Study and Improvement of Recirculation Fan in Direct Reduced Iron (DRI) Plant Gas Heater

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ABSTRACT

The paper focuses on optimum operation of Recirculation Gas (RC)/Flue Gas Fan in Direct Reduced Iron Plant Process. Gas Heater is used to increase temperature of reduced gas from 50 Deg C to desire temperature upto 850-900 Deg C. Gas heater has four chambers namely, D01, D02, D03 and D04. D01 and D02 are the horizontal chambers, D04 is a vertical chamber. In D01 Combustion Chamber, Tail Gas is used as main fuel with Combustion air and LPG is burnt using Main Burner. Between D01 and D02 there is shield called Radiant Shield. The purpose of using radiant shield is to regulate the temperature of flue gas from D01 to D02. D02 chamber has 4 tube bundles installed in series inside which Pressure Swing Adsorption (PSA) Product/Reduced gas (enriched CO & H2) coming at 40°C from PSA unit will be made to pass. Flue gas from Gas chamber is cooled by Recirculation Fan and passed through radiant shield to regulate temperature from D01 to D02 chamber. Problem due to high vibration at Recirculation Fan Drive end bearing restricted the fan speed for optimum operation. To solve the problem the existing operation of Recirculation Fan (RF) was studied and used TQM tool (Brainstorming) to identified the problem and decision is taken to change Material of Construction (MOC) of the impeller and revised the Standard Operating Procedure (SOP) to improve the performance of the Recirculation Fan in Direct Reduction Iron (DRI) plant gas heater.

Keywords: Direct Reduced Iron, Recirculation Fan, Impeller, Cross over Temperature, Speed, Vibration, TQM tool (Brainstorming)

1. INTRODUCTION

Direct reduction is simple process of removal of oxygen from iron ore without melting and it is achieved by chemical reactions with Hydrogen and Carbon monoxide. The source of CO and H_2 could be Natural Gas, Corex Gas, Syngas or even Coke oven gas. There are two products of DRI namely, HDRI (Hot Direct Reduced Iron) and CDRI (Cold Direct Reduced Iron)

Gas heater is the equipment used to elevate the temperature of the reducing gas to 900 Deg C so as to reduction reactions to take place. In the following **Fig 1.1**, the detailed working of gas heater as well as recirculation fan is explained.

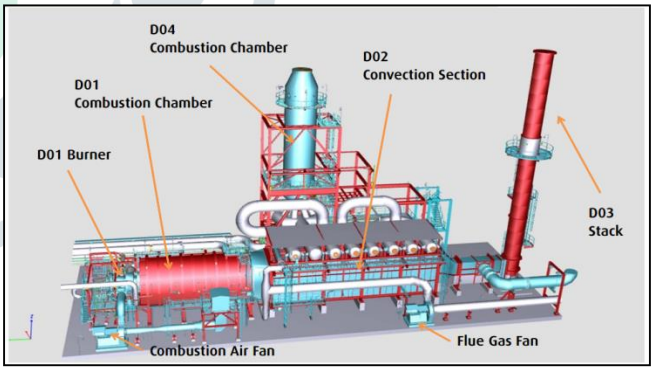


Fig 1.1: Heater –Flue Gas Fan

- In D01 Combustion Chamber, Tail Gas is used as main fuel with Combustion air and LPG & is burnt using Main Burner**.**
- D02 chamber has 4 tube bundles installed in series inside which PSA Product gas (enriched CO & H2) coming at 40°C from PSA unit will be made to pass**.**

- Convection Heat transfer between the gases from D01 & the product gas elevates the temperature of Product gas to 460°C.
- Later in D04, second stage of heating is ensured by direct combustion of PSA Product Gas and Oxygen. This will take the temperature of Product Gas from 460°C to 850°C at which it is sent to Shaft Furnace for the purpose of reduction.
- Flue gases leave D02 at a temperature of around 280 - 300°C.
- Flue gases coming out of D02 has CO_2 and N_2 as its main constituents.
- It is cooled in Seal Gas (SG) Cooler. For cooling, Process Water of 380m3/hr (minimum) is ensured.
- After bringing down the temperature of flue gas to 45°C, part of it is used as suction for Recirculation Fan.
- Portion of the left out Flue gas is routed towards Seal Gas system and Cold flare.

