Kingston University London

School of Engineering and the Environment
Department of Aerospace and Aircraft Engineering

Coursework Assessment Brief

Module Code	**ME6051/6121/6151**
Module Title	**Vehicle Design and Technology**
Title of Assessment	*Pressure distribution on an aerofoil Flow visualisation / Wind Tunnel testing of scale models. (Individual Course work)*
Summative (% of module) or Formative	Summative – this assignment is worth 25% of your module grade
Typical individual student hours required to complete the assessment	State. Rule of thumb 100 hours per 30-credit module, 1% is equivalent to 1 hour.
Assessment set by (and contact)	Dr. Sing Lo/Dr. Malcolm Claus
Submission deadline (date and time)	2nd March 2020, 23h59
Formal feedback	31st March 2020

All assignments must be submitted by the date and time specified above.
Students are required to submit an electronic copy of their completed assignment via the Assignments section of Canvas and follow any specific instructions. Any change to this instruction will be advised via Canvas.

In line with Faculty policy for late submission of coursework, any work submitted up to a week late will be capped at 40%. Coursework submitted after this time will receive 0%.

In case of illness or other issues affecting your studies please refer to the University Mitigating Circumstances policy. Guidance on mitigating circumstances can be found on MyKingston:

https://mykingston.kingston.ac.uk/myfaculty/sec/secstudentsupportMC/Pages/Mitigating-Circumstances.aspx

Please note that if you submit a piece of work you have judged yourself fit to undertake the assessment and cannot claim mitigating circumstances retrospectively.

Guidance on avoiding academic assessment offences such as plagiarism and collusion can be found on MyKingston

https://mykingston/myuni/academicregulations/Pages/default.aspx

Module Learning Outcomes

The following module learning outcomes and professional body learning outcomes are tested in this assessment:

- Understand essential elements of the theory of aerodynamics and run CFD simulations to calculate essential quantities related to high performance vehicle aerodynamics.

Assessment task and specific terms

- Please copy and paste the marking scheme and feedback form following the cover page of your assignment in Word format.
- *Presenting the work of others as your own is academic misconduct and will be subject to penalty. If in doubt you are advised to read the university regulations on academic misconduct: Cheating in assessment and/or consult the lecturer setting the assignment.*
- Referencing and citation requirements: You are expected to refer to the indicative bibliography of the module provided in Canvas and the additional bibliographic sources suggested in the lecture notes. In addition, you must undertake your own appropriate further reading and research in relation to the matters addressed in this coursework brief. Evidence of independent reading and research will be rewarded. A list of References must be presented at the end of the report listing all bibliographic sources cited."

Assessment Criteria

Assessment of your submission will be based on the following weighted assessment criteria as given below which relate to the specified module and PSRB learning outcomes. Assessment criteria are reproduced in Canvas in a rubric.

Specific Criteria (marking scheme)	Marks available
Part 1 and part2:Report writing and Presentation -produce a structured technical report with clear writing style. -describe the equipment and procedures. - present experimental results in the form of graphs.	10
Part 1 a, b and c: Analysis of the results **-** produce non-dimensional pressure distribution plots from the wind tunnel test. - plot graphs of C_p versus x/c for your five sets of readings. - obtain C_L from the areas and plot C_L versus angle of attack.	25
Part 1: Discussions -discuss the results and deduce any trend or observable physical phenomenon - examine the effect of incidence on pressure distribution and discuss the variation in the magnitude and position of the point of minimum pressure. -compare C_L versus angle of attack with the experimental results from the research literature. -discuss the effect of stall on the C_L and pressure distribution.	25
Part 2: **a** Flow Visualization techniques	15
b Underbody downforce	10
c Open wheel race car study	15
	Total = 100%

Academic skills support

For help and advice on this assessment please contact the assessment setter/s or the module leader. For advice on academic writing and referencing please contact the Faculty of Science, Engineering and Computing (SEC) Academic Success Centre (SASC). Trained staff and students will give you guidance and feedback on assessments. SASC can be contacted by email: SASC@kingston.ac.uk

Marking Scheme and feedback
(please copy and paste this after the cover page your report)

