations                         |                        |         |
| Calculation Activities   |            |               |   |  |                   | 2252220015                         |                        |         |
| 9 Nue Extudence  |            |               |   |  |                   |                                    |                        |         |
| D Sufferer   |            |               |   |  |                   |                                    | R relacto              | et et   |
| (Exector)  | stands ( ) |               |   |  |                   |                                    |                        |         |

Fig 5.6.7 Temperature outlet for the radiator at 8m/s



Fig 5.6.9 Temperature outlet for the radiator at 9m/s

| Dende Physics man indust industry in  | and in the                                    | e) (#                        | und inclus   |  |  |                                     | Q term (month) | (Deller )    | 0.0        |
|---|---|------------------------------|--|--|--|-------------------------------------|----------------|--------------|------------|
| Non Linkov<br>→ Otable Delly + Americans<br>→ Delly + Americans<br>→ State of the second<br>→ Stat | Diagont -<br>Ny toposy mature<br>Diagona tana | Beterfaces<br>Bitem<br>Bitem | Mark Months<br>Thereine Media<br>12 Maring Planes<br>13 Tage Robel | forter Hald<br>Trans<br>É Tarte Trainge, | Adapt<br>Ng Hones, Ng Astron<br>Ng Tarana, K. Managa | turian<br>+ Cretter +<br>- Antespi. |                |              |            |
|   |   | y jadat                      | moch   | * 8                                      | ncakel Noviekan                                      | ×B                                  | beng.          | nation right | Ansys      |
| Velocity Spectromer Reliced Augustuch, Acriat in Secondary  |   |                              | 372,000  | -  |  |                                     |                |              | situations |
| Patronical Public Journals  |   |                              |  | 1  |  |                                     |                |              |            |
| And the second s  | 250   |                              | 372.000  |  |  |                                     |                |              |            |
| erners/bild Soup Presse Prilly  | 140   |                              |  | 4  |  |                                     |                |              |            |
| Salahara Sa  |   |                              | 372.4000   |  |  |                                     |                |              |            |
| Textular period (March 1997)  | A   | ea-Weight                    | ed   | 1  |  |                                     |                |              |            |
| Turbine Novem False (a  |   | temperati                    | of 1/2 200   | 1  |  |                                     |                |              |            |
| Augusta (Chouse) (Party   |   | -0.00000000                  | [K]  | 1/                                       |  |                                     |                |              |            |
| Come .  | 102   |                              | 371,800  | 1  |  |                                     |                |              |            |
| n Negeri antatana.<br>L. Mookuri  | a   |                              | 971.6000   |  |  |                                     |                | 11.111       | 1          |
| E del Insystem<br>Endouble Mirch Antagliere<br>Relatation   | <u>.</u>                                      |                              |  | 0 900                                    | 200 300 400  | Iterations                          | 700 800        | 900 10       | 00         |
| ) For Catalogue   |   |                              |  |  |  |                                     |                | 1            |            |
| tanghio:  | (   |                              |  |  |  |                                     |                |              |            |
|   | 818.3025                                      | 4                            |  |  |  |                                     |                |              |            |

Fig 5.6.10 Temperature outlet for the radiator at 10m/s

63

## CHAPTER 6 CONCLUSION

## 6 CONCLUSIONS:

- In this present work, CFD Analysis of Car Radiator is done for different velocities by using Aluminium and Copper and we have observed that as velocity of the coolant increases the cooling capacity of the radiator decreases.
- It is observed that for Copper as radiator material, at a velocity of 1m/s it is preferable to entry the coolant when compared to the remaining values from 1m/s to 10m/s.
- Similarly, it is observed that for Aluminium as radiator material, at a velocity of 1m/s it is preferable to entry the coolant when compared to the remaining values from 1m/s to 10m/s.
- When comparing the Copper and Aluminium as the materials of the radiator, the outlet temperature of coolant is less for copper at a Fluid velocity of 1m/s when compared to Aluminium material. For a velocity of 1m/s the calculated mass flow rate of the coolant is 0.078 kg/s and discharge is 7.85\*10^-2 lit/sec. So, it is advisable to entry the fluid at a velocity as 1m/sec for copper material of the Radiator.

## CHAPTER 7 REFERENCES

## 7 REFERENCES

 Adnan M. Hussein, R.A. Bakar , K. Kadirgama and K.V. Sharma, "Heat transfer enhancement using nanofluids in an automotive cooling system" www.elsevier.com/ locate/ichmt
A.H. Mamun, K.Y. Leong, R. Saidur and S.N. Kazi, Performance Investigation of an Automotive Car Radiator Operated with Nanofluid-Based Coolants (Nanofluid as a Coolant in a Radiator), Applied Thermal Engineering, vol. 30, December 2010, pp.

