Computer Aided Analysis of Rotating Equipment Availability in Petrochemical Carbon Black Plant

Andrew Jewo

Abstract—High availability of industrial plant could only be achieved by adopting best global maintenance practices (computer software). In this research work, a software module was developed using programming tools such as Visual Basic (V.B) 6.0, Structured Query Language (SQL) and Microsoft Access. Operational data were collected from Warri Refinery and Petrochemical Company and was input into the developed software to analyze the plant availability. The performance test results obtained by the software for a five-year period (2009-2013) showed that the software developed is consistently close to 100% accuracy. The output result indicates that the plant availability in 2009 is 9.59%; 2010 is 5.75%; 2011 is 7.12%; 2012 is 1.64% and 2013 is 6.30%. This highly fluctuating and low availability of raw material, inadequate maintenance strategies, aging plant and equipment, lack of spare parts stock for preventive and corrective maintenance for emergency, lack of standby (backup) equipment and utility constraints. It was observed that the aforementioned reasons invariably resulted to constant failure of plant availability could greatly be improved by adopting best global maintenance practices which include the deployment of appropriate software tools.

Index Terms—Software Module; Rotating Equipment; Availability; Petrochemical Carbon Black Plant; Industry.

I. INTRODUCTION

In the present time of automation and modernization, software would be developed for setting up of production plants like carbon black plant, but it involves a huge capital investment, for the long term operation and planning of production, effective reliability analysis and assessment is the crucial factors to be observed. Existing research works show the analysis that generally helps in design improvement of system for minimum failure under given operating conditions [1]-[2]. Besides, existing studies equally highlighted the main factors for component degradation to include corrosion, wear, crack and fatigue [3]. Thus, availability analyses play a key role in production plant and have been effectively applied to enhance system performance [4]. The long run availability analysis of a production plant can help its management to understand the effects of increasing or decreasing the repair and failure rates of a particular component or subsystem on the overall availability of the system [5]. To achieve long run availability, the units should remain operative for the maximum possible duration. Hence, to achieve high productivity and good quality, there should be high system availability effective management of maintenance [6]. Availability is a metric that combines the concepts of reliability and maintainability; it gives the probability of a unit being available not broken and not undergoing repair but can be called upon for use [7]-[8]. Industries that rely on certain key process of equipment have a powerful interest in being able to model and track the availability of these machines. But, the failure can be minimized implementing effective maintenance strategy. In this line, availability can be defined as a measure of the degree to which a system, subsystem or equipment is in a specified operable and committable state at the start of a mission, when the mission is called for an unknown (a random) time. Also, availability can be expressed as the proportion of time a system is in functioning condition. More so, the re-used of the old unit after repairs is most mandatory because replacement by a new unit is the most expensive. To do the manufacturers of repairable system, whose customers will have a major interest in the availability of the products they are buying.

The task of analyzing equipment availability manually can be very hectic and laborious especially when the plants equipment is many, thus, the development of a software that can efficiently compute given data would assist greatly in ameliorating the efforts and possible errors that could occur when the analysis is done manually. Besides, the software developed can be used in determining the availability of the rotating equipment so as to enhance the maintenance strategy of the company by minimizing maintenance backlog. The research work is aimed at the development of a module for analyzing rotating equipment availability in Petrochemical Carbon Black Plant, a case study of Warri Refinery Petrochemical Company (WRPC), Nigeria.

II. MATERIALS AND METHODS

A. Data Collection

The data for this project work were obtained from the carbon black plant in Warri Refinery and Petrochemical Company by means of a sample questionnaire. The data collected spans from 2009 to 2013 and are of two classes

i. Operational data method

ii. Maintenance data method

The operational data method comprises the operation time, downtime, utility downtime and annual failure, while maintenance data method comprises downtime and annual failure.

B. Development of a Software Module

Visual Basic software for analysis of rotating equipment availability in Petrochemical Carbon Black Plant (Area) was developed. For the development of the area, an appropriate software tools such as Visual Basic (V.B) 6.0,
including Structured Query Language (SQL) and Microsoft Access were used. This is done to ensure that the system will support good interface facilities with external programs systems. The area was designed in such a way that the user interacts with the system through a series of input and dialogue forms. The forms permit the user to select required data from a predefined list. The user enters only the values of data of the problem and the system automatically generate the required result on the user interface. It also provides a user friendly interface consisting of menu bars and buttons to help user during data input to the system and facilitates the explicit dictation, play results, in addition, background colours, font sizes and form colours were carefully chosen to enhance the visual effect of the interfaces. Table I shows the carbon black plant downtime data between 2009-2013

<table>
<thead>
<tr>
<th>MONTH</th>
<th>JAN</th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
<th>JUL</th>
<th>AUG</th>
<th>SEPT</th>
<th>OCT</th>
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<td>INST AIR</td>
<td>EQ. FAIL</td>
<td>EQ. FAIL</td>
<td>UT.C</td>
<td>INST FAIL</td>
<td>SCH. MT</td>
<td>SCH. MT</td>
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<td>31</td>
<td>30</td>
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<td>LA</td>
<td>LA</td>
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<td>29</td>
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<td>28</td>
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<tr>
<td>Reasons</td>
<td>S/D</td>
<td>S/D</td>
<td>EQ. FAIL</td>
<td>EQ. FAIL</td>
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C. Data Analysis

The data presented in Table I were analyzed to determine the operating time, annual downtime, utility downtime and annual failure. Equations (1)-(4) were used to determine the relevant parameters for the period of 2009 to 2013.

