EXPERIMENTAL AND COMPUTATIONAL STUDY OF FLOW OVER A ROTATING CYLINDER WITH SURFACE ROUGHNESS

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by

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DECLARATION

I hereby declare that the work reported in this thesis is the result of my own investigation and that no part of the thesis has been plagiarized from external sources. Materials taken from other sources are duly acknowledged by giving explicit references.

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APPENDICES

Appendix A: Calibration data.

Table B1 below presents the load cell calibration data to ensure the constants of load cell for measure lift and drag. The experiments were repeated thrice to get accurate measurements and minimum error. They were found to be linear and quite repeatable.

Table B1: Calibration factor for lift and drag measurement

Test 1		
	Calibration factor	
Applied force (Newton)	Lift	Drag
1	3.4	3.5
2	3.1	3.1
3	3.7	3.8
4	3.4	3.6
5	3.1	3.2
6	3.8	4.0
Test 2		
	Calibration factor	
Applied force (Newton)	Lift	Drag
1	3.5	3.6
2	3.1	3.2
3	3.8	3.9
4	3.4	3.5
5	3.0	3.1
6	3.7	3.9
Test3		
	Calibration factor	
Applied force (Newton)	Lift	Drag
1	3.5	3.6
2	3.1	3.2
3	3.8	3.9
4	3.5	3.6
5	3.1	3.1
6	3.7	3.9

The data from **Table B1**, the values were averaged and entered into **Table B2.**

Table B2: Averaged values of calibration data

	Calibration factor	
Applied force (Newton)	Lift	Drag
1	3.48	3.58
2	3.14	3.18
3	3.80	3.84
4	3.44	3.54
5	3.04	3.14
6	3.76	3.92

LIST OF PUBLICATIONS

Journal publications:

1. **M.T. ABU SEMAN[1], F. ISMAIL[2], H. YUSOFF[3]**, 2015. Rotational effects on vortex shedding behaviour of a cylinder with surface roughness – An experimental PIV and computational approach, *International Journal of Mechanical And Production Engineering*, Volume3, Issue-4. (Scorpus Index)

2. **M.T. ABU SEMAN[1], F. ISMAIL[2], H. YUSOFF[3], M.A. ISMAIL[2],** 2015. Effect of counter-rotating cylinder with surface roughness on stagnation and separation point – A Computational Approach, *Indian Journal of Science & Technology, Vo 8(30), DOI:10.17485*. (ISI Index List)

3. **M.T. ABU SEMAN[1], F. ISMAIL[2], M.Z. ABDULLAH[1]**, 2014. Rotational effects on aerodynamics of a cylinder with surface roughness – An experimental and computational approach, *ScienceAsia Journal*. (ISI Index - Under review)

4. **M.T. ABU SEMAN[1], F. ISMAIL[2] , M.Z. ABDULLAH[1], M.N.A. HAMID[3]** , 2015. Investigation of Aerodynamic Performances on a Rotating Cylinder with Surface Roughness using Light Weight Smart Motor (LWSM), *Iranian Journal of SCIENCE AND TECHNOLOGY Transaction of Mechanical Engineering.* (ISI Index List- Under review)

Conference proceedings:

5. **M.T. ABU SEMAN[1], F. ISMAIL[2], N.I. ISMAIL[3], M.A. ISMAIL[2], H. YUSOFF[3]**, 2015, Effect of counter-rotating cylinder with surface roughness on stagnation and separation point – A Computational Approach. *The 4th International Conference on Computer Science & Computational Mathematics ICCSCM 2015, May 7th-8th, 2015, Langkawi, Malaysia.*

6. **M.T. ABU SEMAN[1], F. ISMAIL[2], H. YUSOFF[3]**, 2015. Rotational effects on vortex shedding behaviour of a cylinder with surface roughness – an experimental PIV and computational approach. *IIER International Conference on Mehanical, Aeronautics and Production Engineering (ICMAPE-2015), Kuala Lumpur, Malaysia,* February 12, 2015

7. **M.T. ABU SEMAN[1], F. ISMAIL[2], M.Z. ABDULLAH[1]**, 2012. Experimental and Computation analysis on vortex shedding behavior behind a counter-rotating circular cylinder with surface roughness. *2nd Mechanical and Aerospace Engineering Research Colloqium (MAERC). University Sains Malaysia, Malaysia* (2012).

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LIST OF ABBREVIATIONS

CFD	Computational Fluid Dynamics
LWSM	Light Weight Smart Motor
PIV	Particle Image Velocimetry
LDA	Laser Doppler Anemometer
RAS	Reynolds Average Simulation
LES	Large Eddy Simulation
RANS	Reynolds Average Navier Stokes
VMS-LES	Variational Multi Scale Large Eddy Simulation
DES	Detached Eddy Simulation
IFEM	Immersed Finite Element Method
FVM	Finite Volume Method
FDM	Finite Difference Method
DAQ	Data Acquisition Board
SA	Spalart Allmaras
TKE	Turbulence Kinetic Energy
VTOL	Vertical Take-off Landing
SIMPLE	Semi-Implicit Pressure-Linked Equations
2D	Two Dimensional
3D	Three Dimensional

LIST OF SYMBOLS

Roman Symbols		**Unit**
C_D	Drag coefficient	-
C_L	Lift coefficient	-
C_P	Pressure coefficient	-
D	Diameter of cylinder	mm
e_i	error	-
F_D	Drag force	N
F_L	Lift force	N
f_r	Friction force per length of pulley contact	N/m
G_v	Production of Turbulent viscosity	-
J	Moment of inertia	$kg.m^2$
R^2	Correlation coefficient	-
R_a	Average Roughness	µm
r_2	Position vector of second node	m
SD	Standard deviation	-
S_C	Motor speed (rpm)	Rad/s
T	Torque	N.m
t	Time	sec
U	Dimensionless velocity	-
U_∞	Free stream velocity	ms^{-1}
u	Velocity	m/s
v	Mean velocity of air	m/s

$\vec{v}$	Velocity vector	-
$\bar{x}$	Mean	-
Y_v	Destruction of Turbulent viscosity	

Greek Symbols	**Description**	**Unit**
μ	Dynamic viscosity	$N.s/m^2$
ν	Kinematic viscosity	m^2/s
α	Rotational rate	Hz
σ_x	Standard deviation	-
$\sigma_{\bar{x}}$	Standard error	-
µ	Friction coefficient	-
ρ	Air density	kg/m^3
θ	angle	° degree
ω_N	Natural frequency	Hz