

Sealing Valve Bell Less Top Blast Furnace Increasing Productivity

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Abstract

Visakhapatnam Steel plant (VSP) is the first shore based integrated steel plant in India producing high quality value added steel of 3. 4 million tons per annum. 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 2kg/cm² pressure, Bell-less top (BLT) charging system. The Bell-less Top Charging System (BTCS) which is a continuous system for charging raw material into a blast furnace for iron making. The valve casing comprising material gate, lower sealing valve and distribution chute assembly is an important unit of the system. This assembly helps to retain the charging material inside the hopper; protect the lower sealing valve during charging; control charging material discharge rate; seal gases of BF reactions; and seal high counter pressure of furnace. In addition, with leakage of BF gas being eliminated, safe working conditions have been established, and productivity has increased with downtime of BF reduced. Good control of the gas flow in the blast furnace ensures greater productivity and a longer life span of the installation.

In this project various failures of BLT mechanical equipment are studied and noted. Based on this failure analysis Sealing valve failure is taken for further study which is causing highest production loss to the company. In proposed work modification of blast furnace bell-less top charging system sealing valve, there is changes in sealing valve which helps in reduce time delay, low maintenance and higher productivity. The modification is based on the alternatives designs suggested to the gland joints and hydraulic circuits and Calculation of forces by the mathematical process.

Introduction

Blast furnace is the major and most important production unit in production engineering and technology. Proper optimization of the charging regimes of the blast furnace is necessary to ensure efficient and high productivity. Blast furnace is a furnace used for smelting iron ore to produce pig iron. Blast furnace is cylindrical, tapered, counter vessel where 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. . The blast furnace charging system consists of two main areas, (1) the stockhouse system – The function of the stockhouse system is the weighing, batching and delivering of the recipe of raw materials to the top charging equipment. (2)The top charging equipment- serves the function of delivering blast furnace raw materials to the furnace top and distributing these materials into the furnace. These are of two types: Bell top charging and Bell less top charging system.

Bell less Top Charging System

Blast furnace is designed to operate at 2 kg/cm^2 working pressure at furnace top to get the rated production. To charge the material in the furnace 2 kg/cm^2 pressure is to be maintained in the bin. A separate bell less top charging system 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 furnace as and when the furnace required. As the volume of blast furnace is very high - its raw material requirement is also very high hence the charging equipment should operate continuously without any break.

