Design of Experiment as a Tool to Check the Feasibility of using A Mathematical Model for Optimization of A Multifuel Boiler

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***Abstract*— Taguchi methodology of optimization is applied extensively in several fields. This paper presents the application of Taguchi methodology of the steam generation in multi fuel Boiler, to optimize the standard parameters and output of total steam production. The target of the study is to enhance the operational excellence in steam generation method with the employment of Taguchi technique. The result shows that the parameters FWT, FWP, PBD, TASS, TAWE, PASS have a effect on the amount of total steam generated. This study helps in improvement of operation and efficiency of multi fuel boiler.**

Keywords- Optimization; Design of Experiment; Taguchi Technique; Orthogonal L8 array; signal to noise ratio; software – Minitab -16.

I. INTRODUCTION

Multi-fuel boiler is a type of boiler, or heater or other fuel-burning device which is designed to burn multiple types of fuels in its operation.

Multi-fuel boilers typically burn a mixture of waste or alternate fuels along with natural gas, fuel oil, and pulverized coal. This provides to us an opportunity to produce steam at lower cost than a basic fossil fuel fired unit but it also make operations more challenging. Waste and alternative fuels vary in Btu content per volume and their supply is often not consistent. This significantly affects the combustion stability and the ability to reliably meet the load. More expensive fossil fuel must be used when waste and alternate fuel is not available to make up for low Btu. Manage this without excessive cost is too difficult. In addition operating within emissions constraints may be a problem with multiple fuel streams in the mix.

The principal energy flows between the various production sections in an integrated steel plant are byproduct gases are generated in the primary reduction process in Blast Furnaces or in Coke ovens and in the steelmaking process in Basic Oxygen Furnaces. Gas holders are available for gas storage to compensate for the temporary imbalances between consumption and production rates. Surplus gas that cannot be used in the processes or in the power plant.

The power plant has steam boilers that can be fired with various combinations of fuels, including byproduct gases, imported natural gas, and byproduct or purchased liquid fuels. The steam produced in the boilers is used to generate electricity in the power plant and supplied to various consumers in the production sections, Chilled water plant building heating etc.

The boilers uses coal dust, Blast furnace gas, Coke Oven Gas, as fuels separately or in combination.

In this case, the gas network consists of three different types of gases with different calorific values as follows:

- Blast Furnace Gas (BFG)
- Coke Oven Gas (COG)
- Basic Oxygen Furnace Gas (BOFG)
- PCM Oil

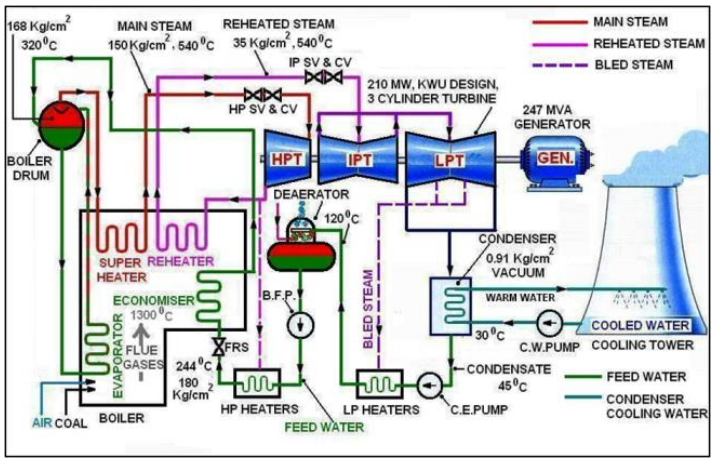

Figure-1 Process of multi-fuel Boiler

Basic components of Multi-fuel Boiler are as follow.

- Boiler drum.
- Economiser.
- Superheater.
- Turbine.

- Condenser.
- Deaerator.
- Pump.

With the help of Taguchi Method we will optimize the input and output parameters. Taguchi methods are statistical methods developed by The Genichi Taguchi to improve the quality of manufactured goods and more recently also applied to engineering biotechnology marketing and advertising.

Taguchi method is a scientifically disciplined mechanism for evaluating and implementing improvements in product, process, materials, equipments and facilities. There improvements are aimed at improving the desired characteristics and simultaneously reducing the number of defects by studying the key variables controlling the process and optimizing the procedures or design to yield the best result.

II. LITERATURE SURVEY

Jian-GuoWang In this paper A data-driven modeling and optimization scheme for thermal efficiency is developed based on the real operation data from a multi fuel boiler. The input variables of Plants are transformed into the derived variables which are physically and statistically meaningful for modeling. Then the study proposed an adaptive modeling approach by employing nonnegative garrote variable selection and auto-regression integrated moving average correction. The high accuracy of the proposed modeling approaches makes the implementation of the model based control of ratio of air to fuel for improving boiler's efficiency readily practicable.