Fig 1.2: RC Fan with SG Cooler

Recirculation flue gas fan Specifications

- **Supplier** Howden Turbowerke GmbH
- **Fan Type** VRE 0710/5021 Z 148/61
- **Flow** 51840 Nm3/h
- **Suction Temp** 47 °C
- **Motor** 250KW **& RPM** 1488

Fig 1.3: CS MOC impeller coated with Rubber lining on it.

Application point of Re-circulated Flue Gas

- Flue gas entry to D02 is regulated at 900°C.
- This regulation is required to ensure enhanced life of Tube bundles as well as process optimization.
- To achieve this, there is Radiant shield sandwiched between D01 and D02 chambers as shown in **Fig 1.4.**
- Inside the Radiant Shield, flue gases cooled in Seal Gas Cooler is circulated through Recirculation Fan.
- By controller set point (Temperature), the speed of Fan varies so as to maintain the D02 entry temperature at 900°C.

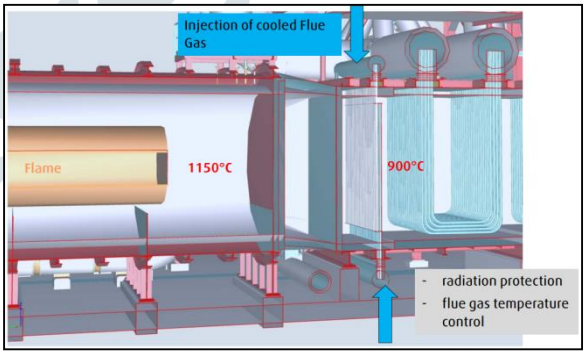


Fig 1.4: Temperatures at D01 & D02

2. PROBLEM IDENTIFICATION

Voice of Business	Business issue	Critical Business requirement	Critical to process
Increase production by optimum operation of RC Fan.	• In-efficient operation of RC Fan resulting from increased vibration. • Increased Specific O_2 Consumption. • Poor quality of Reduced gas	• To bring down the consumption Sp. O_2 % • To maintain Reduced Gas quality	Specific. O_2 < = 55 CO_2% in Reduced Gas < = 5.2

2.1 Importance of Recirculation Fan

It is treated as a prime organ of the Heater as it regulates the temperature of the system at very precise levels.

What happens, if the RC fan fails to perform as desired?

- Any deviation in the performance of the RC Fan will have a very major impact on the life of the bundle as they will get exposed to temperature beyond designed tolerances.
- To safeguard the tube bundles, if the fan is made to operate at its reduced capacity, temperature set points to be brought down which in turn will lower the temperature of the product gas at D02 outlet (Cross over Temperature).
- Lowered D02 outlet temperature will result in increase in oxygen & PPG consumption in D04 chamber to elevate the product gas temperature so as to maintain furnace inlet temperature at 850 Deg C.
- Additional injection of PSA Product Gas (PPG) in D04 will straight away affect on Production loss.
- Increased O_2 in DO4 will also have an adverse impact on Reduced Gas Quality as its CO_2% varies thereby, bringing down the reductants (CO & H_2) in Furnace.

3. METHODOLOGY

3.1 Brainstorming to list out the probable causes in RC Fan : Affinity Based

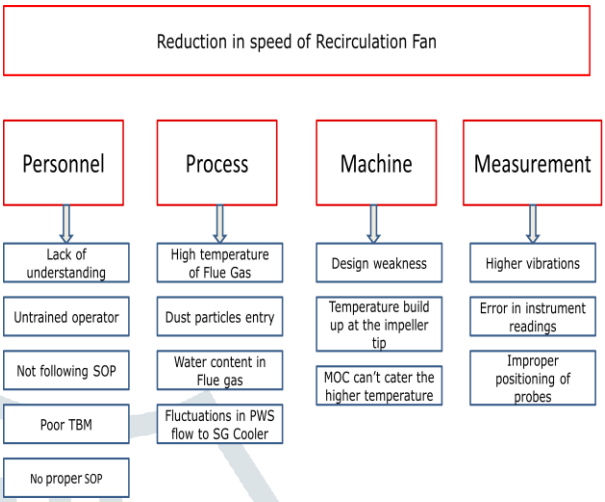


Fig 3.1: Results of Brain storming

Fan Speed Vs Fan Vibration Plotted (Before)

By varying fan speed, vibration of drive end bearing (**Before modification**) is noted and graph is plotted to know increase in vibration with fan speed **Fig. 3.2.**

