Reliability Analysis of Electro-Hydraulic Based Auto-Leveling System for Mobile Platform

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II. DESCRIPTION OF AUTO LEVELLING SYSTEM

The levelling of platform is done using four number of outrigger cylinders integrated on the vehicle platform. These outrigger actuators are operated through electro-hydraulic system consisting of proportional solenoid valves, which receives signals through level sensor and levelling algorithm. The hydraulic power required to operate outrigger cylinder is given through a hydraulic power pack. There are two pumps; one operates from vehicle Power Take-Off (PTO) and another through electric motor. The salient features of hydraulic systems are:

(i) Redundancy in hydraulic pump
(ii) Strainer in pump inlet
(iii) Filters in pressure and release valves
(iv) Off line filtration system with contamination monitor to reduce system failure due to oil contamination

This process continues till the platform is levelled with specific accuracy of + 6 min. The block diagram [2] of Auto Levelling system is shown in Fig. 1 and Hydraulic System in Fig. No. 2. The major system for Auto-levelling consists of following sub-systems & components:

(i) Hydraulic system to actuate outrigger cylinders:
   (a) Hydraulic power pack
   (b) Proportional Direction Control Valves
   (c) Outriggers, with pilot operated check valve

(ii) Control signal consists of power supply, software (algorithm) and hardware. This will supply the power to proportional valve for operation of outrigger cylinders.

(iii) Platform tilt angle indication system consists of level sensors, A/D converter and power supply. Two sensors have been used, one for longitudinal and other for lateral shift of the platform. Once the platform is levelled, the outrigger cylinder movement is locked using hydraulic motor driven mechanical sleeves to avoid creep of platform. Figure 1& 2 are shown in Appendix.

III. FAILURE MODE & EFFECT AND CRITICALITY ANALYSIS (FMECA) OF AUTO-LEVELLING SYSTEM

It is the first step for working of the system reliability analysis. During the analysis, the major components, sub-systems and assemblies are reviewed to identify various failure modes. The objective is to identify all possible failure modes, causes and effects of such failures. Such analysis which were done successfully for important projects, e.g. Chemical Mixing Equipment [3], RML

**A. Mean & Standard Deviation**

From the RPN values shown in Table 1 the mean & standard deviations worked out & shown in Table 2. From the Table 2, it is seen that mean value is 145 & Standard deviation is 46. The distribution of 13 nos RPN values, here, shows the extreme asymmetrical distribution. It is better to use median, instead of mean. This is done after arranging data in ascending order to take the mid value. In this case the median is 180, which could be taken as “Thresholding” value for determining the criticality of the system. All sub-systems having RPN value above 180 are hyper critical and their design or performance or both may be reviewed and necessary precautionary steps undertaken to make the overall system more reliable.

Assuming mission time for each element as 1 hour of continuous working, for \( \lambda_{T3} \) equation (1) is given as follows [11]

\[
\lambda_{T3} = \frac{\lambda_{T1}(Z_{T1} - 1) + \lambda_{T2}(Z_{T2} - 1)}{Z_{T1}Z_{T2} - 1} - - - - (1)
\]

\[
\frac{1}{Z_j} = (1 - e^{-\lambda_j}) \\
Z_{T1} = \frac{1}{(1 - e^{-0.22})} = 5.06 \\
Z_{T2} = \frac{1}{(1 - e^{-0.17})} = 6.40
\]

\[
\lambda_{T3} = \frac{0.022(4.06 - 1) + 0.017(5.40 - 1)}{5.06 \times 6.40 - 1} = 0.006 / hr
\]

\[
\lambda_{T7} = \lambda_{T3} + \lambda_{T4} + \lambda_{T6} = 0.046 / hr
\]

Following the same procedure \( \lambda_{T0} \) can be calculated as

\[
\lambda_{T0} = \lambda_{T7} + \lambda_{T8} + \lambda_{T9} = 0.070 / hr
\]

Hence, the overall failure rate of the system is 0.070/hr

Reliability of Auto-levelling system \( (R_{AL}) \) is obtained by following equation

\[
R_{AL} = e^{-0.07t}
\]

Assuming mission time for Auto-levelling is Maximum 3 Minutes (0.05 hr.) the reliability of system is obtained as

\[
R_{AL} = e^{-0.07 \times 0.05} = 0.99650
\]

Thus FMEA & FTA are the powerful tools for reliability analysis.
V. CONCLUSION

For carrying out the reliability analysis of Auto-Leveling system for Mobile Platform FMECA & FTA tools have been used & the result obtained during the trials show the high degree of viability with the theoretical analysis.

(i) The reliability of Auto-leveling system using FTA for mission time of 3 min is worked out 99.65%, which is very high for such complex system.

(ii) Oil contamination reduces the reliability. However, the reliability can be improved by proper control & monitoring of oil contamination.

(iii) FMEA determines all possible ways the equipment can fail & the effect of such failure on the system. It focuses on the part of which the system is comprised.

(iv) FTA determines the possible causes of the system failure and failure rate at various levels. It focuses on the total system failure and hence helps in finding reliability of system.

