

TABLE OF CONTENTS

	Page
ABSTRACT.....	i
ACKNOWLEDGEMENT.....	iii
TABLE OF CONTENTS.....	iv
NOMENCLATURE.....	vii
LIST OF FIGURES.....	ix
CHAPTER 1: INTRODUCTION.....	1
1.1 Turbine Cooling.....	1
1.2 Film Cooling.....	4
1.3 Objectives.....	6
CHAPTER 2: LITERATURE SURVEY.....	7
2.1 Introduction.....	7
2.2 Experimental Studies of Film Cooling	7
2.2.1 Anti-Vortex Techniques.....	9
2.2.2 Effect of Compound Angle.....	11
2.2.3 Effect of Hole Configurations.....	13
2.2.4 Effect of Mainstream Pressure Gradient.....	13
2.3 Numerical Studies of Film Cooling	14
2.3.1 Anti-Vortex Techniques.....	15
2.3.2 Effect of Compound Angle.....	16
CHAPTER 3: EXPERIMENTAL TEST RIG AND MEASURING	
INSTRUMENTS.....	18
3.1 Test Rig.....	18
3.1.1 Mainstream Air Supply.....	19
3.1.2 Film Cooling Jets Supply.....	19
3.1.3 Orifice Meter Section.....	19
3.1.4 Jet Flow Heating Element.....	20
3.1.5 Experimental Test Section.....	20
3.1.5.1 Flat Plate (Zero Pressure Gradient).....	20
3.1.5.2 Flat Plate with Applied Pressure Gradient (Wedge).....	21
3.1.5.3 Temperature Measurement.....	23
3.1.5.4 Film Cooling Hole Geometry.....	24
3.2 Measuring Instruments.....	28
3.2.1 Duct Main Stream Velocity.....	29
3.2.2 Coolant Volume Flow Rate.....	29

3.2.3 Temperature Measurement.....	29
CHAPTER 4: EXPERIMENTAL AND CALCULATION PROCEDURE.....	31
4.1 Introduction.....	31
4.2 Experimental Program.....	31
4.3 Experimental Procedure and Measurements.....	32
4.4 Measurements and Procedure of Calculation.....	33
4.4.1 Blowing Ratio (BR).....	33
4.4.2 Momentum Ratio (MR).....	33
4.4.3 Injectant Reynolds Number.....	34
4.4.4 Free Stream Reynolds Number.....	34
4.4.5 Film Cooling Effectiveness.....	34
4.5 Uncertainty Analysis.....	35
4.5.1 Uncertainty in Coolant Mass Flow Rates.....	35
4.5.2 Uncertainty in Film Cooling Effectiveness.....	36
CHAPTER 5: NUMERICAL TECHNIQUE.....	30
5.1 Governing Equations in Turbulence Model	38
5.1.1 Boussinesq Approach Vs. Reynolds Stress Transport Model.....	39
5.1.2 The $K-\epsilon$ Models in Fluent.....	39
5.1.3 The Realizable $K-\epsilon$ Equations.....	41
5.2 Geometry and Grid Details.....	43
5.3 Boundary Conditions.....	46
5.3.1 Solid Wall Boundaries.....	46
5.3.2 Inlet and Outlet Boundaries.....	47
5.4 Numerical Solution Procedure.....	48
CHAPTER 6: RESULTS AND DISCUSSIONS.....	49
6.1 Numerical Results.....	49
6.1.1 Film Cooling Effectiveness.....	49
6.1.2 Spanwise Averaged Film Cooling Effectiveness.....	53
6.1.3 Overall Area Averaged Film Cooling Effectiveness.....	59
6.2 Experimental Results.....	61
6.2.1 Spanwise Averaged Film Cooling Effectiveness.....	61
6.2.2 Overall Area Averaged Film Cooling Effectiveness.....	68
6.3 Comparison between Experimental and Numerical Results.....	70
6.3.1 Present Work Experimental and Numerical Results Comparison.....	70
6.3.2 Comparison with Previous Works.....	72
6.4 Effect Of Different Pressure Gradients.....	75

6.4.1 Spanwise Averaged Film Cooling Effectiveness.....	77
6.4.2 Overall Area Averaged Film Cooling Effectiveness.....	77
6.4.3 Comparison between the Studied Pressure Gradients.....	83
6.5 Boundary Layer Velocity Distribution.....	90
CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS.....	97
7.1 Conclusions.....	97
7.2 Recommendations for Future Works	98
REFERENCES.....	99
APPENDIX A.....	105
APPENDIX B.....	109