CHAPTER 7

REAL TIME TEXTILE EFFLUENT ANALYSIS USING HEURISTIC CONTROLLERS

In this chapter, the proposed heuristic algorithm based BFO-PI and FA-PI controllers are implemented to control the pH of textile wastewater samples. The textile wastewater samples are collected from wastewater treatment plant of Madhura Dyeing located at Erode, Tamil Nadu, India. The performances of proposed controllers are validated against the GA-PI and PSO-PI controller.

7.1 COLLECTION OF SAMPLES

The importance of pH control in the wastewater treatment process during various stages is explained in chapter 3. A wide pH variation in the effluent is observed during the study of wastewater treatment process. The presence of various chemical compositions in the effluent is a major factor for the variation of the pH. In this research work, samples are collected at the following stages of the treatment process.

- Feed water to the coagulation in the primary treatment process.
- Feed water to the Aerated lagoon tank in the secondary treatment process.
The pH of the wastewater at the above stages is measured in the period of three months at the regular intervals. Table 7.1 presents the pH range of the effluent at the above stages. In this, the raw effluent sample is collected from the equalization tank in the primary treatment process.

Table 7.1 Characteristics of wastewater pH at different stages

<table>
<thead>
<tr>
<th>Feed to Coagulation Process</th>
<th>Feed to Aerated Lagoon</th>
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</thead>
<tbody>
<tr>
<td>9 – 12.9 pH</td>
<td>8 – 9 pH</td>
</tr>
</tbody>
</table>

7.2 PERFORMANCE ANALYSIS OF HEURISTIC-BASED CONTROLLERS WITH EFFLUENT

The performance analysis of heuristic algorithm based GA-PI, PSO-PI, BFO-PI and FA-PI controllers are investigated to control the pH of textile industry effluent.

7.2.1 pH Control at Coagulation Process

In the coagulation process, ferric chloride is added as coagulant with effluent in the wastewater treatment plant of Madhura Dyeing, Erode. This coagulant has positive charges. The positive charges of the coagulant react with the negative charge of dissolved and suspended particles of the effluent and make them neutralized. This neutralization process, bind together the small suspended particles to form large particles. These large particles are called as floc and settled down quickly at the bottom tank. The consecutive sedimentation process removes the settled particles. The Equation 7.1 describes the reaction between the Calcium Bicarbonate presented in the effluent and Ferric Chloride.
The effective performance of the coagulation process is obtained at the optimum pH of 11. The value of the pH of the effluent is treated as an important parameter in the coagulation process because it controls hydrolysis species. Large quantities of soluble species are formed, when the coagulant ferric chloride is added in the effluent. Based on the pH value, hydrolysis species has positive or negative charges. When the pH is low, hydrolysis species are positively charged. The positively charged hydrolysis species are destabilized the colloidal particles by neutralization of the surface charge. This process makes the particles adhere to each other to form a large size of particles and settle due to gravity. This method is called as ‘charge neutralization’. Due to time consuming and less effectiveness, the method is not preferred in many water treatment plants.

In the alternative high pH method is called as ‘sweep-floc coagulation.’ In this coagulation process, the created ferric hydroxide is physically sweeping the colloidal particles from the suspension (Kim et al 2001). In the wastewater treatment plant of Madhura Dyeing, the coagulation process is carried out at pH 11 due to the merits of sweep-floc coagulation method in COD removal. Also, the literature study indicated that COD removal efficiency is high at the pH is 11 when the FeCl₃ is used as a coagulant (Aygun & Yilmaz 2010).

Hence, when the pH of the effluent is above 11, it is required to reduce and maintain the pH at 11 to improve the effectiveness of the coagulation process. In this study, the flow rate of a strong acid (HCl with
0.1 N) is controlled through the control valve CV-1 using PI controller. The flow rate of effluent to the process tank is fixed at 0.5 lpm through the control valve CV-2. The study has been conducted to control the pH of the effluent at 11 using GA, PSO, BFO and FA based PI controller for the collected two samples of effluent. The performances of the controllers are shown in Figures (7.1–7.4) for the sample 1.

**Figure 7.1** Performance of GA-PI controller for the sample-1 at the operating point of pH-11

**Figure 7.2** Performance of PSO-PI controller for the sample-1 at the operating point of pH-11
Figures (7.1-7.4) indicate that GA and PSO based controllers have more oscillatory response than the proposed BFO and FA controllers. Also, the figures reveal that the FA-PI controller is accurately maintaining the setpoint when compared with other controllers. The error indices such as IAE and ISE are used for performance measure of the controllers. Table 7.2 indicates the performance of the controllers at the operating point 11. The table exposes the better controller efficiency of FA-PI, because it has registered the lowest IAE (193.68) and ISE (66.04) when compared to the other controllers.
Table 7.2  Performance indices of controllers at the operating point of pH-11 of the effluent sample 1

<table>
<thead>
<tr>
<th>Controller Type</th>
<th>IAE</th>
<th>ISE</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA-PI</td>
<td>1184.14</td>
<td>741.44</td>
</tr>
<tr>
<td>PSO-PI</td>
<td>1014.65</td>
<td>510.68</td>
</tr>
<tr>
<td>BFO-PI</td>
<td>416.40</td>
<td>113.31</td>
</tr>
<tr>
<td>FA-PI</td>
<td>193.68</td>
<td>66.04</td>
</tr>
</tbody>
</table>

The performances of the controllers for the sample 2 at the operating point pH 11 are shown in Figures (7.5 – 7.8)

Figure 7.5  Performance of GA-PI controller for the sample-2 at the operating point of pH-11