Criteria	Max Mark	Your Grade	Feedback comments
Part 1 and part2:Report writing and Presentation - produce a structured technical report with clear writing style. -describe the equipment and procedures. - present experimental results in the form of graphs.	10		
Part 1 a, b and c: Analysis of the results **-** produce non-dimensional pressure distribution plots from the wind tunnel test. - plot graphs of C_p versus x/c for your five sets of readings. - obtain C_L from the areas and plot C_L versus angle of attack.	25		
Part 1: Discussions -discuss the results and deduce any trend or observable physical phenomenon - examine the effect of incidence on pressure distribution and discuss the variation in the magnitude and position of the point of minimum pressure. -compare C_L versus angle of attack with the experimental results from the research literature. -discuss the effect of stall on the C_L and pressure distribution.	25		
Part 2: **a** Flow Visualisation techniques	15		
b Underbody downforce	10		
c Open wheel race car study	15		
	100%		

Assignment Briefs

There are 2 parts to this assignment – students are to complete both parts. To assist students with this assignment, students can email their draft reports to s.lo@kingston.ac.uk or m.claus@kingston.ac.uk at least one week before the submission deadline. This is to allow the lecturer to give formative feedback on how to improve the report.

Part One

Students are required to carry out the experiment described below. On completion of the experiment students must complete an individual report that addresses the following points.

a) A description of the equipment and procedures employed in completing the experiment

b) To produce non-dimensional pressure distribution plots from the wind tunnel test using a spread-sheet. Plot graphs of C_P versus *x/c* for your five sets of readings. (-4°, 0°, 4°, 8°, 12°)

c) To examine the effect of incidence on pressure distribution and to provide comment about this and in particular the variation in the magnitude and position of the point of minimum pressure

Title of Experiment: Pressure distribution on an aerofoil

Aim:

The aim of this experiment is to examine the pressure distribution on an aerofoil and its variation with incidence.

Introduction:

An aerofoil is the two-dimensional cross section of a wing, tail or helicopter rotor blade. The lift and pitching moment on an aerofoil is determined by the pressure distribution on it. The pressure distribution changes with the angle of incidence. Understanding the behaviour of aerofoils requires some understanding of the variation of the pressure distribution with incidence.

Apparatus:

This experiment uses a pressure tapped aerofoil mounted inside a low speed open return wind tunnel. The pressure tapings are connected to a multi-tube manometer, which is also used to measure the dynamic pressure.

Students should check and record all the connections on the multitube manometer.

Procedure:

1. Level and adjust the multitube manometer in the vertical position with the indicator registering 90°, then incline it to approximately 40° to the horizontal.
2. Check and record all of the manometer connections.
3. Record the NACA aerofoil designation of the aerofoil.
4. Set the model at zero incidence and turn the wind tunnel on. Run the fan up to about ¾ of its full speed.
5. Record all of the manometer heights.

6. Adjust the angle of incidence to -4° and repeat the previous step. Adjust the motor control if necessary to maintain a constant dynamic pressure.
7. Repeat the previous step for 4°, 8° and 12°
8. Determine the stall angle of the aerofoil and qualitatively observe the changes in pressure distribution near the stall angle.

Theory:

The non-dimensional pressure coefficient is defined as:

$$C_P = \frac{P_i - P_\infty}{\frac{1}{2}\rho V^2}$$

Where

P_i	-	pressure at tapping *i*
P_∞	-	free stream pressure
ρ	-	air density
V	-	free stream velocity
S	-	wing area
c	-	aerodynamic mean chord

The quantity of $\frac{1}{2}\rho V^2$ *is known as the dynamic pressure and for low speeds it is equal to* the difference between the stagnation pressure P_o and the free stream pressure P_∞. This means that we calculate C_P using the relation:

$$C_P = \frac{P_i - P_\infty}{P_0 - P_\infty}$$

For an open return wind tunnel, we may assume that the stagnation pressure is equal to the room pressure and we measure the free stream pressure in the test section.

In this experiment students measure pressure differences using a multitube manometer. The difference in pressure is proportional to the difference in height of the liquid levels in the manometer. Since the pressure coefficient is a ratio of two pressure differences, it is also equal to the ratio of differences in height of liquid levels.

$$C_P = \frac{h_i - h_\infty}{h_0 - h_\infty}$$

where *h* indicates the height of the liquid in the manometer.

