

TURBULENT BOUNDARY LAYERS IN INCOMPRESSIBLE FLOW

J. C. ROTTA

Aerodynamische Versuchsanstalt, Göttingen

Contents

	<i>Page</i>
CHAPTER I. FUNDAMENTALS OF TURBULENT BOUNDARY LAYER THEORY	
1. Introduction	5
2. Basic equations and mathematical formulation of the problem	6
2.1 Equations of motion	6
2.2 Boundary conditions	9
2.3 Pressure fluctuations	10
3. Statistical theory of turbulence	11
4. Boundary layer equations in statistical mean values	12
5. Hypothetical relations	17
 CHAPTER II. UNIVERSAL ASPECTS OF THE MECHANISM OF TURBULENT BOUNDARY LAYER FLOW	
6. Double velocity correlation functions and spectrum functions	22
6.1 The double velocity correlation function	22
6.2 Experimental results	25
6.3 Spectrum functions	34
7. Energy dispersion by viscosity	35
7.1 Process of turbulent energy dissipation	36
7.2 Locally isotropic turbulence	37
7.3 Energy spectrum of locally isotropic turbulence	37
8. Double velocity equations	43
9. The energy transfer among different velocity components	47
10. The equilibrium conditions in turbulent shear flow	49
11. The flow near the wall	54
11.1 Similarity considerations	54
11.2 The behaviour of the flow in the immediate vicinity of the wall	58
11.3 Energy balance	59
11.4 Further details of the structure of wall flow	66
11.5 Generalization of the universal law of the wall	70
11.6 Wall flow on rough surfaces	73
11.7 Representation of the mean velocity distribution	76
12. The free stream boundary of the turbulent layer	82
12.1 Statistical description of the free stream boundary	83

12.2 The process of vorticity propagation	85
12.3 Inference of turbulence properties from the intermittent signals	91
12.4 Turbulent diffusion in the region of the free stream boundary	93
12.5 Flow outside the turbulent regime	94

CHAPTER III. THE GENERAL BEHAVIOUR OF TURBULENT BOUNDARY

LAYERS

13. Boundary layer on a flat plate with zero pressure gradient	96
13.1 Local similarity	97
13.2 Experimental results	100
13.3 Theoretical background of the local similarity	105
13.4 The energy balance	114
14. Equilibrium boundary layers	119
14.1 Conditions for equilibrium layers	120
14.2 Experimental verification of equilibrium layers	124
14.3 Downstream stability	127
15. Boundary layers in arbitrary pressure distribution	129
15.1 Non-dimensional representation	131
15.2 Details of the motion	138
16. Separation	145

CHAPTER IV. THE CALCULATION OF THE TURBULENT BOUNDARY LAYER

17. The problem of boundary layer calculation	153
17.1 Boundary layer equations	153
18. Description of the mean velocity profiles	156
19. Local skin friction coefficient	166
19.1 Skin friction formulae	166
19.2 Determination of skin friction coefficient for experimental boundary layers	170
20. Determination of shearing stress distribution	172
20.1 The direct problem	173
20.2 The inverse problem	179
20.3 The integral of the energy dissipation	182
21. The turbulent boundary layer on a flat plate	185
21.1 Integration of the momentum equation	185
21.2 Boundary layer on smooth surface	187
21.3 Boundary layer on uniformly rough surface	189
21.4 The total skin friction coefficient	191
22. The shape parameter equation	192
22.1 Empirical shape parameter equations	196
22.2 Shape parameter equations based on boundary layer equations	197
22.3 Examination of the shape parameter equation	199
23. Some remarks on the numerical boundary layer calculation	204
23.1 Initial values	205
23.2 Approximate methods	207