Figure 7.6  Performance of PSO-PI controller for the sample-2 at the operating point of pH-11
Figure 7.7  Performance of BFO-PI controller for the sample-2 at the operating point of pH-11

Figure 7.8  Performance of FA-PI controller for the sample-2 at the operating point of pH-11

Table 7.3  Performance indices of controllers at the operating point of pH-11 of the effluent sample-2

<table>
<thead>
<tr>
<th>Controller Type</th>
<th>IAE</th>
<th>ISE</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA-PI</td>
<td>1283.79</td>
<td>795.80</td>
</tr>
<tr>
<td>PSO-PI</td>
<td>934.62</td>
<td>421.90</td>
</tr>
<tr>
<td>BFO-PI</td>
<td>377.84</td>
<td>78.76</td>
</tr>
<tr>
<td>FA-PI</td>
<td>181.73</td>
<td>43.50</td>
</tr>
</tbody>
</table>
Table 7.3 presents the performance indices of controllers at the operating point of pH-11 of the effluent sample 2. Table 7.3 has confirmed the better performance of the FA based controller against the other controllers such as GA, PSO and BFO at the operating point of pH-11.

7.2.2 pH Control at Biological Process

The aerated lagoons store the wastewater for 2 to 6 days for the biological treatment process. The aerator has the inlet facility for the entry of wastewater at one end and outlet facility at another end for the exit flow of effluent after the period of retention. The mechanical aerators in the lagoons are maintaining the aerobic environment as well as it prevents the settling of the suspend biomass. The high rate of organic degradation is obtained due to the function of the aerators. The sufficient population of microorganisms consume the dissolved organic as food and degrade the organic matters of the wastewater. The optimum population of microorganisms is obtained by maintaining the suitable atmosphere in the lagoon. The main factors decide the enhancements of high-density microorganisms are dissolved oxygen, temperature and pH of the effluent. The mechanical aerators provide the sufficient dissolved oxygen to the microorganisms. The temperature of the effluent has been reduced in the equalization process of the primary treatment. Hence, it is necessary to maintain the pH between 6.8 and 7.4 in the wastewater to ensure the sufficient population of the microorganisms.

The study is conducted to maintain the pH of the effluent at 7 using various heuristic based controllers for two samples collected from wastewater treatment plant of Madhura Dyeing. The effluent has been collected from the inlet of the aerated lagoon for the investigation. Figures (7.9-7.12) show the performance of heuristic based controllers at the operating point of pH 7.
Figure 7.9  Performance of GA-PI controller at the operating point of pH-7 of sample-1

Figure 7.10  Performance of PSO-PI controller at the operating point of pH-7 of sample-1

Figure 7.11  Performance of BFO-PI controller at the operating point of pH-7 of sample-1
Figures (7.9-7.12) indicated that the proposed BFO and FA based PI controllers outperform the GA and PSO based PI controller in the process of pH control. Table 7.4 confirms the superior functionality of the FA based PI controller with lowest error indices at the operating point pH-7. The error indices IAE and ISE values are 162.75 and 44.50 respectively for the FA based PI controller.

**Table 7.4 Performance indices of controllers at the operating point of pH-7 of the effluent sample-1**

<table>
<thead>
<tr>
<th>Controller Type</th>
<th>IAE</th>
<th>ISE</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA-PI</td>
<td>625.04</td>
<td>381.88</td>
</tr>
<tr>
<td>PSO-PI</td>
<td>467.54</td>
<td>237.30</td>
</tr>
<tr>
<td>BFO-PI</td>
<td>294.61</td>
<td>97.97</td>
</tr>
<tr>
<td>FA-PI</td>
<td>162.75</td>
<td>44.50</td>
</tr>
</tbody>
</table>

The performances of the controllers for the sample 2 at the operating point pH 7 are shown in Figures (7.13-7.16)
Figure 7.13 Performance of GA-PI controller at the operating point of pH-7 of sample-2

Figure 7.14 Performance of PSO-PI controller at the operating point of pH-7 of sample-2

Figure 7.15 Performance of BFO-PI controller at the operating point of pH-7 of sample-2
Figures (7.12-7.16) have confirmed the best performance of the FA based PI controller at the operating point pH-7. Table 7.5 presents the performance indices of controllers at the operating point of pH-7 of the effluent sample 2. Table 7.5 shows the superior controller capability of the FA based controller against the other controllers such as GA, PSO and BFO in controlling pH of the effluent at the operating point of pH-7.

Table 7.5  Performance indices of controllers at the operating point of pH-7 of the effluent sample-2

<table>
<thead>
<tr>
<th>Controller Type</th>
<th>IAE</th>
<th>ISE</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA-PI</td>
<td>577.35</td>
<td>361.23</td>
</tr>
<tr>
<td>PSO-PI</td>
<td>478.06</td>
<td>244.49</td>
</tr>
<tr>
<td>BFO-PI</td>
<td>271.81</td>
<td>80.14</td>
</tr>
<tr>
<td>FA-PI</td>
<td>161.82</td>
<td>34.22</td>
</tr>
</tbody>
</table>
7.3 SUMMARY

The heuristic algorithm based GA-PI, PSO-PI, BFO-PI and FA-PI controllers have been implemented to control the pH of the textile industry effluent. The effluent samples have been collected in the coagulation process and biological treatment process. The performance measures of controllers have been computed using the error indices such as IAE and ISE. The investigation indicated that the FA-PI controller provided better results among the selected heuristic controllers in controlling the pH of the textile industry effluent.