CAMBRIDGE

Cambridge University Press
978-1-107-07638-9 - Robot-Oriented Design: Design and Management Tools for the Deployment of Automation and Robotics in Construction
Thomas Bock and Thomas Linner
Table of Contents
More information

# Contents

*Acknowledgements* *page* ix
*Glossary* xiii

1 **Advanced Construction and Building Technology** . . . . . 1
1.1 Robot Technology Becomes Ubiquitous 2
1.2 The Origins of Automated Construction and Its Disruptive Nature 5
1.3 The Mission and Structure of the Series 9
1.3.1 Volume 1: *Robot-Oriented Design – Design and Management Tools for the Deployment of Automation and Robotics in Construction* 11
1.3.2 Volume 2: *Robotic Industrialization – Automation and Robotic Technologies for Customized Component, Module, and Building Prefabrication* 12
1.3.3 Volume 3: *Construction Robots – Elementary Technologies and Single-Task-Construction Robots* 13
1.3.4 Volume 4: *Site Automation – Automated/Robotic On-site Factories* 14
1.3.5 Volume 5: *Ambient Robotics – Automation and Robotic Technologies for Maintenance, Assistance, and Service* 15

2 **The Structure of this Volume** . . . . . 18

3 **The Role of Complementarity of Products, Organization, Information, and Machine Technology** . . . . . 21
3.1 Current State of Product Structures in Construction 24
3.2 Current State of Organization and Management in Construction 24
3.3 Informational Aspects in Construction 29
3.4 State-of-the-Art Machine Technology in Construction 33
3.4.1 The Roots of Component Manipulation in the Middle Ages 37
3.4.2 *Bauschiffe* (from 1910 onwards) 39



© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-07638-9 - Robot-Oriented Design: Design and Management Tools for the Deployment of Automation and Robotics in Construction
Thomas Bock and Thomas Linner
Table of Contents
More information



3.5 Neufert–Bauschiff/Hausbaumaschine (1943) 41
3.5.1 Mechanized On-Site Construction in Russia (since the 1940s) 41
3.5.2 7-Degrees-of-Freedom Manipulator Kinematics for Construction Purposes: Location Orientation Manipulator (1969) 42
3.5.3 Fusion of Prefabrication and Lifting Technology: BMW Tower (1972) 43
3.5.4 Zuse's Extendable/Retractable Helix Tower (1985–1995) 43
3.5.5 Focus on Machine Technology 44

**4 Introduction of Relevant Terms, Concepts, and Technologies . . . . . 49**
4.1 Productivity, Efficiency, and Economic Performance 50
4.1.1 Means of Production 51
4.1.2 Productivity 52
4.1.3 Efficiency 55
4.1.4 Health and Safety 58
4.1.5 Quality and Construction Defect Rate 59
4.1.6 R&D Spending in Construction 60
4.1.7 Investment Strategy 61
4.1.8 Low Capital Intensity of the Construction Industry 61
4.1.9 Integration along the Value Chain 63
4.2 Multilevel Modularity (Products, Processes, Organization, and Machines) 66
4.2.1 Types of Modularity 69
4.2.2 Frame and Infill Strategies 69
4.2.3 Flexibility and Adaptability of Buildings: Role and Design of Interfaces and Connectors 73
4.2.4 Flexibility and Adaptability of Manufacturing Systems 77
4.3 Technology and Organization in Manufacturing 79
4.3.1 Representative Production Systems 80
4.3.2 Analysing Manufacturing Systems 84
4.3.3 Logistics, the OEM Model, and Supply Chain Design 84
4.3.4 Flexibility and Adaptability of Manufacturing Systems 91
4.3.5 Manufacturing and Sustainability 92
4.3.6 Future Concepts in Manufacturing 93
4.4 Automation and Robot Technology 96
4.4.1 Robot Kinematics 100
4.4.2 Actuators 102
4.4.3 Sensor and Process Measuring Technology 103
4.4.4 End-Effectors 103
4.4.5 Modularity in Robotics 107
4.4.6 Human–Robot Cooperative Manipulation 109
4.4.7 Towards Open Source in Robotics 120
4.4.8 New Manufacturing Concepts Based on Robotic Self-Organization 122

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-07638-9 - Robot-Oriented Design: Design and Management Tools for the Deployment of Automation and Robotics in Construction
Thomas Bock and Thomas Linner
Table of Contents
More information



