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Operational anomalies identification of the turbo blowers using statistical analysis of the experimental data

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Abstract. In this paper is presented a method for anomalies identification that may occur in equipments operation because of the large variations, above the limits, of the process parameters. The method is developed by using statistical approach and visualization tools of the processed data. The scientific visual method is generally used to control, monitor and improve processes by removing special cause variation. The statistical process control (SPC) has an advantage over other methods, because it can be applied to any process with its emphasis on early detection and prevention of problems. The objective for this paper is to present the technique used to control and monitor the Turbo Blower equipment, from steel industry. The purpose of statistical analysis is to ensure that all processes function as accurately as possible within the tolerance limits.

1. Statistical process control in industry

Companies are in constant competition and the fact the prices of the raw materials is constantly increasing leads to increasingly difficult financial situation in all sectors of activity. If the price of the raw materials can be controlled, the companies must focus on what they can control: their industrials processes and their equipment. For this must strive for efficiency, continuous improvement in quality and cost reduction. The Statistical Process Control (SPC) is implemented to go a company in different directions and one of this direction is to prevention based by quality controls than detection. With the help of monitoring the performance of a process in real time can detect the changes in process or trends of process before them consequences in non-conforming scrap and product. Statistical process. It is a strategy for reducing variability, which is the cause of most quality problems. [1]

SPC includes graphical tools to illustrate the charts and control charts and statistical process control methods provide objective means of controlling quality in any transformation process.

The transformation of a set of inputs, which can include actions, materials, operations and methods, into outputs, in the form of information, services, products or results is characterized by a process. Each process is analyzed by an examination of entries based on the process and the outputs. These measurements will determine the action necessary in the analysis to improve quality.

The first step to analyze and to monitor any process is to identify which are the processes, the entries and the outputs. To set up the scope of a process is indispensable, because it will determine both the required inputs and the outputs.



Fig. 1 Applied method for Statistical process control analysis [2]

To identify the major abnormalities is necessary to collect the data to discover the actual situation, compared to the past and to predict future problems. After data are collected, they are analyzed, and the information is extracted through the use of statistical methods. [3]

2. General description for Turbo Blowers equipment

The Turbo Blowers is the first equipment in the air blast system, it's given a steadier blast and a better measurement of blast for blast furnace. A blast furnace (BF) produces hot metal (liquid iron) as result of the reduction of ore with decreasing gases. The decreasing gases are produced by reaction of oxygen with coal and coke. This equipment suctions the air from atmosphere and compresses it to the required pressure and flow. The compressed air used in the chemical reduction process is generated by the turbo blower and injected into the blast furnace. [4] In the figure below is shown the major components of the blast furnace and the circuit of the air to blast furnace.



Fig. 2 Schematic of air blast system for BF

The main elements of an air blast system of a blast furnace is composed by: cold blast main, hot blast stove, blow tubers and pipes, hot blast main and the controls instruments. For some very large BF is operate two blowers which are assemble with auxiliary equipments: turbine, compressor, circulator, air coolers and capacitor. The achievement of the control for parameters is very important because air blowers can influence the BF operating condition.

In generally, for turbo blowers (TB), variation of the air flow and pressure is made by adjustment of the turbine speed. The control system is composing of the following controllers: speed controller, airflow controller. Each one of these controllers is monitoring with the help of sensors and due to the complexity of TB equipment is named critically.

Because the turbo blower is very complex equipment, the control of all functionalities and all involved needs to be done through statistical and predictive analysis.

3. Visualization software used for SPC analysis

Power BI is classified as business analytics software and is created by Microsoft and provide to business intelligence and interactive visualizations. The interface disposes by a desktop-based interface, named "Power BI Desktop", which offer data warehouse capabilities for data preparation, data discovery and interactive dashboards. [5] Moreover, Power BI offers the opportunity to create formula based approaches or statistical methods and this is the ability to automatically generate graphical views for realizes a developed analysis. The applied statistics formulas in this study are briefly represented in the next table (Table 1).