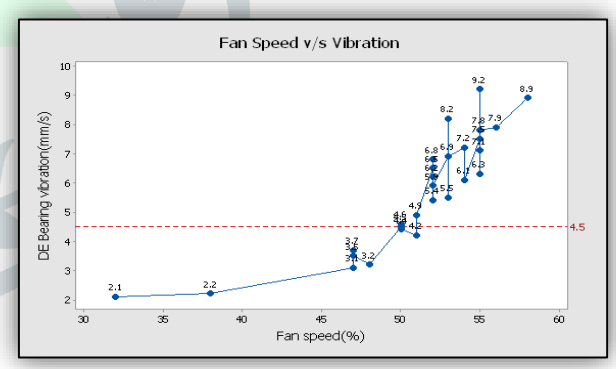


Fig 3.2: Line graph for Fan speed Vs Vibration.

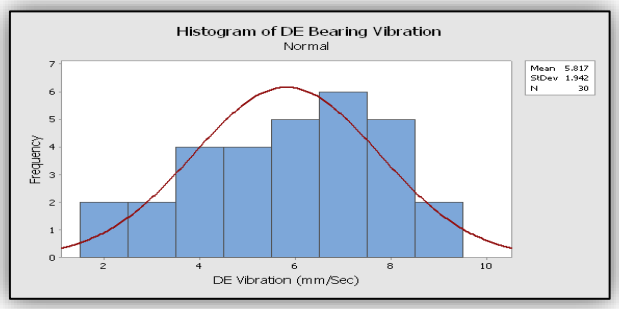
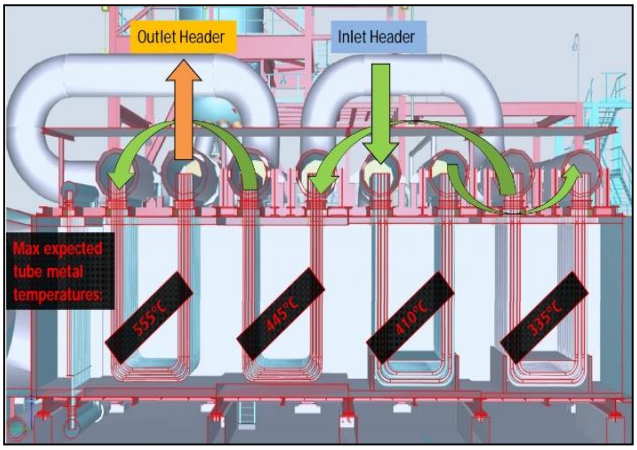


Fig 3.3: Histogram of DE bearing Vs vibration

- It is observed that (**Before modification**) Vibration is exceeding the specified limits (4.5mm/s) when the RC Fan is operating at >50% speed.
- Frequency of RC Fan operation at vibration levels > 4mm/sec is also high which is evident from Histogram **Fig.3.3**



Fig

Effect of operating RC Fan at reduced speed on Specific O_2 & Reduced Gas (RG) CO_2 (Before modification)