The multitube manometer is inclined, which means that it does not read the difference in height directly. This is done to increase the difference in manometer reading. Since all of the tubes are inclined at the same angle, the difference in manometer reading is proportional to the difference in height and it can be written:

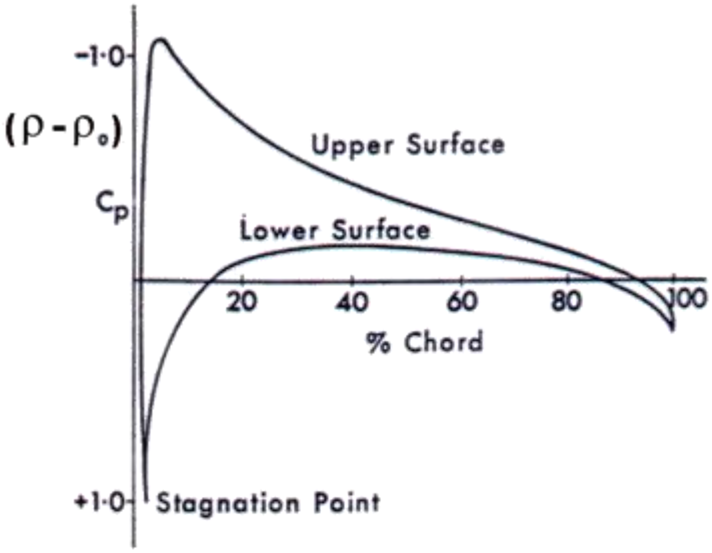
$$C_P = \frac{r_i - r_\infty}{r_0 - r_\infty}$$

where *r* indicates the manometer reading.

Aerofoil pressure plots are usually given with C_P on the vertical axis, with negative values above the axis and x/c on the horizontal axis.

Force Coefficients:

The force coefficient on an aerofoil may be determined from the non-dimensional pressure plot. A typical pressure plot is shown below:



Pressure Distribution Around an Aerofoil (Angle of Attack approx 10°)

The force coefficient perpendicular to the aerofoil is the area enclosed by the figure. The lift is defined as the force perpendicular to the airflow, not the aerofoil, but for small angles of attack, the difference is negligible. Therefore the area enclosed is approximately equal to the lift coefficient at small angles of attack.

Results

1. Complete the data table provided. Obtain the x-coordinates of the pressure tapings (corresponding to the marked numbers) on both upper and lower surfaces and the chord length c from the technician.
2. Convert all the manometer readings h_i into pressure coefficients C_p using the equation given in the theory for all pressure tapping positions x. Repeat this for all angles of attacks. A negative value of C_P indicates low pressure (suction) ,while a positive value corresponding to high pressure.
3. Plot C_P on the vertical axis, with negative values above the axis and x/c on the horizontal axis. You should obtain two curves (the upper and lower surfaces) joining together at the leading edge at x/c =0 and the trailing edge x/c =1.0 for each angle of attack. Count the area enclosed by the two curves, taking into account the scales

of both vertical and horizontal axes. The area is equal to the force coefficient (approximately equal to the lift coefficient). You should plot five graphs and obtain five values of force coefficients from the enclosed areas at different angles of attack.

References:

1. Race Car Aerodynamics Joseph Katz ISBN 0837601428

2. Low speed Wind Tunnel Testing-William H.Rae, ISBN: 047 1874027.

Part Two

Title of Experiment: Flow Visualization / Wind Tunnel testing of scale models

Introduction:

The second part of the assignment relates to flow visualisation techniques and wind tunnel testing of scale models.

Procedure:

In this laboratory session a scale model of a vehicle is mounted within the wind tunnel. Air is passed around the model at a set velocity. Smoke is introduced upstream so that visualisation of the air flow is facilitated.

Students are required to:

a) Describe alternative flow visualisation techniques.

b) Discuss how underbody channels can create downforce.

c) Describe a real world case study of an open-wheel race car wings design. Discuss what the design features and aerodynamic phenomena can be applied to maximise the downforce.

Late Submission of Coursework

According to the faculty policy for the late submission of coursework, any work submitted up to a week late will be capped at **40%**, anything submitted later than one week will receive **a zero mark**.

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