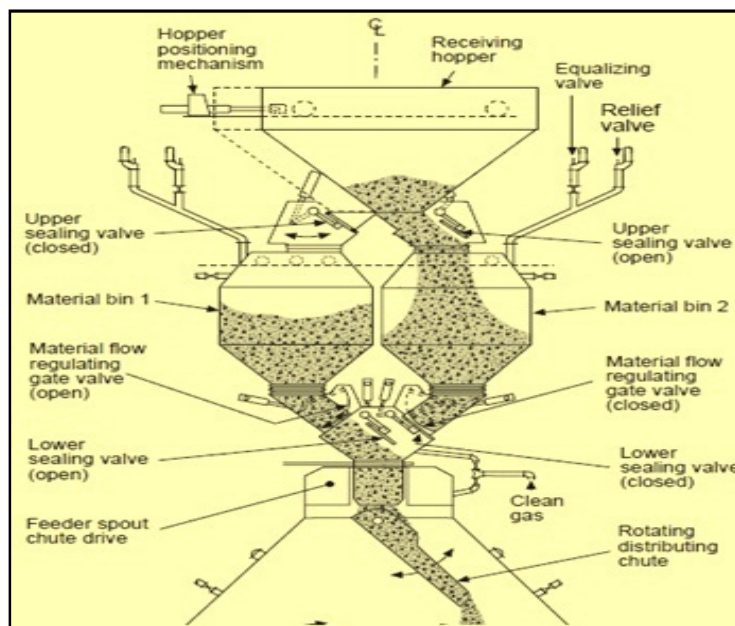


Fig. 01 Bell less Top Charging System

Function of Bell less Top Charging System

Two bins having useful volume of 47m³ and each bin is having two sealing valves to avoid from BF gas leakage, one at the top of the bin and other at the bottom. Each bin is having one material gate at the lower portion to hold the burden and is located above the lower sealing valve. Receiving hopper to receive the material from the main charging conveyors and to guide to either of the bins. Receiving hopper is having one material gate at the bottom of the hopper. Material gate is not to allow any material to fall when the hopper is in transition from one bin to the other bin. Distribution chute gearbox situated at the bottom of the bins and just above the furnace. The main function of the gearbox is to hold, rotate and tilt the main distribution chute. Chute having length of 4 m is to receive the material from the bins- and to distribute uniformly in the furnace. The process of bell less top charging process are shown in fig. 03

The provision of chute rotating and tilting facilitates to charge the material into the furnace in concentric circles. It is N₂ cooled gearbox having a lubrication interval of 8 minutes. Raw material charging will be charged into the furnace, in batches. In which iron ore material is one batch and coke as another batch. Either of the batches is first taken into one bin through receiving hopper from the main charging conveyor. Then the bin will be pressurized up to 2 Kg/sqcm pressure by using semi cleaned B. F. gas and nitrogen. After pressure equalization, lower sealing valve is opened fully and lower material gate is opened partially to regulate the flow. Due to gravity the material falls into the chute and gets distribute into the furnace.

Sealing Valve

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 silicon rubber seal. 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 at top of the bin and other at the bottom. From the last three years data (Table 1) it is clear that the failure of Sealing Valve is resulting in maximum loss 5577 tones of hot metal production. Fig shows bar graph of Failure analysis of BLT charging system. As the sealing valve problem is contributing 5577 tones of the total down time. Therefore it is considered for further analysis.

Methodology

The fig 02 shows the research methodology flow chart and fig 03 shows the process flow chart of bell less top charging system if furnace.

