LIST OF FIGURES

Chapter 1  Introduction

Fig.1.1.  System costs versus maintenance strategy  5
Fig.1.2.  Decomposition of Fuzzy system  6

Chapter 2.  Machine, Fault and Fault Diagnosis

Fig.2.1.  Jacquard looms in the factory Gevers and Schmidt in Schmiedeberg (Deutsches Museum, Munchen)  32
Fig.2.2.  Warp and Weft  34
Fig.2.3.  Rapier weaving machine  36
Fig.2.4.  Air jet weaving machine mechanism  38
Fig.2.5.  Typical Bathtub curve  41
Fig.2.6.  Time dependency of faults: (a) abrupt (b) incipient (c) intermittent  45
Fig.2.7.  Basic fault models: (a) Additive fault for an output signal, (b) Multiplicative fault  46
Fig.2.8.  Overall Concepts of Fault Diagnosis System  47
Fig.2.9.  Time vs. estimated capacity and actual load (run-to-failure maintenance)  49
Fig.2.10.  Time vs. estimated capacity and actual load (Scheduled Maintenance)  50
Fig.2.11.  Time vs. estimated capacity and actual load (Condition-Based Maintenance)  52
Fig.2.12.  Conditioning Base Maintenance (CBM)  53
Fig.2.13.  Fault Detection methods  56
Fig.2.14.  General Scheme for Fault Detection and Fault Diagnosis  57
Fig.2.15.  Fault-Symptom Relationship: (a) Physical System: From Fault to Symptoms (b) Diagnosis System: From Symptoms to Faults  60
Fig.2.16.  Fault Diagnosis Methods  61
Fig.2.17.  Signal flow of fault detection, fault diagnosis and fault management  62
Chapter 3. Modeling of Fault Detection and Fuzzy Diagnosis

Fig.3.1. Modeling, Fault Detection and Fuzzy Diagnosis 75
Fig.3.2. Motor Fault Tree 76
Fig.3.3. Motor Condition Status 77
Fig.3.4. Motor Condition determination Setup Layout 78
Fig.3.5. FIS to Determine Motor Status 80
Fig.3.6. Membership functions of Motor Condition 81
Fig.3.7. Membership functions of Stator Currents: $I_a$, $I_b$, and $I_c$ 81
Fig.3.8. Simulink Model for Motor Condition determination 85
Fig.3.9. Rule viewer for Good condition 87
Fig.3.10. Rule viewer for Phase open 88
Fig.3.11. Rule viewer for Input Unbalanced Input Voltage 89
Fig.3.12. Rule viewer for Good Condition using five rules 89
Fig.3.13. Rule viewer for Phase open using five rules 90
Fig.3.14. Rule viewer for Overload using five rules 90
Fig.3.15. Surface View of Motor Condition FIS for 23 rules 91
Fig.3.16. Surface View of Motor Condition FIS for five rules 92
Fig.3.17. Environmental parameter sensing scheme 101
Fig.3.18. FIS of Environment 107
Fig.3.19. Membership functions of Temperature, Humidity and Environment Condition 108
Fig.3.20. Rule Viewer of Environment Condition 109
Fig.3.21. Environment surface view 110
Fig.3.22. Simulink Model for Environment Condition determination with constant 111
Fig.3.23. Simulink Model for Environment Condition determination with constant Humidity 111
Fig.3.24. Simulink Model for Environment Condition 112
Industrial Fault Detection And Fuzzy Diagnosis System for Textile Industry

determination with variable input

Fig.3.25. FIS of Oil tank unit 114
Fig.3.26. Membership functions of Oil Tank unit 115
Fig.3.27. Rule Viewer for Bad Oil tank unit 117
Fig.3.28. Rule base viewer for Good Oil tank unit 117
Fig.3.29. Surface view of Oil tank 118
Fig.3.30. Block Diagram of Liquid Level System 118
Fig.3.31. Liquid level Process 119
Fig.3.32. Schematic of Oil Tank level Model 121
Fig.3.33. Simulink Model for Oil tank unit with pressure constant 122
Fig.3.34. Simulink Model for Oil tank unit with quantity constant 122
Fig.3.35. Simulink Model for Oil tank unit with variable input 122
Fig.3.36. Machine Health status 123
Fig.3.37. FIS Machine Health determination 123
Fig.3.38. FLC for Machine Health determination 124