Capability Parameters	Performance Parameters
s-> standard deviation	S-> standard deviation of the individuals in the
T-> tolerance	subgroup.
USL-> value of the upper specification limit	T-> tolerance
LSL-> value of the lower specification limit	USL-> value of the upper specification limit
\bar{x} ->average of measurement values	LSL-> value of the lower specification limit
$s = \sqrt{s^2}$	Avg->Average
$s^{2} = \frac{1}{n-1} \sum_{i=1}^{n} (x_{i} - \bar{x})^{2}$	$S = \sqrt{\frac{m_2 - \frac{m_1^2}{m_0}}{m_0 - 1}} Avg = \frac{m_1}{m_0} m_0 = \sum x_i^0 \ m_1 = \sum x_i^1$
$\bar{x} = \frac{1}{n} \sum_{i=1}^{n} x_i$	$m_2 = \sum x_i^2 m_3 = \sum x_i^3 m_4 = \sum x_i^4$ $P_p = \frac{\text{USL-LSL}}{\text{USL-LSL}}$
$IISI = \overline{x} + 3s$ $ISI = \overline{x} - 3s$	$P_{pu} = \frac{\text{OSL-AVg}}{3S} P_{pl} = \frac{\text{AVg-LSL}}{3S}$; Process performance
USL-LSL	for upper and lower limit
$L_p = \frac{1}{3s}$; Process capability for lower and	$P_{nk} = \min[P_{nl}, P_{nu}];$ Process performance for
upper limit	assumes process output is normally distributed
$C_{nu} = \frac{USL - \bar{x}}{2\pi}$ $C_{nl} = \frac{\bar{x} - LSL}{2\pi}$; Process capability	USL-LSL
for upper, lower limit and average	$P_m = \frac{1}{6S}$
$C_{nk} = \min[C_{nl}, C_{nn}]$; Process capability for	$P_{nm} = \frac{P_p}{P_p}$; Taguchi performance index
assumes process output is normally distributed	$\sqrt{1+(\frac{Avg-T}{S})^2}$
$C = \frac{USL - LSL}{USL - LSL}$	100
$c_m = \frac{1}{6s}$	$P_r = \overline{P_p}$

$$C_{pm} = \frac{C_p}{\sqrt{1 + (\frac{\bar{x} \cdot T}{s})^2}}; \text{ Taguchi capability index} \qquad P_{Zu} = \frac{\text{USL-Avg}}{s} P_{Zl} = \frac{\text{Avg-LSL}}{s} P_{Zu} = \frac{\text{Isl} \cdot Avg}{s} P_{Zl} = \frac{\text{Avg-LSL}}{s} P_{Zu} = \frac{100}{s} P$$

Table. 1 Statistical Process Control [6]

In the next fig. is show the main statistical methods control used for identifier the operational anomalies identification of the TB and calculate from sample points, formulas or are predefined the control limits. Moreover, historical data can be viewed from control charts, and for a chosen process, all control charts of its characteristics with the help of statistical methods control are shown in one place. Other visualization methods include histograms, diagrams, probability and general statistics of data. They provide methods for analysis of the observed data, for checking whether the data is normally distributed and when the data is not normally distributed, SPC can generate some alarms. [7]



Fig. 3 Control Chart view implemented in Power BI

4. Data analysis of compressor from TB

The role of this component is to compress the atmospheric air for injection in BF. It's built in single equipment, with 2 parts, which disposes 4 air gears, in the first two gears of compressing; the air is directed to cooler air situated outside of the compressor. The third and the fourth gears is realizing in a single workflow.

This part of TB equipment serves to secure the required air flow and the pressure for BF and in the forthcoming figure is show the air circuit from turbine to BF, the compressor localization and the air blast which entered in the stove, from compressor, it was preheated by hot bricks and exited the stove as a hot blast. The air blower is required to be operated to meet the air flow conditions which in turn are determined by the operating condition of the blast furnace.



Fig 4. General diagram – flow of the compressed air

In order to analyze the performance of the TB compressor are necessary the parameters: air flow and air flow under conditions of suction, pressure, number of rotations, the variation of limits, numbers of cylinders, temperature of air aspired, temperature discharge of air and these are simulated with Power BI software. The parameters are analyzed using SPC methods control and it's transposed in Power BI software.

The parameters collected using the SPC methods control in Power Bi software are presented in Fig. 5 where we can be observing the evolution of air flow which is reveal the evolution, the variation for air flow and air flow under conditions of suction and pressure. These parameters are based on steady and in a range numbers of rotation and approximately the same atmospheric temperature. Data acquisition is made in 3 timeframes and based on monitoring and analysis of the process inputs and outputs to determine if the process doesn't respect the limits. The principal goal is to prevent defects.



Fig. 5 Data analysis from compressor

In fig. 6 the control limits are set with the help of USL (upper specification limit) and LSL (lower specification limit) formula, which is descript by standard deviation and average of measurement values for established the upper and lower process control limits for airflow TB.



Fig. 6 Control limits for airflow

Control limits of pressure, in fig. 7 are set with USL and LSL formulas for established control limits. For pressure was established 3.2 bar for LSL and 4 for USL, but it can be seen the average is situated under lower specification limit with a percentage between 10-19%.



Fig. 7 Control limits for pressure

5. Conclusion

The method described above for control and monitoring the important parameters from TB process help us to identify a functional anomaly to compressor. In Power Bi software, the statistical formulas were implemented in order to obtain the desired results. The graphic from Fig.8 emphasis that the pressure from compressor is not located between UCL and LCL and it can be seen that the airflow is declining. These results are very important for the maintenance engineering staff for checking and control the compressor, part of TB equipment. The functionality of TB is vital for BF and this equipment is very critical.

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