Annual Downtime = ((EQ FAIL + LA + UT.C + UL.C + SCH.MT + SCH.S/D + INST.AIR FAIL) x 24) Hours

(1)

Utility Downtime = ((UT.C + UL.C + A.I) x 24) Hours

(2)

Uptime = (Number of days in a year * 24) – (Annual Downtime) Hours

(3)

Annual failure = (Annual Downtime + Utility Downtime) Hours

(4)

Also, EQ.FAIL, INST.AIR, SCH.MT, UT.C, UL.C, S/D, and I.A were determined by summing the downtime of equipment for each year.

In the year, 2009

EQ. FAIL = 25 + 22 + 18 = 65
INST AIR = 21 + 30 = 51
SCH.MT = 31 + 31 + 30 + 30 + 31 + 31 = 184
UT.C = 30; UL.C = 0 S/D = 0; I.A = 0
Annual Downtime = (65 + 51 + 184 + 30 + 0 + 0) x 24 = 7920 hours
Utility Downtime = (30 + 0 + 0) x 24 = 720 hours

Operating Time = (365 x 24) – 7920 = 840 hours
Annual failure = 7920 + 720 = 8640 hours

In the year, 2012

SCH.MT = 31 + 29 + 31 + 30 + 31 + 30 + 31 = 213
UT.C = 0; UL.C = 0 S/D = 0; I.A = 30 + 31 = 61
Annual Downtime = (85 + 0 + 213 + 0 + 0 + 61) x 24 = 8616 hours
Utility Downtime = (0 + 0 + 61) x 24 = 1464 hours
Operating Time = (365 x 24) – 8616 = 144 hours
Annual failure = 8616 + 1464 = 10080 hours

In the year, 2013

EQ.FAIL = 30 + 30 + 27 + 23 + 27 + 29 + 28 + 28 = 222
INST AIR = 0; SCH.MT = 0; UT.C = 0; UL.C = 0
S/D = 31 + 28 + 31 + 30 = 120; I.A = 0
Annual Downtime = (222 + 0 + 0 + 0 + 120) x 24 = 8208 hours
Utility Downtime = (0 + 0 + 0) x 24 = 0 hours
Operating Time = (365 x 24) – 8208 = 552 hours
Annual failure = 8208 + 0 = 8208 hours

D. Availability Analysis

To determine the operational availability of the carbon black plant, the operating annual downtime and the utility downtime were calculated as shown below.

In the year, 2009

Annual uptime = 840 hrs.; Annual downtime = 7920 hrs.

\[
\text{availability} = \frac{840}{840 + 7920} = 9.6\%
\]
In the year, 2010
Annual uptime = 504 hrs., Annual downtime = 8256 hrs.
\[
\frac{504}{504+8256} \times 100 = 5.8\%
\]

In the year, 2011
Annual uptime = 624 hrs., Annual downtime = 8136 hrs.
\[
\frac{624}{624+8136} \times 100 = 7.1\%
\]

In the year, 2012
Annual uptime = 168 hrs., Annual downtime = 8616 hrs.
\[
\frac{168}{168+8616} \times 100 = 1.9\%
\]

In the year, 2013
Annual uptime = 552 hrs., Annual downtime = 8208 hrs.
\[
\frac{552}{552+8208} \times 100 = 6.3\%
\]

E. Development of Flow Chart

A flowchart is a diagrammatical representation that illustrates the sequence of operation to be performed to enable to get the solution of a problem. Flowcharts are generally drawn in the early stages of formulating computer solutions by the user of standard symbols which are in form of rectangle; circle, diamond etc. They are usually connected by arrows which indicate the order in which the system is being developed. The flowchart shown in Fig. 1 is the model on which the Analysis of Rotating Equipment Availability System Software were built.

![Flowchart for Software Development](image)

F. Development of Algorithm for Analysis of Rotating Equipment Availability Module

An algorithm is a specific set of instruction for carrying out a procedure of solving problem, usually with the requirement that the procedure terminate at some point. The algorithm developed for the Analysis of Rotating Equipment Availability Module is based on the flow chart and consists of the sequence of determining the operational result.

The steps involved are as follows:

1. Start
2. Enter password

- 30 - Is password correct?
- 40 - If yes, display main menu screen, Else Go to 20
- 50 - Enter range of years
- 60 - Input operation data
- 70 - Input operation time (hours)
- 80 - Input annual down time (hour)
- 90 - Input utility down time (hours)
- 100 - Input annual failure (hours)
- 110 - Input maintenance data (hours)
- 120 - End
G. Coding of the Software Module

In the development of the Analysis of Rotating Equipment Availability (AREA) software, a modular approach has been adopted to ensure great flexibility in updating or adding modules in the future. Thus, active liaison with end user and software programmer has been carried out at all stages of the system development. When the Analysis for Rotating Equipment icon is selected from the desktop, the login page is displayed and the user is prompted to enter username and password as shown Fig. 2. Correct entry of username and password takes the user to the main window shown in Fig. 3. Otherwise, the user is alerted of invalid password as shown in Fig. 4.