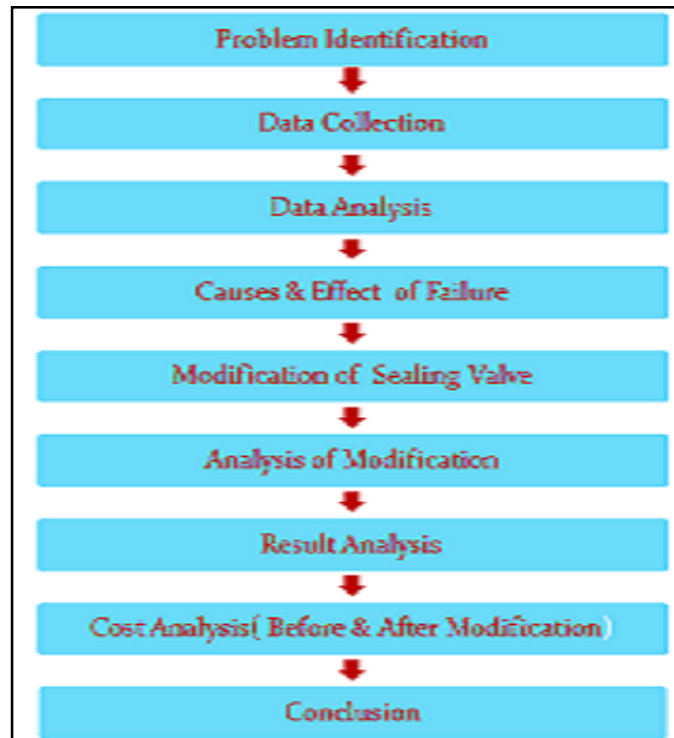


Fig. 02 Research methodology flow chart

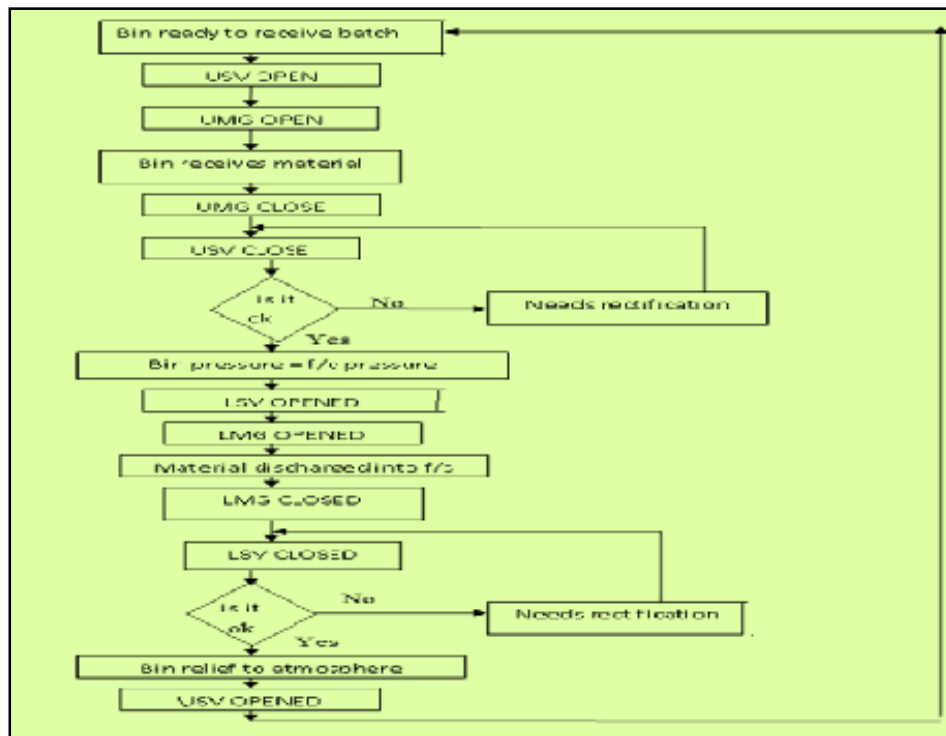


Fig. 03 Process Flow Chart

Problem Identification

The main problem arises in bell less top charging system is the blast furnace is failure of sealing valve. The two major reasons for sealing valve failures are (a) Actuator Hydraulic cylinder end flange failure and (b) Actuator crank failure. Due this, there is many effects in sealing which is shown in fig. 04.

Table. 01 failure analyses of BLT

s.no	Problems	Off blast	Low blast	Wind restriction	Loss of hot metal(tons)
1.	Sealing valve failure	nil	nil	71.5	5577
2.	Hydraulic problems	8.15	5.30	6.10	3106
3.	Bleeder valve	10.20	Nil	Nil	2553
4.	Sealing valve seat leakage	6.25	Nil	Nil	1584
5.	Hatch cover leakage	3.25	1.25	0.25	1014
6.	Main charging conveyer	Nil	1.35	3.45	453
7.	Mobile hopper wheel failure	4.45	Nil	Nil	1128
8.	Up takes leakage	Nil	Nil	Nil	437

