Failure Analysis and Rectification of Sealing Valve Failures in Blast Furnace

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Abstract- Blast Furnace is one of the major departments of VSP where the conversion of raw materials like Iron ore, Sinter and Coke into molten metal (Pig iron) takes place. To charge raw material into Blast Furnaces which are operated at 2 Kg/cm$^2$ pressure Bell-less top (BLT) charging system supplied by M/s. PAULWURTH, LUXUMBURGE is provided.

In this project various mechanical equipment failures are studied and noted. Based on that failure analysis Sealing Valve failure is taken for further study, which is causing highest production loss to the company.

The function of all BLT equipment’s studied and various probable causes for Sealing Valve failure are noted. Major causes contributing to the failure of Sealing Valve analysed and suitable alternatives are suggested.

Key words: Pressure value, Blast furnace, Bell less System.

1. Introduction

Blast Furnace

The line diagram of blast furnace is shown in figure 1.1 Blast furnace is cylindrical, tapered, counter vessel was several reactions take place at different zones. The process of reduction will tap hot metal as the main product and slag as by product from four tap holes, which are provided at the bottom side of the furnace.

A blast furnace is designed to operate at 2 kg/cm$^2$ working pressure at the furnace top to get the rated production. To charge the material in the furnace 2kg/cm$^2$ pressure is to be maintained in the bin. A separate bell less top charging is provided. The system is provided exactly on the top of the furnace and the main purpose of it is to distribute the required quantity of material uniformly into the furnace as and when the furnace required. As the volume of the blast furnace is very high - its raw material requirement is also very high, hence the charging equipment should operate continuously without any break.

Fig 1.1 Blast Furnaces
2.2. Bell less Top Charging System

Bell less top valves like an upper sealing valve, lower sealing valve, material gate, equalizing valve and relief valves are required to be operated 300 times a day, especially receiving hopper material gate is required to be operated 600 times a day. Failure of any of these valves, valves leads to stoppage of B.F completely. Fig 1.2 shows different parts of Bell less top charging system.

The prime mover connected to these valves should very reliable and should work continuously without any problem. As the location of this valve is at height, weight of the prime mover should be less as possible to bear the structure weight. Considering all these points, hydraulic actuators was chosen as prime mover to all Bell less top charging equipment.

![Bell less Top Charging System](image)

Fig 1.2 Bell less Top Charging System

Failure Analysis of the Bell less Top Charging System

3.1 Selection of problem

To select a problem for this project, data regarding various failures in Bell less top charging system are collected from past records. The following is the data in Table 1 of the major problems identified for the past three years:

Table 1:

<table>
<thead>
<tr>
<th></th>
<th>Problem</th>
<th>Wind restriction</th>
<th>Loss of hot metal (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sealing valve failure</td>
<td>Nil</td>
<td>71.5</td>
</tr>
</tbody>
</table>
2. Problem Definition and Analysis

Sealing valve description: Sealing valve plays an important role in Bell Less Top Charging System. These valves are meant for sealing the bin from Blast Furnace gas leakage which is driven by Hydraulic cylinder. They consist of flap and a seat with silicone rubber seal. The flap closes against the seat during closing, once the valve is closed, it will not allow any leakage through the valve. These valves are located one on top of the bin and another at the bottom. These are very critical valves. These valves are driven by hydraulic cylinders.

Sealing Valve Failure Means:

1. Bin is connected to furnace.
2. Bin is not ready to receive a fresh charge of raw material.
3. Entire bin operation that is charging process is stopped.
4. The complete Blast furnace production effected.

The two major reasons for failures are:

- Actuator Hydraulic cylinder end flange failure
- Actuator crank failure

From the above table it is clear that Actuator crank failure and Hydraulic actuator end flange failure together contributing to two third of the total failures. If these two failures are avoided, total sealing valve failures will be reduced to one third. Hence these two main causes are considered for further analysis.

Analysis and Rectification of Actuator Crank Failure

4.2 Loads on the Crank/Lever

A total force acting on the lever at point A in Fig 1.3

\[
F = \frac{\pi}{4} \times d^2 \times \text{pressure.}
\]

\[
= \frac{\pi}{4} \times (125)^2 \times 35.
= 429.514KN \approx 430KN.
\]

[Since cylinder bore = 125mm
Hydraulic test pressure = 350 bar

1 bar = (10)5 N/m²
1 bar = 0.1 N/mm². Therefore 350 bar = 35 N/mm²]

Total load acting on the lever at point A, \( F = 430KN \).
Tangential Component of the Load  
= \( F \cos 40^\circ \) = \( 430 \times \cos 40^\circ \)
= 329.39KN \( \approx \) 330KN.

Radial component of the load
= \( FSin40^\circ \) = \( 430 \times \sin 40^\circ \)
= 276.39KN \( \approx \) 276KN

**Considering the reaction at point O**

\[ 330 \times 350 = FTk \times 110 \]
\[ FTk = \text{Tangential force acting on the crank at key way} \]
\[ = \frac{(330 \times 350)}{110} = 915KN \]

**Crank failing at cross-section x-x**

Cross-section of the crank at failure area = 10 x 218 + 10 x 95/2 x 2
= 2180 + 950 = 3130mm\(^2\)

For given material C.S gr-4 IS2644

Maximum tensile strength = 1030 Mpa

Maximum yield strength = 850 Mpa

Therefore Induced stress in the Crank = Tangential force / Area of cross section

\[ = \frac{915 \times (10)}{3130} = 292 \text{ N/mm}^2 \]

Maximum tensile strength = 1030 N/mm\(^2\)

As the nature of the load is “impact load”. Consider factor of safety is 4
Then safe working stress = \( \frac{1030}{4} = 257 \text{ N/mm}^2 \)

As the Induce tensile stress in the Crank is 292 N/mm² which is more than safe working stress. Therefore the design is unsafe.

**Alternative**

*Increase the web thickness from 10mm to 25mm.*

Then Area of resistance of keyway = \( 10 \times 218 + 25 \times 95/2 \times 2 \)

\[ = 2180 + 2375 = 4555 \text{ KN/mm}^2 \]

Then stress in the Crank = \( 915 \times 10^3/4555 = 200 \text{ N/mm}^2 \)

As the Induced tensile stress is less than safe tensile stress.

Therefore new design is safe.

**Key dimensions:**

\( L = 204\text{mm} \quad B = 50\text{mm} \quad t = 22\text{mm} \quad \text{No. of keys} = 2 \text{Nos.} \)

Generally, the key will be the weakest joint in any design. Maximum torque that can be handled by this key is considering the shearing of key:

Max Torque transmitted \( T = L \times w \times \frac{d}{2} \)

\[ = 204 \times 50 \times 42 \times 219/2 \]

\[ = 46909800 \text{ N-mm} = 46910 \text{ KN-mm}. \]

Considering Crushing of the key:

Max Torque transmitted \( T = L \times \frac{t}{2} \times \frac{d}{2} \times c \times \frac{d}{2} \)

\[ = 204 \times 11 \times 70 \times 219/2 \]

\[ = 16414860 \text{ N-mm} = 16415 \text{ KN-mm}. \]

Taking smaller of the two values, we have maximum Torque transmitted by a single key = 16415KN-mm. Because two keys are provided to crank Maximum Torque transmitted by two keys = \( 2 \times 16415 = 32830 \text{KN-mm}. \)

Since the key is the weakest joint in the entire system. The torque transmitted by the lever/Crank should be more than 32830KN-mm. By using this analysis we can increase the production rate of the company.

**References**

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