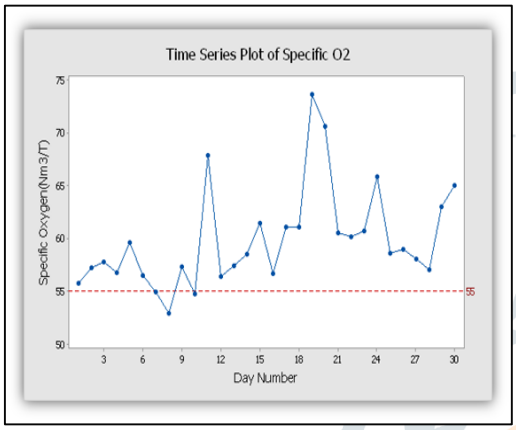


Fig 3.4: Times series plot of specific O_2

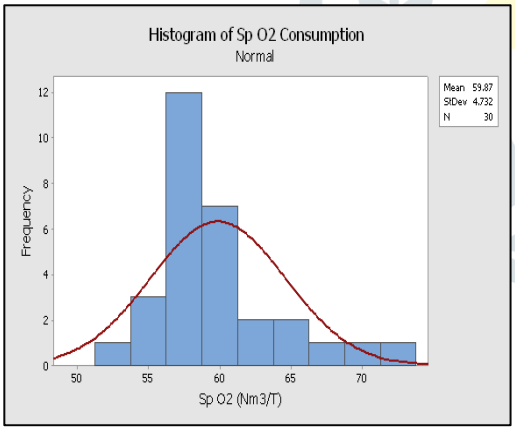
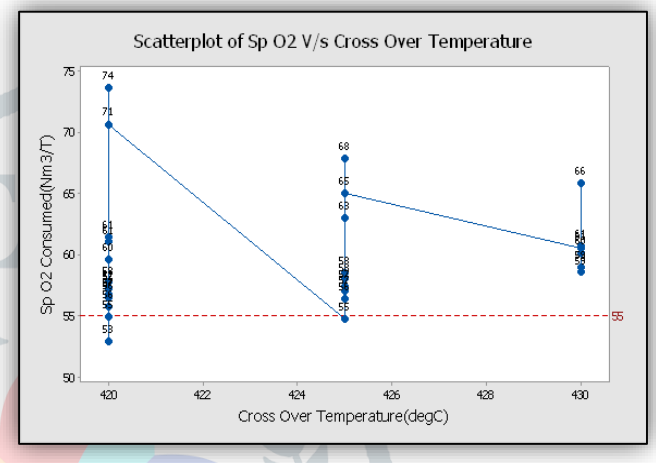


Fig 3.5: Histogram of Specific O_2 consumption

- Due to the restricted speed of RC Fan, Specific O_2 consumption went high as the Cross over Temperature at Heater D02 was brought down by 30deg C.
- Due to the increased O_2 consumption in Heater-D04, RG CO_2 % went high thereby reducing the reductant in the Furnace.



3.6:

Effect of Decreased Cross Over Temperature on O2 Consumption

Fig 3.7: Scatter plot of Sp O2 Vs Cross over temperature

- It can be inferred from the plot that restricting the cross-over temperature between 420°C & 430°C at Heater D02 resulted in increased O_2 consumption as additional injection was needed to increase the temperature by 30°C.

Standard Operating Procedure of RC fan

- The Standard Operating Procedure instructs to start RC Fan after attaining D01/D02 temperatures 800°C.
- This has resulted in High temperature at the inlet of the Fan (But, Fan designed for Max. of 80°C) and has resulted in Heater trips also during start-up.
- Due to high temperature at the inlet of the fan during start-up of Heater resulted in detoriation of the fan as shown in **Fig.3.8**.

Fig 3.8: Deteriorated rubber lining on the Impeller

Problem Identified	**Probable Solutions**
High Flue Gas temperature at the inlet	To see alternate rubber material which can cater for the deviation in gas composition at different operating condition on trial and error method
	To go for upgraded Material of Construction (MOC) for the impeller which is corrosive resistant and high temperature withstanding capability

- It is decided to change MOC of the impeller with Duplex stainless steel which is corrosive resistant, work hardenable alloy and replaced impeller with upgraded MOC as shown below.

Fig 3.8: Duplex stainless steel Impeller

4. RESULTS

After changing impeller Material of Construction with Duplex stainless steel, the fan vibration reduced even at high speeds. Results are shown in **Fig. 4.1, 4.2 & 4.3**

Fan Speed V/s Fan Vibration (After)