The main window consists of two buttons which activate appropriate interface that allows the user to interact with the AREA and access desired report. The users select their enquiries from the system through command boxes, list boxes and text boxes. The system processes the information stored in the data base and generate appropriate reports on the screen. The various dialogue boxes are of the software are shown in Fig. 5 to Fig. 7, containing information that provide directives for running the AREA and their functions are presented as shown.

![Fig. 2. Screen shot for User Login](image1)

![Fig. 3. Screen Shot of Main page](image2)

![Fig. 4. Screen Shot Showing Invalid Password Entry](image3)

![Fig. 5. Screen Shot of Dialogue Box for Entering Range of years](image4)

![Fig. 6. Screen shot of Dialogue Box for Updating Range of Years](image5)

![Fig. 7. Screen shot of Dialogue box for Data Entry (2009)](image6)

III. RESULTS AND DISCUSSION

The collected data from the petrochemical carbon black plant on the operating time, annual downtime, utility downtime and annual failure of the rotating equipment are computed to obtained the availability of the plant. The result obtained from the computations were used to plots graphs, which actually show the operating time, downtime and
availability of the entire plant. Table II indicates the total availability of rotating equipment used in the carbon black plant with accordance annual operation time and annual down time from 2009 to 2013. On the other hand, Fig. 8 shows the annual operating time of rotating equipment. From the graph in Fig. 8, it can be observed that, in 2009, the operating time was 840 hrs. and was the highest operating time under periods considered. In 2010, it dropped to 504 hours and in 2011, operating time increased from 504 hours to 624 hours. However, in 2012, the operating time experienced relatively steep drop, but that was not the case in 2013, there was a sharp increase from 144 hours of the preceding year to 552 hours and this was due to the high annual down time of the plant. Fig. 9 shows the plot trend of down time for 5 years. The results obtained show that in 2009, the down time was 7920 hours, while it increased to 8256 in 2010. However, from the year 2011 to 2012, there was a down time was that fluctuated between 8136 hours. In same line, 2012 had the highest down time of 8616 hours within the period under consideration. The down time of the plant indicates that the plant witness equipment and instrument failure, scheduled maintenance and shut down as well as haulage constraint. Fig. 10 shows the plot trend of the plant annual availability. In Fig. 10, it was observed that the plant availability fluctuated between 1.9 and 9.6 and the plant witnessed the highest availability in 2009 of 9.7%. Nevertheless, in 2012, the lowest availability of 1.9% was recorded, and 2013 has a close availability of 5.8% and 6.3% respectively, while in 2011, the availability obtained was 7.1%. The low availability of the plant for the years under consideration could be attributed to be high down time experience in the plant.

### Table II: Result of Rotating Equipment Availability of 2009-2013

<table>
<thead>
<tr>
<th>Year</th>
<th>Operating Time (Hours)</th>
<th>Annual Down Time (Hours)</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>840</td>
<td>7920</td>
<td>9.589041095890410</td>
</tr>
<tr>
<td>2010</td>
<td>504</td>
<td>8256</td>
<td>5.7534246575342465</td>
</tr>
<tr>
<td>2011</td>
<td>624</td>
<td>8136</td>
<td>7.1232876712328768</td>
</tr>
<tr>
<td>2012</td>
<td>144</td>
<td>8616</td>
<td>1.6438356164383561</td>
</tr>
<tr>
<td>2013</td>
<td>552</td>
<td>8208</td>
<td>6.3013698630136989</td>
</tr>
</tbody>
</table>

Fig. 8. Plot of Annual Operating Time for Rotating Equipment

Fig. 9. Plot of Annual Down Time for Rotating Equipment

DOI: [http://dx.doi.org/10.24018/ejers.20118.3.12.996](http://dx.doi.org/10.24018/ejers.20118.3.12.996)
IV. CONCLUSION

The overall objective of the development of a software module for analysis of rotating equipment availability is to enhance the analysis of plant availability. In this study, operational data were collected from Warri, refinery and petrochemical company and was used to test the developed software to analyze the plant availability. The performance test results obtained by the software for a five years’ period (2009-2013) showed that the software developed is consistently close to 100% accuracy. The output result indicates a highly fluctuating and low availability of raw material, inadequate maintenance strategies, aging plant and equipment, lack of spare parts stock for preventive and corrective maintenance for emergency, lack of standby (backup) equipment and utility constraints. High availability of industrial plant could be enhanced by employing appropriate software tools in line with best global maintenance practice.

V. RECOMMENDATION

Having realized the aim and the objective of this project work, it is recommended that:

a. Further performance test be carried out using other production equipment in a laid industry such as a manufacturing company.

b. The software developed should be upgraded to accommodate more modules so as to enhance its versatility.

c. Government should support effort toward the computerization of industrial plant maintenance in line with global best practices.

REFERENCES


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