Yuri B. Zudin

Theory of Periodic Conjugate Heat Transfer

With 41 Figures and 11 Tables

Springer

Contents

Abbreviations XV

Symbols XVII

1 Introduction 1
1.1 Heat Transfer Processes Containing Periodic Oscillations ... 1
1.1.1 Oscillation Internal Structure of Convective Heat Transfer Processes 1
1.1.2 Problem of Correct Averaging the Heat Transfer Coefficients 3
1.2 Physical Examples 6
1.3 Numerical Modeling of Conjugate Convective–Conductive Heat Transfer 10
1.4 Mechanism of Hydrodynamic Oscillations in a Medium Flowing Over a Body 12
1.4.1 Van Driest Model 12
1.4.2 Periodic Model of the Reynolds Analogy 13
1.4.3 Model of Periodical Contacts 15
1.5 Hydrodynamic HTC 18
1.6 Previous Investigations of Heat Transfer Processes with Periodic Intensity 20
1.7 Analytical Methods 20
References 21

2 Construction of a General Solution of the Problem 27
2.1 Boundary Value Problem for the Heat Conduction Equation 27
2.2 Spatial and Temporal Types of Oscillations 30
2.3 Interrelation between the Two Averaged Coefficients of Heat Transfer 31
2.4 Dimensionless Parameters 34

2.5 Factor of Conjugation: An Analysis of Limiting Variants 35
References 36

3 Solution of Characteristic Problems 37
3.1 Construction of the General Solution 37
3.2 Harmonic Law of Oscillations 39
3.3 Inverse Harmonic Law of Oscillations 43
3.4 Delta-Like Law of Oscillations 53
3.5 Step Law of Oscillations 55
3.6 Comparative Analysis of the Conjugation Effects (Smooth and Step Oscillations) 68
3.7 Particular Exact Solution 69
References 70

4 Universal Algorithm of Computation of the Factor of Conjugation 73
4.1 Smooth Oscillations (Approximate Solutions) 73
4.2 BC on a Heat Transfer Surface (Series Expansion in a Small Parameter) 75
4.3 Derivation of a Computational Algorithm 77
4.4 Phase Shift Between Oscillations 80
4.5 Method of a Small Parameter 83
4.6 Application of the Algorithm for an Arbitrary Law of Oscillations 85
4.7 Filtration Property of the Computational Algorithm 91
4.8 Generalized Parameter of the Thermal Effect 92
4.9 Advantages of the Computational Algorithm 93
References 93

5 Solution of Special Problems 95
5.1 Complex Case of Heating or Cooling 95
5.2 Heat Transfer on the Surface of a Cylinder 102
5.3 Heat Transfer on the Surface of a Sphere 103
5.4 Parameter of Thermal Effect for Different Geometrical Bodies 104
5.5 Overall ATHTC 105
5.5.1 Overall EHTC 105
5.5.2 Bilateral Spatiotemporal Periodicity of Heat Transfer (A Qualitative Analysis) 108
References 110

6 Step and Nonperiodic Oscillations of the Heat Transfer Intensity 111
6.1 Asymmetric Step Oscillations 111
6.2 Nonperiodic Oscillations 117
References 120

7 Practical Applications of the Theory 121
7.1 Model Experiment 121
7.2 Dropwise Condensation 122
7.3 Nucleate Boiling 126
7.3.1 Theory of Labuntsov 126
7.3.2 Periodic Model of Nucleate Boiling 129
References 136

A Proof of the Fundamental Inequalities 139
A.1 Proof of the First Fundamental Inequality 139
A.2 Proof of the Second Fundamental Inequality 145

B Functions of the Wall Thickness 147
B.1 Spatial Type of Oscillations 148
B.2 Temporal Type of Oscillations 148

C Infinite Chain Fractions 151
C.1 Fundamental Theorems of Khinchin 151
C.2 Generalization of the Third Theorem of Khinchin 152

D Proof of Divergence of the Infinite Series 155
D.1 Spatial Type of Oscillations 155
D.2 Temporal Type of Oscillations 156

E Functions of Thickness for Special Problems 159
E.1 Heat Transfer from the Ambience 159
E.2 Heat Transfer from an External Semi-Infinite Body 160

Index 161