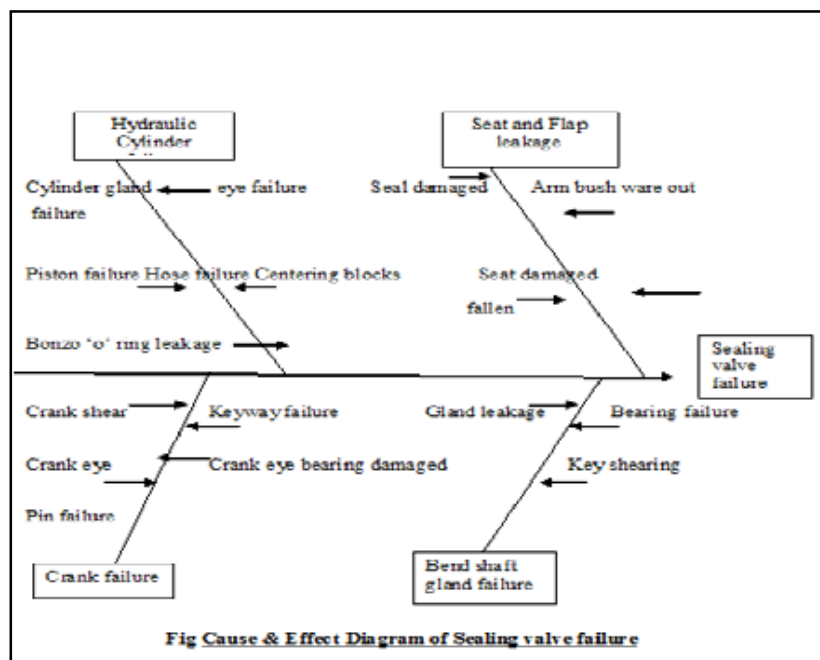


Fig 04 Causes & Effect Diagram of Sealing Valve failure

Analysis and modification of Hydraulic Cylinder Gland Failure

Calculation of forces on gland joint:

Total External forces on gland joint = Exposed area of bronze ring X Hydraulic test pressure

$$= \pi/4[(d_2)^2 - (d_1)^2] \times \text{Pressure} = \pi/4[(110)^2 - (90)^2] \times 35 = 109955.74 \text{ N}$$

{Cylinder dimensions: D2 = 110mm; D1 = 90mm, Test pressure 350 bar = 35N}

No. of bolts = 06 Nos.

Then External load on each bolt = $109955.74/6 = 18325.95 \sim 18330 \text{ N}$.

Total tensile load on each bolt = Initial tension + External load

Total load on each bolt = $14200 + 18330 = 32530 \text{ N}$. (Initial tension = $1420 \text{ d} = 1420 \times 10 = 14200 \text{ N}$)

Design Load

Gland cover is fixed to the Hydraulic cylinder with M₁₀ Hexagonal socket head bolts of 06Nos. made with C-40 cold drawn material having ultimate tensile strength of 750N/sqmm. For any bolt or screw the shearing of the bolts will take place at the weakest point of the entire bolt, so that the bolt or screw will generally shear at neck point. Hence for calculation purpose hexagonal socket head bolt in hydraulic cylinder is taken in to consideration.

Load carried by each M₁₀ bolt in Hydraulic cylinder

Strength of the joint against shear at head = Stress area X Safe tensile strength /Factor of safety

$$= 58 \times 750/2 = 21750 \text{ N. (Stress area for M}_{10} \text{ bolt is } 58 \text{ mm}^2 \text{ from data book).}$$

From the above calculation it is clear that actual load (32, 530N) on each bolt is much more than design load is 21750N. Hence it is found that root cause for gland bolts failure in faulty design. Therefore alternation solution is required.

Load on Hydraulic cylinder: Alternative Designs to End Flange Joint

Alternative 1: Increase size of the bolts from M₁₀ to M₁₂

Design tensile load that can be taken by M₁₂ bolt = $84.3 \times 750/2 = 31612.5 \text{ N}$

(Stress area for M₁₂ bolt is 84.3mm² from data book).

This is also much below the actual load. (Actual load on M₁₂ bolt = $1420 \times 12 + 18330 = 35370 \text{ N}$)

Consider M₁₆ (because M₁₄ is non-standard)

Design tensile load that can be taken on M₁₆ bolt = $157 \times 750/2 = 58875 \text{ N}$.

This is well above the actual load (Actual load = $1420 \times 16 + 18330 = 41050 \text{ N}$)

So 06 nos. of M₁₆ bolts can be used for gland cover instead of M₁₀.