5 **Complex Products in Other Industries and Relevance of Fixed-Site/On-Site Manufacturing Technology** . . . . . 125
5.1 Tunnelling by TBMs 125
5.1.1 Product 126
5.1.2 Manufacturing Strategy 126
5.1.3 Manufacturing System 127
5.1.4 Robot-Oriented Design 127
5.2 Shipbuilding 128
5.2.1 Product 128
5.2.2 Manufacturing Strategy 129
5.2.3 Manufacturing System 130
5.2.4 ROD 139
5.3 Aircraft Manufacturing 139
5.3.1 Product 139
5.3.2 Manufacturing Strategy 140
5.3.3 Manufacturing Systems 142
5.3.4 ROD 143
5.4 Automotive Manufacturing 143
5.5 Comparative Analysis 144
5.6 Performance Multiplication by Mechanization, Automation, and Robot Technology 147
5.7 Systematization of Final Assembly by a Combination of OEM and the Factory Approach 152

6 **Synchronization of Organization, Building Structure, and Manufacturing Technology by Robot-Oriented Design** . . . . . 156
6.1 From DfX to ROD 157
6.1.1 Design for Production 157
6.1.2 Design for Function 158
6.1.3 Design for End-of-Life 159
6.1.4 Design for Business Model 160
6.2 Designing within Capabilities of the Manufacturing System 161
6.2.1 ROD Related to Production Aspects 163
6.2.2 ROD Related to Functional Aspects 164
6.2.3 ROD Related to End-of-Life Aspects 165
6.2.4 ROD Related to Business Model Aspects 166
6.3 Dimensions of ROD 167
6.3.1 Reduction of Kinematic/Mechatronic Complexity 168
6.3.2 Reduction of Sensor, Process Measuring, and Control Complexity 169
6.3.3 Reduction of Organizational Complexity 170
6.3.4 Reduction of Gripper-/End-Effector Complexity 172
6.3.5 Reduction of Information/Computational Complexity 174
6.3.6 Reduction of Complexity Throughout the Life Cycle 175
6.3.7 Complexity Reduction Along the Value Chain by ROD 176
6.4 Application of ROD in Various Architectonic Scales 184

© in this web service Cambridge University Press www.cambridge.org

CAMBRIDGE

Cambridge University Press
978-1-107-07638-9 - Robot-Oriented Design: Design and Management Tools for the Deployment of Automation and Robotics in Construction
Thomas Bock and Thomas Linner
Table of Contents
More information



6.5 Guidelines for Robotic Production and Assembly-Oriented Design in Construction 185
6.5.1 How Product Structure, Component Design, and Variation Influence the Manufacturing System 187
6.5.2 Identification and Coordination of Relations between Design and Manufacturing Methods 197
6.5.3 Geometric Coordination 200
6.5.4 Robotic Production–Oriented Design in Construction 201
6.5.5 Robotic Assembly–Oriented Design in Construction 204
6.5.6 Choosing, Designing and Redesigning of the Construction Robot System 225

**7 Utilizing Innovation Science to Develop and Deploy Automated/Robotic Systems in Construction** . . . . . 231

7.1 Innovation Mechanisms in General 231
7.1.1 Typological Viewpoint 232
7.1.2 System Viewpoint 233
7.1.3 Process Viewpoint 234
7.1.4 Novelty Level Viewpoint 234
7.2 Innovation Mechanisms in Construction 235
7.2.1 Innovation by Production Technology 235
7.2.2 Innovation by Modularity 235
7.2.3 Innovation by Performance 236
7.2.4 Innovation by Technology Transfer 236
7.2.5 Innovation by Transformation 237
7.2.6 Innovation by Overlay 238
7.2.7 Innovation by Customer 238
7.3 Realizing Innovation in Construction by 7-Dimensional View 239
7.4 Examples for Application of the Proposed Methodology 241
7.5 Reverse Innovation – Using the Construction Industry as an Incubator for Future Manufacturing Systems 241
7.5.1 Current Strategy of Automation and Robot Technology Providers 244
7.5.2 The Idea of Reverse Innovation 245
7.5.3 Advanced Approaches to Be Re-transferred from Automated Off-/On-Site Construction 246
7.6 Concept of Life-Cycle Integrated Manufacturing Technology 253

**8 Competitive Advantage by Co-adapted Expansion of Products and Manufacturing Systems** . . . . . 256

*References* 261

*Index* 275

© in this web service Cambridge University Press www.cambridge.org