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REFERENCES


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APPENDIX

Fig.1. Block Diagram for Auto Levelling system for Mobile Platform
Fig. 2 Hydraulic System for Autolevelling

Table 1. FMEA for Auto-Levelling System
<table>
<thead>
<tr>
<th>Components/Systems</th>
<th>Function</th>
<th>Failure Mode</th>
<th>Effect of Failure</th>
<th>Causes of Failure</th>
<th>Occurrence of Failure</th>
<th>Severity</th>
<th>Detection</th>
<th>RPN</th>
<th>Corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor / P.T.O.</td>
<td>To operate the pump</td>
<td>Mal-functioning</td>
<td>Hydraulic Pump will not operate</td>
<td>Fluctuation in power supply/engine RPM</td>
<td>2</td>
<td>9</td>
<td>6</td>
<td>108</td>
<td>OK</td>
</tr>
<tr>
<td>Pump</td>
<td>Source of Hydraulic Power</td>
<td>Not delivering oil properly</td>
<td>Hydraulic System will not operate / Slow operation</td>
<td>High contaminati on level of oil</td>
<td>5</td>
<td>9</td>
<td>4</td>
<td>180</td>
<td>Providing monitoring of filter prior to oil in</td>
</tr>
<tr>
<td>Pressure line filter</td>
<td>To filter oil / remove contaminants</td>
<td>Oil supply irregular / stopped</td>
<td>Slow movement of outrigger cylinder</td>
<td>Clogging of filter due to contaminant of oil</td>
<td>4</td>
<td>9</td>
<td>5</td>
<td>180</td>
<td>To control and monitor oil contamination</td>
</tr>
<tr>
<td></td>
<td>To supply oil to outrigger cylinder</td>
<td>Oil supply irregular / stopped</td>
<td>No / Slow movement of outrigger cylinder</td>
<td>High contaminati on level of oil</td>
<td>5</td>
<td>9</td>
<td>4</td>
<td>180</td>
<td>To control and monitor oil contamination</td>
</tr>
<tr>
<td></td>
<td>No power supply</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>9</td>
<td>5</td>
<td>90</td>
<td>OK</td>
</tr>
<tr>
<td>Outrigger cylinder</td>
<td>To level the platform</td>
<td>No / Irregular oil supply</td>
<td>Levelling of platform not possible</td>
<td>Pilot operated valve not functioning</td>
<td>2</td>
<td>9</td>
<td>4</td>
<td>72</td>
<td>OK</td>
</tr>
<tr>
<td></td>
<td>Leakage through seals</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>8</td>
<td>6</td>
<td>144</td>
<td>Seals to be changed</td>
</tr>
<tr>
<td>Level sensor for Platform tilt angle</td>
<td>To indicate platform tilt angle</td>
<td>Malfunctioning</td>
<td>No proper levelling of platform</td>
<td>Improper power supply</td>
<td>3</td>
<td>9</td>
<td>7</td>
<td>189</td>
<td>Ensure proper power supply</td>
</tr>
<tr>
<td></td>
<td>Not functioning of A/D converter</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>9</td>
<td>7</td>
<td>189</td>
<td>Use ruggedized &amp; proven components</td>
</tr>
<tr>
<td>Control signals for proportional DC valve</td>
<td>To operate outrigger cylinder proportional to tilt angle of platform</td>
<td>Erratic signals / non signals</td>
<td>Valve will not function / properly function</td>
<td>Not functioning of D/A converter</td>
<td>3</td>
<td>9</td>
<td>7</td>
<td>189</td>
<td>Use ruggedized &amp; proven components</td>
</tr>
<tr>
<td></td>
<td>Software not functioning</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>9</td>
<td>7</td>
<td>189</td>
<td>Improve software &amp; do periodical checking</td>
</tr>
</tbody>
</table>

Table 2. Mean and Std. deviation Calculation Table For RPN

<table>
<thead>
<tr>
<th>S. No</th>
<th>RPN (Xi)</th>
<th>(X-Xi)</th>
<th>(X-Xi)^2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>108</td>
<td>-37</td>
<td>1369</td>
</tr>
<tr>
<td></td>
<td>Value</td>
<td>Deviation</td>
<td>Total</td>
</tr>
<tr>
<td>----</td>
<td>-------</td>
<td>-----------</td>
<td>---------</td>
</tr>
<tr>
<td>2</td>
<td>180</td>
<td>+35</td>
<td>1225</td>
</tr>
<tr>
<td>3</td>
<td>72</td>
<td>-73</td>
<td>5329</td>
</tr>
<tr>
<td>4</td>
<td>180</td>
<td>+35</td>
<td>1225</td>
</tr>
<tr>
<td>5</td>
<td>108</td>
<td>-37</td>
<td>1369</td>
</tr>
<tr>
<td>6</td>
<td>180</td>
<td>+35</td>
<td>1225</td>
</tr>
<tr>
<td>7</td>
<td>90</td>
<td>-55</td>
<td>3025</td>
</tr>
<tr>
<td>8</td>
<td>72</td>
<td>-73</td>
<td>5329</td>
</tr>
<tr>
<td>9</td>
<td>144</td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>189</td>
<td>+44</td>
<td>1936</td>
</tr>
<tr>
<td>11</td>
<td>189</td>
<td>+44</td>
<td>1936</td>
</tr>
<tr>
<td>12</td>
<td>189</td>
<td>+44</td>
<td>1936</td>
</tr>
<tr>
<td>13</td>
<td>189</td>
<td>+44</td>
<td>1936</td>
</tr>
<tr>
<td><strong>Σ</strong></td>
<td><strong>1890</strong></td>
<td></td>
<td><strong>Σ</strong> = <strong>27841</strong></td>
</tr>
<tr>
<td><strong>X</strong></td>
<td><strong>1890/13 = 145</strong></td>
<td></td>
<td><strong>σ = (ΣX^2)/N - X^2</strong></td>
</tr>
</tbody>
</table>

σ = 46.27

Fig 3. FTA for Auto-Levelling of Mobile Platform