Applying STAMP/STPA to Analyze the Causes of the Unexpected Fire Happening at the Heat Treatment Process

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http://www.uvc.co.jp/
Unexpected Fire

It’s the 1st time after the equipment was adopted 10 years ago

Size of the door

W  1,500
L  220
H  1,300
Last year, there is an unexpected fire happening in the tempering furnace at our plant. According to the FTA analysis, we understand the cause is that the cleaning liquid, which is flammable, was brought into the furnace together with the work-pieces. And, when the volatilized flammable gas was close to the heater and heated up to the firing point, the fire was caused.
About the Accident

Stations of the production line

- Carburizing furnace
- Tempering furnace
- Vacuum Degreasing Machine
- Quenching Oil
- Cleaning liquid
- Alkali Washer

- Weak alkali liquid (harmless)
- Technology 40 years ago

※Before

- Petroleum-based liquid (≒heating oil)
- Adopted from 10 years ago
Here is the production line. After carburization, the quenching oil will stay on the work-piece. In order to remove the quenching liquid, the work-piece needs to be sent into the Vacuum Washer before it gets into the furnace.
Analysis and Countermeasure

Cause Analysis

The flammable cleaning liquid was heated up at the Carburizing Furnace

Countermeasure

Adding a Visual Check Process

Concept of FTA
(http://en.wikipedia.org/wiki/Fault_tree_analysis)
After the FTA analysis, we found the main cause of the unexpected fire is that the flammable cleaning liquid was heated up at the Tempering Furnace. Therefore, as our countermeasure, we added an operator into the process, to check if there is any liquid left on the work piece or not. To prevent the recurrence completely, we recently applied STAMP/STPA to review the countermeasure again.
Process of STAMP/STPA

**STPA Preparation ①**
- Defining Hazard

**STPA Preparation ②**
- Building Control Structure

**STPA Step 1**
- Recognizing Unsafe Control Action

**STPA Step 2**
- Analyzing Hazard Factors
According to the process of STPA, we tried to build the Control Structure.
Control Structure

Object

Signal

Work-piece + Cleaning liquid

Work-piece

Operator

Confirmation:
No liquid

Instruction: check if there is liquid or not

Controller

Permit to eject

Permit to receive

Degree of vacuum and temperature of liquid is normal

Vacuum Degreasing Machine

Tempering Furnace

Analysis by STAMP/STPA
First, before the work-piece goes out from the Vacuum Degreasing Machine, The Degreasing Machine will send signal to the Controller to report the degree of vacuum and temperature of the liquid is normal or not. If everything is normal, the Controller will then send the signal to permit the The Degreasing Machine to eject the work piece out. And then, the Controller will ask the operator the check if the liquid has been removed or not. If everything is ok, the operator will push the button to send feedback to the Controller. Then, the Controller will permit the Tempering Furnace to receive the work-piece.
## Recognition of Unsafe Control Action

<table>
<thead>
<tr>
<th>Command</th>
<th>Not provided</th>
<th>Incorrectly provided</th>
<th>Provided too early/late, out of sequence</th>
<th>Stopped too soon</th>
</tr>
</thead>
<tbody>
<tr>
<td>It’s OK to receive the work-piece</td>
<td>No hazard</td>
<td>No hazard</td>
<td>No hazard</td>
<td>No hazard</td>
</tr>
<tr>
<td>It’s NG to receive the work-piece</td>
<td>No hazard</td>
<td>If OK signal is inputted when there is liquid left, Hazard happens.</td>
<td>No hazard</td>
<td>No hazard</td>
</tr>
</tbody>
</table>

### Analysis by STAMP/STPA

| Condition: Liquid stays on the work-piece | Much identifiable | Little Not identifiable ↓ Because of it is a tiny amount, effect is little ↓ Once accumulated in the furnace, Hazard happens | Observable identifiable | NOT Observable Not identifiable ↓ Because of it is a tiny amount, effect is little ↓ Once accumulated in the furnace, Hazard happens |
And next, we tried to find out the Unsafe Control Actions. For example, if the operator considers that the work piece shall not be thrown into the furnace, BUT he just pushes the wrong button. And then the hazard will happen. Or, if the quantity of the liquid is too little to see, it will accumulate in the furnace gradually and leads to the hazard finally.
Whole picture of the hazard recognized

- Malfunction of Controller
- OK signal is miss-inputted while the situation is NG
- Miss-input by the operator
  - SOP is not clear
  - Auxiliary tool is not enough for the check

- Inconsistency of Process model
  The ability of visual check is limited
  The existence of the blind area
- Wrong instruction by Controller

- Miss-input
  - SOP is not clear
  - Auxiliary tool is not enough for the check
  - Inconsistency of Process model
    Operator can not insure there is no liquid left only by visual check
    Operator can not check the blind area

- Malfunction of the machine
  Operator

Analysis by STAMP/STPA
After the STAMP analysis, we can see that there are some inconsistency of the Process Model that the current FTA cannot find out, such as “the ability of visual check is limited” or “the existence of the blind area”…etc.
Advantage of STAMP/STPA

Risks we analyzed by STAMP/STPA

<table>
<thead>
<tr>
<th>FTA</th>
<th>The cleaning liquid should not be brought into the furnace.</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMEA</td>
<td>It is unavoidable that the cleaning liquid gets into the furnace.</td>
</tr>
<tr>
<td>STAMP/STPA</td>
<td>To prevent the liquid from accumulating, a periodical burn-out is adopted.</td>
</tr>
</tbody>
</table>
As a conclusion, we found that the FTA or FMEA will only try to prevent the cleaning liquid from getting into the furnace. However, on the other hand, the STAMP analysis shows us that it is unavoidable that the cleaning liquid gets into the furnace. Therefore, according to the result of STAMP/STPA, we did some modification on our countermeasures. For example, to prevent the liquid from accumulating, a periodical burn-out is adopted.