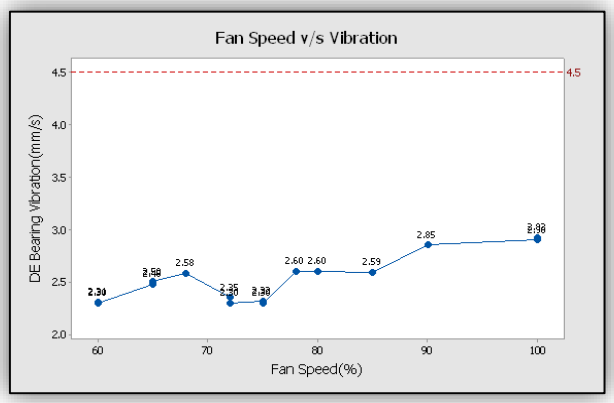


Fig 4.1: Line graph for Fan speed Vs **V**ibration

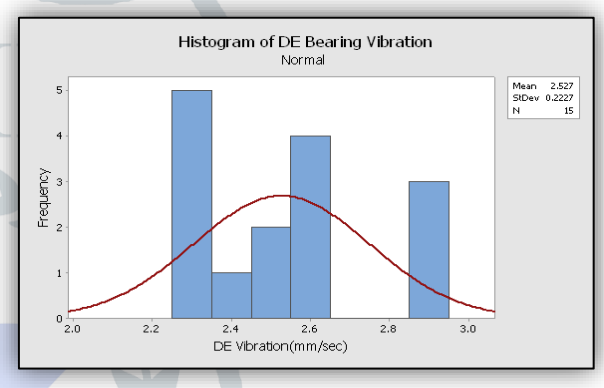


Fig 4.2: Histogram of DE bearing Vibration

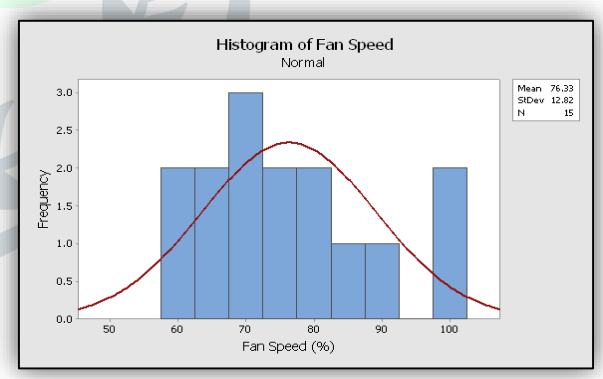


Fig 4.3: Histogram of Fan Speed

- It can be seen that vibrations are satisfactory for operating speeds of the Fan ranging from 60% to 100%.
- Mean of vibrations is 2.527mm/sec as can be seen from Histogram.
- Mean of Operating speed is 76.33% as can be seen from Histogram.

Sp. O_2, Reduced Gas (RG) CO_2% and Cross over Temperature before and after Modification

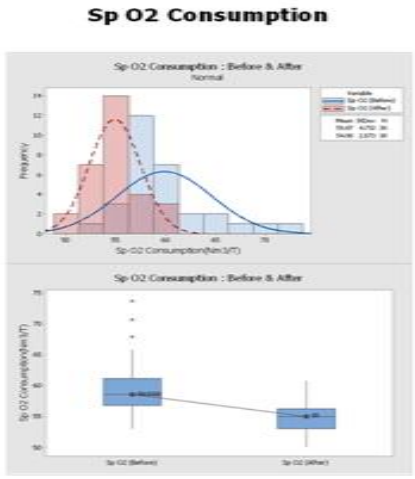


Fig 4.4: Histogram of Sp. O_2

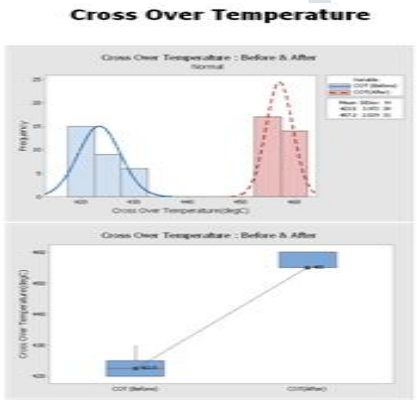


Fig 4.5: Histogram of Cross over temp

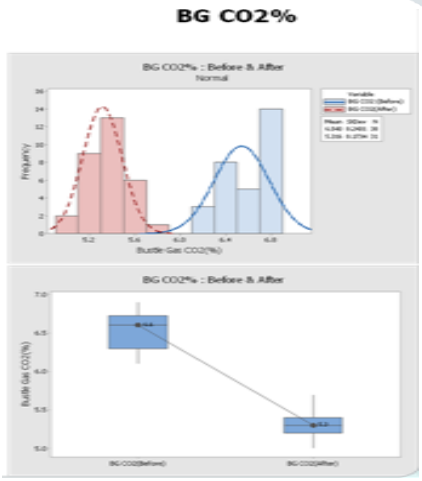


Fig 4.5: Histogram of RG (BG) CO_2%

5. CONCLUSION

In the present work TQM tool like Brainstorming is used on a RC Fan to identify the probable causes, and identified problem in the existing SOP, which resulted in high vibration at the Drive end bearing, also in tripping of RC fan and forced to operate the fan at reduced speeds. To eliminate this problem SOP has been revised and changed the MOC of the impeller from Carbon Steel with Rubber lining on it to Duplex Stainless steel, resulting in improved operating conditions of the Recirculation (RC) fan.

REFERENCES

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