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Design Concepts and Process Analysis for Transmutter Fuel Manufacturing

QUARTERLY PROGRESS REPORT #3
UNLV AFCI University Participation Program

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Date: July 1, 2005
Project Milestones

- A Hot Cell robotic assembly: Pick and place dynamic simulation, including feedback control with Matlab, for dispersion Fuel manufacture was developed further. We also started a systematic study seeking to arrive at an optimized plant configuration, using value engineering techniques.
- A conference paper summary was submitted for the ANS Winter meeting in November 2005. The paper was accepted with modifications

Value Engineering Analysis of Hot Cell Manufacturing Plant

Value Engineering (VE) is used to maximize the product of a process while utilizing the minimum amount of resources. In previous reporting periods a powder processing hot cell was designed and simulated. A VE study will be initiated for this work cell. A manipulator reliability study and a workspace study are performed in this work period. The above noted studies can be combined, and improvements can be made in the operations of the work cell.

1) Introduction

Value engineering is a vast field that encompasses many disciplines. Performing a value engineering study on a specific project requires the division of the project into different tasks. This division allows for the optimization of each task apart. Studying each task apart requires teams of engineers trained in different disciplines. The studies performed can be combined by a team of certified value engineers.

A VE study for the powder processing work cell is presented here. The functionality of the work cell can be divided into different subjects to be studied separately. Estimates of manipulator reliability and a workspace study are presented below.

The powder processing hot cell uses two robotic manipulators. A separate value analysis study is performed for each robot. The results will be combined later and recommendations to improve operations will be presented.

2) Manipulator Reliability

The robotic manipulator must be as safe and reliable as technically possible. The difficulties of applying robotics in a hot cell environment include limited access for service and maintenance, possible radiation damage to electronics and insulators, and abrasion damage to bearings and sliding surfaces, see [3]. Robots may contain electrical, mechanical, pneumatic, electronic and hydraulic parts. Their complexity compounds the reliability problem because of the many different sources of failures. According to [4], the best mean time between failures
(MTBF) achieved by robots is only 2,500 hours. There is definite room for further improvement in robot reliability, see [5].

Dhillon et al. [5] presented a Markov model, see [1], which allows the integration of robot reliability, safety, and probabilistic analyses. A basic system transition diagram for both the models is shown in Figure 1. It is assumed that the robot system is composed of a robotic manipulator and an associated safety system. The inclusion of safety systems with robots is widely practiced in the industry, and would be a necessity for manipulators operating in hot cells. Let $i$ be the state of the system (see Figure 1), then the probability that the robot system is in state $i$ can be expressed as $P_i(t)$. $\lambda_s$, $\lambda_r$, $\lambda_{ri}$, and $\lambda_{rs}$ are assumed to be constant failure rates.

Using the Markov approach, a system of initial-value differential equations defines the failure dynamics.

Figure 1 Basic Reliability Diagram

The reliability of the both robot and the safety system is denoted as $P_0(t)$ and $P_1(t)$, respectively. The reliability of the robot with safety system is the sum of both reliability values:

$$R_r = P_0(t) + P_1(t)$$

Figure 1 shows the reliability of the manipulator alone, and the reliability of the manipulator with the safety system added. The failure rates of the robotic system states are assumed to be constant. Their numerical values are expressed below:

<table>
<thead>
<tr>
<th>Failure Rate</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda_s$</td>
<td>0.0001</td>
</tr>
<tr>
<td>$\lambda_r$</td>
<td>0.0002</td>
</tr>
<tr>
<td>$\lambda_{ri}$</td>
<td>0.00005</td>
</tr>
<tr>
<td>$\lambda_{rs}$</td>
<td>0.00004</td>
</tr>
</tbody>
</table>
The failure rates listed above are common failure rates of industrial robots. Specific experience ratings for the Wäelischmiller TELBOT manipulator are not available.

References


