Reliability Analysis of Isothermal Forming Hydraulic Press Body Based on FMECA

FENGHE WU, KAI XING, YUEMING WU, BAOSU GUO and YUHANG DENG

ABSTRACT
As a special kind of advanced aerospace sheet metal forging equipment, more and more attention has been paid to the design and development of isothermal forming hydraulic press. Failure Modes, Effects and Criticality Analysis (FMECA) method is an effective technique to improve the reliability of products. To improve the reliability of isothermal forming hydraulic press, this paper propose FMECA method to predict all potential failure modes, causes and effects in the design stage. Then improvement and preventive measures are accordingly put forward to alleviate or eliminate failure effects. Finally, the reliability of hydraulic press body is improved using the FMECA method, which also provides a basis for reliability analysis and design of other systems.

1 INTRODUCTION
Isothermal forming hydraulic press is a new type of aviation sheet metal forming equipment. Processed sheet metal parts are performed as low residual stress, small deformation resilience and high forming quality. It is widely applied in the field of aviation manufacturing. Some foreign companies such as ACB of France, CYRILBATH and ACCUDYNE of America can manufacture this kind of special isothermal forming equipment. Although some domestic companies can produce this kind of equipment, performance, stability and reliability are poor. Then the normal production will be seriously affected, and the market share of domestic equipment is low. The reasons are manifold: first, the new design requirements can...

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not be met by the old design concept; second, the new reliability design techniques have not been widely used in the design department. In fact, reliability and other performance should be fully considered in the process of product development and design, guaranteed by manufacturing and management [1-3].

FMECA represents an analytical technique which is able to analyze each potential failure mode, failure effect and classify each potential failure mode according to its severity and occurrence probability. Then corresponding measures are taken to improve the reliability of system according to the results. The feature is that the unreliable factors of the system can be found out without quantitative reliability data [4]. FMECA method has been researched in order to improve the product design. Zhao Y S and Liu S G applied the FMECA method in railway vehicle components design stage to analyze failure factors and corresponding measures were adopted to improve products reliability [5]. Nurul Hayati Hasbullah and Rosmaini Ahmad used FMECA method in a tyre manufacturing industry to rank and prioritize failures systematically and thus help engineering team to perform the improvement project [6]. As the main component, the reliability of hydraulic press body can seriously affect the reliability of complete machine. But the analysis with FMECA during the design process on hydraulic press body is rarely studied. So reliability analysis of isothermal forming hydraulic press body based on FMECA is applied in order to find out the weak parts and the key parts in the early stage of design. Then corresponding measures are taken to eliminate or reduce the failure effects and improve the reliability of complete machine.

2 THE METHOD AND PROCEDURE OF THE FMECA ANALYSIS

FMECA analysis procedure of hydraulic press body as depicted in Figure 1 is made according to GJB 1391-92《Failure Modes, Effects and Criticality Analysis Program》 [7].

This paper uses Risk Priority Number (RPN) method to analyze the criticality. RPN enables a priority ranking among the identified failure modes and combined effects. The RPN is obtained from the product of these three parameters:

\[
RPN = S \cdot O \cdot D
\]  

(1)

Where

- S denotes the index of severity.
- O represents the occurrence index.
- D represents the detection index.

The severity, occurrence, detection index evaluated by the criteria for severity, occurrence, detection of potential failures as shown in Table I.
3 THE STRUCTURE ANALYSIS OF THE HYDRAULIC PRESS BODY

Hydraulic press body is a main component of complete machine, adopts the pre-tight frame structure, and mainly consists of an upper beam, lower beam, pillar, tension rod, slide forward, a movable table and working cylinder etc. As depicted in Figure. 2, tension rod 4 penetrates the closed frame consisted of upper beam 1, Pillar 3 and lower beam 4. The whole is connected through the pre tightening of the hydraulic cylinder. Slider 6 is guided by four guide posts 8.
4 THE FMECA ANALYSIS RESULTS OF ISOTHERMAL FORMING HYDRAULIC PRESS BODY

As the FMECA analysis table II shown, hydraulic press body has 11 failure modes totally among which slider jitter, slider slowly downward under high pressure, workbench crawling in the process of moving, workbench cylinder leak oil have high RPN, and tension rod fracture, the excessive deformation of the upper beam, lower beam and the pillar has high severity index. In view of the above failure modes corresponding design improvement and compensation measures were taken. For example, the measures of regular inspection, reliability design improvements, strengthen material selection and finite element analysis were taken for the failure modes with high RPN, and the measures of reliability design improvements, lubricate periodically and check regularly were taken for the failure modes with higher severity index.
TABLE II. AN EXTRACT OF THE ISOTHERMAL FORMING HYDRAULIC PRESS BODY
FMECA ANALYSIS TABLE.

<table>
<thead>
<tr>
<th>Code</th>
<th>Part</th>
<th>Failure mode</th>
<th>Possible failure cause</th>
<th>Final effect</th>
<th>S</th>
<th>O</th>
<th>D</th>
<th>RPN</th>
<th>Improvement measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>Upper beam</td>
<td>Beyond deformation allowance</td>
<td>Stiffness shortage</td>
<td>Affect performance</td>
<td>7</td>
<td>3</td>
<td>5</td>
<td>105</td>
<td>Strengthen material selection and finite element analysis</td>
</tr>
<tr>
<td>12</td>
<td>Pillar</td>
<td>Beyond deformation allowance</td>
<td>Stiffness shortage</td>
<td>Affect performance</td>
<td>7</td>
<td>3</td>
<td>5</td>
<td>105</td>
<td>Strengthen material selection and finite element analysis</td>
</tr>
<tr>
<td>13</td>
<td>Tension rod</td>
<td>Threaded damage</td>
<td>Strength shortage</td>
<td>Affect performance</td>
<td>8</td>
<td>2</td>
<td>3</td>
<td>48</td>
<td>Regular inspection and replacement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tension rod fracture</td>
<td>Fatigue damage</td>
<td>Damage equipment, Security incidents occur</td>
<td>9</td>
<td>1</td>
<td>3</td>
<td>27</td>
<td>Regular inspection and replacement</td>
</tr>
</tbody>
</table>

5 CONCLUSION

Reliable hydraulic press body is the precondition of realizing high reliability of complete machine. Through the above FMECA analysis, we found out slider, moving workbench and workbench cylinder are weak parts, so reliability improvement design should be made for the slider and moving workbench, and working cylinder should be checked regularly. The upper and lower beams, tension rod and pillar are the key parts, so material selection and the reliability design should be strengthened. At the same time, the corresponding management files and rules can be established to improve the reliability of the hydraulic press body which also could be taken the reference for other systems’ reliability study.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial supports of National Science and Technology Major Project (Grant No. 2013ZX04001-041), Research Project of
Hebei Educational commission (No. ZD20131066), Specialized Research Fund for the Doctoral Program of Higher Education of China (Grant No. 20121333110011).

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7. GJB 1391-92《Failure Modes, Effects and Criticality Analysis Program》.