[3] Alhassan Salami Tijani and Ahmad Suhail bin Sudirman, "Thermos-physical properties and heat transfer characteristics of water/anti-freezing and Al2O3/CuO based nanofluid as a coolant for car radiator"www.elsevier.com/locate/ijhmt

[4] A. Sing, Thermal conductivity of nano fluid" defence science journal 58(2008)

[5] **Chavan & Tasgaonkar**, Study, Analysis & Design of Automobile Radiator Proposed with CAD Drawings & Geometrical Model of the Fan, Inter. Journal of Mech. & Prod. Engg. Research & Dev., 3(2), (2013) 137 to 146.

[6] **Devireddy Sandhya , M. Chandra Sekhar Reddy** and **Veeredhi Vasudeva Rao**, A paper on "Improving the cooling performance of automobile radiator with ethylene glycol water based TiO2 nanofluids"www.elsevier.com/ locate/ichmt

[7] **D.H. Lee, L.D. Tijing, B.C. Pak** and **B.J. Baekand**, A Study on Heat Transfer Enhancement Using Straight and Twisted Internal Fin Inserts, International Communications in Heat and Mass Transfer, vol. 33, March 2013, pp.

[8] **Hardik kumar Patel** and **Deepu Dinesan**, Optimization & Performance Analysis of an Automobile Radiator using CFD, Inter. Journal for Innov. Research in Sci. & Tech., 1(7) (2014)

[9] Jama. H, S. Watkins, C. Dixon and E. Ng, "Air flow distribution through the radiator of a typical Australian passenger car" 15 th Australian Fluid Mechanics Conference 15 (2004).

[10] **John Vetrovec**, Engine Cooling System with a Heat Load Averaging Capability, SAE International, April 2008, pp

[11] JP Yadav and Bharat Raj Singh, Study on Performance Evaluation of Automotive Radiator, SAMRIDDHI-A Journal of Physical Sciences, Engineering and Technology, vol. 2, June 2015, pp.

[12] **Komalangan Krishnakumar, Navid Bozorgan** and **Nariman Bozorgan**, Numerical Study on Application of Cuo-Water Nanofluid in Automotive Diesel Engine Radiator, Modern Mechanical Engineering, vol. 2, November 2012, pp. [13] **M. Seifi Jamnani, S.M. Peyghambarzadeh, S.H. Hashemabadi** and **S.M. Hoseini**, Improving the Cooling Performance of Automobile Radiator with Al2O3/Water Nano Fluid, Applied Thermal Engineering, vol. 31, February 2011, pp.

[14] **N. Galanis, C.T Nguyen, G. Roy** and **C. Gauthier**, Heat Transfer Enhancement Using Al2o3-Water Nanofluid for an Electronic Liquid Cooling System, Applied Thermal Engineering, vol. 27, 2007, pp.

[15] Nor Azwadi CheSidika, Muhammad Noor Afiq WitriMohdYazida and Rizalman Mamatb, "Recent advancement of nanofluids in engine cooling system".

[16] **Oliet. C, A. Oliva, J. Castro** and **C. Pérez-Segarra**, "Parametric studies on automotive radiators" Applied Thermal Engineering, 27 (2007)

[17] **S. Kakac** and **A. Pramuanjaroenkij**, "Review of convective heat transfer enhancement with nanofluids", International Journal of Heat and Mass Transfer 52 (2009)

[18] S. Cheong, D. Kim, Y. Kwon, Y. Cho and Y. Hwang, Convective Heat Transfer Characteristics of Nanofluids under Laminar and Turbulent Flow Conditions, Current Applied Physics, vol. 9, 2009, pp.

[19] S. Zenial Heris, M. Shokrogzar, S.Poorpharhang, M. Shanbedi and S.H. Noie, "Experimental study of heat transfer of a car radiator with CuO/Ethylene glycol-water as a coolant" Journal of Dispersion Science and Technology (2014).

[20] Siraj Ali Ahmed, Mehmet Ozkaymak, Adnan Sözen, Tayfun Menlik and Abdul karim Fahed "Improving car radiator performance by using TiO2-water nanofluid" www.elsevier.com/ locate/jestch

[21] **Yiding Cao** and **Khokiat Kengskool**, "An automotive radiator employing wickless heat pipes" Florida International University, Miami, Conference Paper, 1992.