Chapter 4 Hardware Implementation of Fault Detection and Fuzzy Diagnosis

Fig.4.1. Overview of Fault Diagnosis System for Textile Industry 129
Fig.4.2. General Block Diagram of Fault collection unit 132
Fig.4.3. Block Diagram of Environment Fault 133
Fig.4.4. Circuit Diagram of Environment Fault Collection Unit 138
Fig.4.5. Block Diagram of Motor Fault Collection Unit 140
Fig.4.6. Current Transformer 142
Fig.4.7. Rogowski Coil current 143
Fig.4.8. Ideal model of VT. Resistance of winding and non-linearity of core have not been considered 145
Fig.4.9. Circuit Diagram of Motor Fault Collection Unit 147
Fig.4.10. Block Diagram of Oil Tank Fault Collection 148
Fig.4.11. Pressure Transmitter 151
Fig.4.12. Float Level Sensor 152
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fig.4.13</td>
<td>Circuit Diagram of Oil Tank Other Fault collection</td>
<td>153</td>
</tr>
<tr>
<td>Fig.4.14</td>
<td>Block Diagram of Other Fault Collection Unit</td>
<td>154</td>
</tr>
<tr>
<td>Fig.4.15</td>
<td>Stop mechanism with optical sensor; (a) Work Position, (b) Yarn Breakage Position, (c) Out Position</td>
<td>155</td>
</tr>
<tr>
<td>Fig.4.16</td>
<td>Yarn Break Detection (Optical) Sensor</td>
<td>155</td>
</tr>
<tr>
<td>Fig.4.17</td>
<td>Circuit Diagram of Digital Fault Collection Unit</td>
<td>157</td>
</tr>
<tr>
<td>Fig.4.18</td>
<td>Flowchart of the Sensor Unit</td>
<td>158</td>
</tr>
<tr>
<td>Fig.4.19</td>
<td>Block Diagram of Central unit</td>
<td>159</td>
</tr>
<tr>
<td>Fig.4.20</td>
<td>Circuit Diagram of Central Unit</td>
<td>160</td>
</tr>
<tr>
<td>Fig.4.21</td>
<td>Flowchart of the Central Unit</td>
<td>161</td>
</tr>
<tr>
<td>Fig.4.22</td>
<td>CAN node with integrated CAN module</td>
<td>162</td>
</tr>
<tr>
<td>Fig.4.23</td>
<td>Block diagram of the CAN Communication</td>
<td>162</td>
</tr>
<tr>
<td>Fig.4.24</td>
<td>Interfacing Microcontroller with MCP2551</td>
<td>163</td>
</tr>
<tr>
<td>Fig.4.25</td>
<td>Circuit diagram of the CAN Communication between two different nodes</td>
<td>164</td>
</tr>
<tr>
<td>Fig.4.26</td>
<td>Experimental setup for Measurement of Motor Parameters</td>
<td>165</td>
</tr>
<tr>
<td>Fig.4.27</td>
<td>Experimental System Test setup</td>
<td>166</td>
</tr>
<tr>
<td>Fig.4.28</td>
<td>GUI Main window</td>
<td>167</td>
</tr>
<tr>
<td>Fig.4.29</td>
<td>GUI of Weaving Section</td>
<td>168</td>
</tr>
<tr>
<td>Fig.4.30</td>
<td>GUI of Motor Condition</td>
<td>169</td>
</tr>
<tr>
<td>Fig.4.31</td>
<td>GUI of Environment Condition</td>
<td>170</td>
</tr>
<tr>
<td>Fig.4.32</td>
<td>GUI of Oil Tank condition</td>
<td>171</td>
</tr>
<tr>
<td>Fig.4.33</td>
<td>GUI of Emergency Faults</td>
<td>172</td>
</tr>
</tbody>
</table>

**Chapter 5. Results and Conclusions**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fig.5.1</td>
<td>Simulink Model for Motor Status determination</td>
<td>179</td>
</tr>
<tr>
<td>Fig.5.2</td>
<td>Waveforms Normal Mode Operation of Motor</td>
<td>180</td>
</tr>
<tr>
<td>Fig.5.3</td>
<td>Waveforms for Unbalanced input voltage</td>
<td>181</td>
</tr>
<tr>
<td>Fig.5.4</td>
<td>Waveforms for Open Phase Motor Condition</td>
<td>182</td>
</tr>
<tr>
<td>Fig.5.5</td>
<td>Waveforms of Current of Motor with no load</td>
<td>184</td>
</tr>
<tr>
<td>Fig.5.6</td>
<td>Waveforms of Current of Motor with load</td>
<td>184</td>
</tr>
</tbody>
</table>
Fig. 5.7. Waveforms of Current of Motor with Overload
Fig. 5.8. Waveforms of Current of Motor with Critically Overload
Fig. 5.9. Simulink Model for Environment condition determination with constant temperature
Fig. 5.10. Simulation results with Temperature constant for Environment determination
Fig. 5.11. Simulink Model for Environment Condition determination with constant Humidity
Fig. 5.12. Simulation results with Humidity constant for Environment determination
Fig. 5.13. Simulink Model for Environment Condition determination with variable input
Fig. 5.14. Modeling Results for Environment determination with Variable Environment Parameters
Fig. 5.15. Waveforms for Environment Condition set 1
Fig. 5.16. Waveforms for Environment Condition set 2
Fig. 5.17. Schematic of Simulink Model to study the response of Oil Tank Level model
Fig. 5.18. Step response of Oil Tank Level Model
Fig. 5.19. Response of Oil Tank Level Model at Random Input for qi Signal, a) Inflow Control Signal, b) Corresponding Level
Fig. 5.20. Simulink Model for Oil tank unit with pressure constant
Fig. 5.21. Simulation results for Oil Tank with Constant Pressure
Fig. 5.22. Simulink Model for Oil tank unit with quantity constant
Fig. 5.23. Simulation results of Oil Tank with Optimal Oil Quantity
Fig. 5.24. Simulink Model for Oil Tank unit with variable input
Fig. 5.25. Simulation results of Oil Tank with Variable Oil Quantity and Pressure
Fig. 5.26. Simulink Model of Machine Health with Constant Environment Parameter
Fig. 5.27. Simulation results for Machine Health with Constant Environment Parameter
Fig. 5.28. Simulink Model of Machine Health with Constant Motor Condition Parameter

Fig. 5.29. Simulation results for Machine Health with Constant Motor Condition Parameter

Fig. 5.30. Simulink Model of Machine Health with Constant Oil Tank Parameter

Fig. 5.31. Simulation results for Machine Health with Constant Oil Tank Parameter

Fig. 5.32. Simulink Model of Machine Health with Constant Emergency Parameters

Fig. 5.33. Simulation results for Machine Health with Constant Emergency Parameters

Fig. 5.34. Simulink Model of Machine Health with Variable Parameters

Fig. 5.35. Simulation results for Machine Health with Variable Parameters