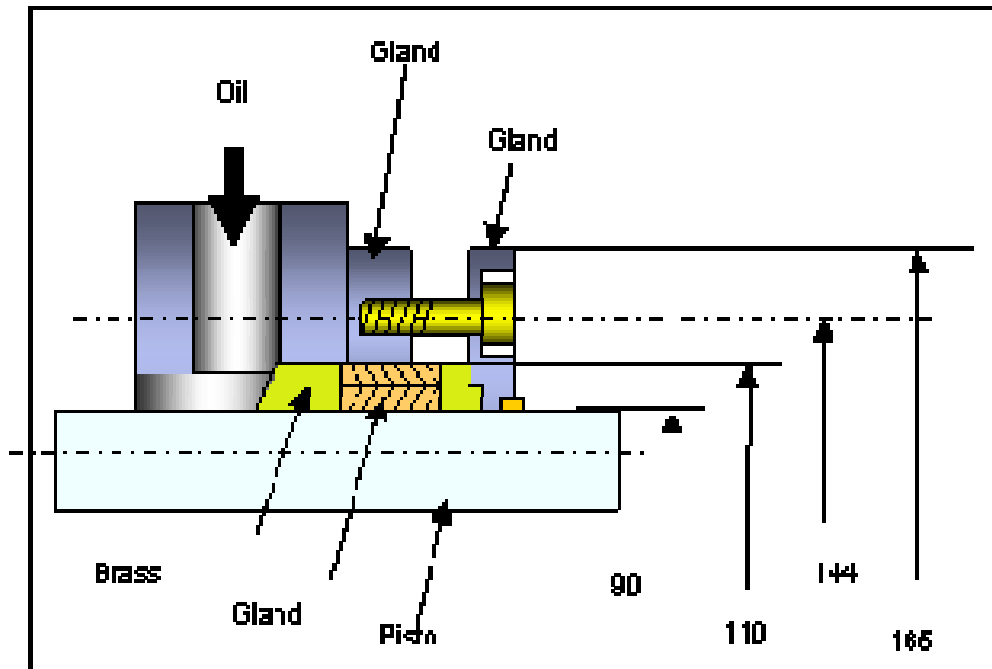
Limitations:

Fig 05 Cut Section of Hydraulic Cylinder Housing

Outer diameter of the existing housing = 165mm; PCD of the bolts = 144mm.

Nominal size of the bolt = 16mm; Actual wall thickness = 5.5mm.

Left out wall thickness of the gland housing = $(165-144-16)/2 = 2.5$ mm.

As per the design standards minimum wall thickness = $0.5 \times$ Nominal size of the bolt = $0.5 \times 10 = 5$ mm for M_{10} bolt.

For M_{16} bolt minimum wall thickness is 8mm. Hence the design is unsafe

Alternative 2: Changing the existing material

Changing the existing material of the hexagonal head cap bolt with material having high ultimate tensile strength when compared with the present one. Existing material of hexagonal head bolt i. e. , 40 Cr Mo28 having ultimate tensile strength $1050\text{N}/\text{mm}^2$. may be replaced with 0.35-0.45Carbon, Silicon 0.1-0.35, Manganese 0.5-0.8, Cr. 0.9-1.2%, Mo 0.2-0.35.

Then working load per bolt changes to ultimate tensile strength = $58 \times 1150/2 = 33350\text{N}/\text{mm}^2$.

This will be above the actual working load of 32530N. Hence changing the material of bolts can be considered.

Limitations

As per the design standard maximum spacing between two consecutive bolts in fluid pressure flange joint should be less than equal to $6d$ (from data book).

For M_{10} bolt maximum spacing = $6d = 60\text{mm}$.

In this case spacing between two consecutive bolts = $\text{PCD}/\text{No. of bolts} = \pi \times 144 / 6 = 3.14 \times 144 / 6 = 75.3\text{mm}$.