Nakao Nobuyuki, Shimamoto Hiroyuki and Yamamoto Koji (3) have developed a new combustion control system that is capable of achieving the stable combustion for various multi-waste-fuels in the circulating fluidized bed boiler (CFB). This system has advanced control functions with a rule based type multipurpose control. This device was applied to furnace temperature control exhaust gas stabilization control and blowing control.

Andrew Dobrzanski the 651 MW coal-fired River Rouge Power Plants (RRPP) of Detroit Edison, a subsidiary of DTE Energy was constructed in the late 1950's at a location near integrated steel mills equipped with coke oven batteries and blast furnaces. This plant is also located adjacent to an oxygen pipe line. This paper describes the present and planned use of alternative fuels at RRPP focusing on the COG. It also considers the BFG program and several additional opportunity fuels. It also considers the potential for oxygen enhanced combustion at RRPP as a process now under consideration. The paper focuses upon the characteristics of the alternative fuels the current and potential method of firing these fuels, the typical frequencies and percentages of fuel supplied by COG and BFG issues of potential combustion control, and the consequence of their use. Consequence include Improved pulverizes performance and coal combustion, reduced air burne emissions reduced ash management issues and related mechanical systems consideration.

Qingyan Fang carried out A computational fluid dynamics (CFD) model of a 200 MW multi fuel tangentially fired boiler has been developed using Fluent(6.3.26) which is able to modeling the three fuel combustion system of coal, blast furnace gas (BFG), and coke oven gas (COG) with an eddy dissipation model for simulating the gas phase combustion. A level of confidence in the current CFD model has been established by carrying out a mesh independence test and validation against the experimental data obtained from the boiler for case study. The validated CFD model was then applied to investigate the effects of different BFG and COG flow rates on the boiler performance.

III. PROBLEM IDENTIFICATION

In boiler the total steam generation may varied due to the variations of amount of the different parameters. When value of parameters was different with respect to the time then the total steam generation was not stable it also may vary. How to know which parameter was very responsible for large amount of steam generation was not a possible. Now the task is the selection of best combination of values of parameters for the large steam production.

IV. METHODOLOGY

- Data collection, Some of the vital parameter which will be recorded are as follows Feed water temp, Super heated steam temp, boiler drum pressure, Steam load etc although the number of parameters would eventually exceed the one listed and the number of parameters would be increased as per the requirement of the experimental model.
- Identify the critical parameters affecting the experimental model in the preliminary studies the sound vital parameters are as follows Water level, water consumption, air pressure, feed water pressure, consumption of fuel, gas pressure etc.
- Formulation of mathematical model will involve the backup of the thermal calculation coupled with the various non conventional methods under the non linear optimization process this can be pure model or hybrid model as per the requirement.
- To improve the efficiency.

V. EXPERIMENT AND DATA COLLECTION

A. Experimental setup

Collection of data from Multi fuel Boiler for Optimization of Boiler. There are different kinds of parameter in which selected the best effective parameters and also select the two level for Analysis of data In this analysis we select the input and output parameters and solve this with the help of Taguchi method.

B. For Experiment Work

To achieve the optimum Steam Generation in the multi fuel boiler with the help of following parameters:-

There are six input parameters they are-

i) FWT
ii) FWP
iii) PBD
iv) TASS
v) TAWE
vi) PASS

There are one Output parameter –

i) TSP – TOTAL STEAM PRODUCTION

C. Planning phase input parameters and there levels are following-

TABLE- I PARAMETERS AND ABBREVIATION OF MULTI FUEL BOILER

PARAMETERS FOR TESTING		
PARAMETERS	**ABBREVIATION**	**SYMBOL**
Feed Water Temperature	FWT	Factor A
Feed Water Pressure	FWP	Factor B
Pressure in Boiler Drum	PBD	Factor C
Temperature After Steam Super heater	TASS	Factor D
Temperature After Water Economizer	TAWE	Factor E
Pressure After Steam Super heater	PASS	Factor F

TABLE- II SELECTED LEVEL OF INPUT PARAMETER

LEVEL	FWT	FWP	PBD	TASS	TAWE	PASS
1	82	439	37.8	618	268	5
2	101	452	41.4	665	285	9

D. Design Of Experiments (DOE)

For selected input parameters experiments are designed using Taguchi L8 orthogonal standard array. For this purpose software Minitab 16.0 is used for Design of Experiment was done to check the Optimization of multi fuel Boiler.

TABLE III PARAMETERS ARE ARRANGED IN AN ORTHOGONAL L8 ARRAY

EXP. NO.	FWT	FWP	PBD	TASS	TAWE	PASS
1	82	439	37.8	618	268	5
2	82	439	37.8	665	285	9
3	82	452	41.4	618	268	9
4	82	452	41.4	665	285	5
5	101	439	41.4	618	285	5
6	101	439	41.4	665	268	9
7	101	452	37.8	618	285	9
8	101	452	37.8	665	268	5

E. Experimentation

Taguchi method stresses the importance of studying to the response variation using the signal-to-noise (S/N) ratio resulting in minimization of quality characteristic variation due to parameters. In this experiment we take six input parameters which are shown in table and one Output parameter which is Total Steam Production. Total Steam Production as the quality characteristic with the concept of the larger-the-better. The S/N ratio used for this type response is given by:-

The S/N ratio for (the larger the better) is:-

S/N = -10*log (mean square deviation)

$S/N = -10 \log 1/n (\Sigma 1/y_2)$

Where n is the number of measurement in a trial / row, in this case (n=1) and y is the measured value in a run / row. The values of S/N ratio are calculated by taking into consideration. The response values measured from the experiments and their corresponding S/N ratio values are listed in table- 4.

TABLE IV RESPONSE VALUE AND S/N RATIO VALUE FOR EXPERIMENTS

S. No.	TSP	S/N RATION
1	930	59.29
2	907	59.26
3	948	59.38
4	923	59.3
5	938	59.33
6	917	59.29
7	905	5925
8	928	5931

VI. RESULTS

TABLE- V TABLE OF RESPONSE FOR SIGNAL TO NOISE RATIOS

LEVEL	FWT	FWP	PBD	TASS	TAWE	PASS
1	59.34	59.3	59.25	59.37	59.38	59.37
2	59.29	59.33	59.38	59.26	59.26	59.27
DELTA	0.05	0.03	0.13	0.11	0.12	0.1
RANK	**5**	**6**	**1**	**3**	**2**	**4**

Regardless of the category of the performance characteristics a greater S/N ratio value corresponds to a better performance. Therefore, the optimal level of Steam generation will be done and these parameters are the level with the greatest S/N value.

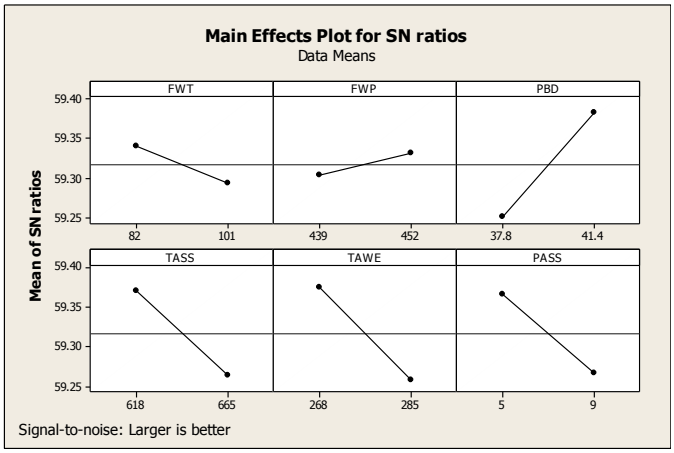

Figure-2 Main Effect plot For S/N Ratio

In this experiment we put all the values of parameters in taguchi technique (in Minitab-16) and get the result which are shown in table 5.

Based on the calculations the optimal Total steam production obtained when Pressure in Boiler drum was 37.8 (level 1) and 41.4 (level 2) this is the very responsive parameter.

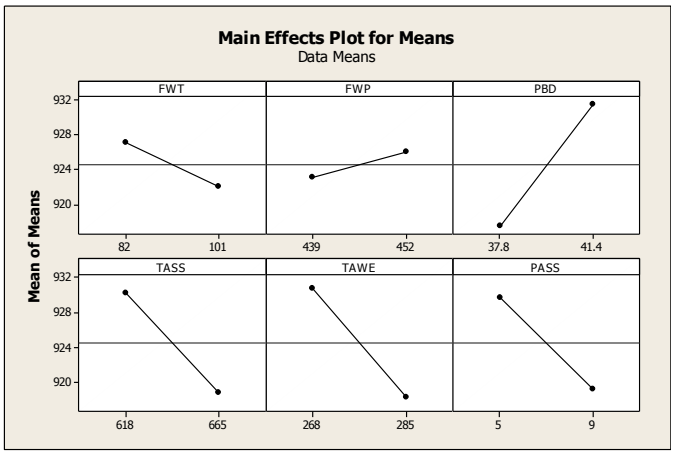

Figure 3 Main Effect plot For Means

VII. CONCLUSION

This paper explains the application of the Taguchi method in the optimization of multi fuel Boiler for steam generation. From the analysis of the results using the signal-to-noise (S/N) ratio approach and Taguchi's optimization method the following can be concluded-

1) In this work the effect of amount of different parameters FWT, FWP, PBD, TASS, TAWE, PASS are studied on the optimal steam generation for a multi fuel Boiler.

2) For larger and optimal TSP we select the lager S/N ratio. We select the rank which is in the observation table it indicates the best combination of value of the parameters.

3) We conclude that the PBD is the very responsive parameter and shows the great effect of this parameter in TSP. According to the observation PBD has a rank first. FWP is very less effective parameter for TSP.

4) From the graph S/N ratio it can be observed that the optimal value of TSP was obtained as when the input is 37.8 (level 1) and 41.4 (level2) and we get the final output TSP was 948 and the best S/N ratio was 59.38.

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