As per design standards maximum 60mm spacing is allowed. Here the space is 75.3mm. Hence the design is unsafe.

Alternative 3: Increase in No. of bolts from 6 to 12.

Now the actual load on each bolt = Initial tension + external load on each bolt
 $= 14200 + 109960/12 = 23363\text{N}$.

This load is also more than safe load i. e. 21750N. Even after increasing number of bolts from 6 to 12. Thus the design is unsafe.

Hence consider No. of bolts as 18 (Since 18 is considered because 18 threaded holes can be equally spaced between exists 6 threaded holes)

Now actual load on each bolt = $14200 + 109960/18 = 20308\text{N}$

This is below the safe working load of 21750N. Hence design is safe.

Checking

Spacing between two consecutive bolts = $\pi \times \text{PCD} / 18 = 3.14 \times 144 / 18 = 25.13\text{mm}$.

This is much below the allowable limit of 60mm ($6d$) given in design standards. Hence design is safe.

Finally it is considered that $M_{10} \times 40$ Hexagonal socket head bolts of 18 nos. instead of 6 nos. to lock the gland cover.

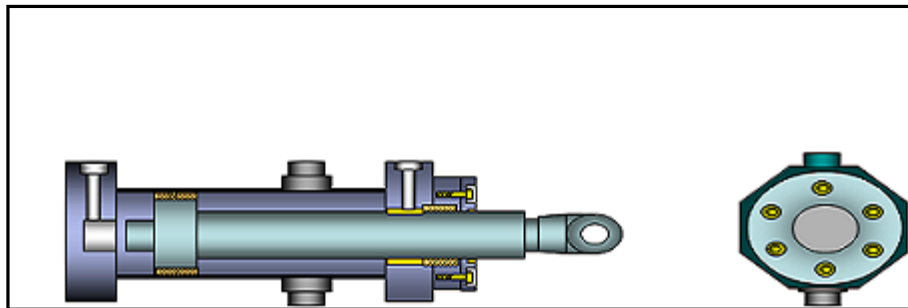


Fig. Before Modification

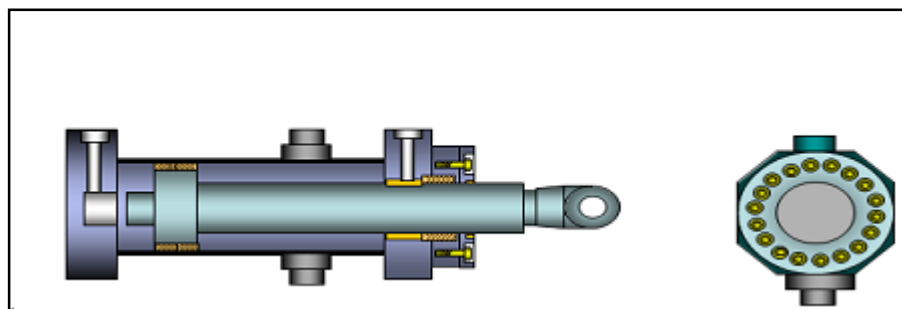


Fig. After Modification

CONCLUSIONS

1. Bell-Less top charging system of blast furnace is intended for distribution of charging ingredients into the furnace as per preset requirements.
2. Most of the components of the system are hydraulically operated and any failure of these leads to the stoppage of blast furnace.
3. From the problems that exist in Bell-Less top charging system "Sealing Valve crank and gland of Hydraulic Cylinder" failure is of serious concern as it involves major loss in production.
4. Alternatives suggested for failure of gland.
 - Increase the size of bolts.
 - Increase the number of bolts.
 - Changing the material of the bolt with a material having higher ultimate tensile strength.
 - Increase the number of bolts 6 to 18 is found to be the best alternative.
5. Reduction in production loss and its cost.
6. There will be need of low maintenance in sealing valve and hydraulic cylinder.

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