Design of Furnace Burner For Thermal Power Plant Using CFD And It's Optimization

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Abstract - Thermal power plants are one of the most important process industries for engineering professionals. Over the past few decades, the power sector has been facing a number of critical issues. Also look after a range of activities, including research and development, starting from power generation, to environmental assessment of power plants.

Keywords - Power Plant, Furnace Burner, Optimization, CFD.

I. INTRODUCTION

1.1 Introduction Of Tangentially Fired Burners In Thermal Power Plants

Thermal power plants are one of the most important process industries for engineering professionals. Over the past few decades, the power sector has been facing a number of critical issues. Also look after a range of activities, including research and development, starting from power generation, to environmental assessment of power plants. In thermal power plant, the chemical energy stored in fossil fuels such as coal, fuel oil, natural gas is converted successively into thermal energy, mechanical energy and finally electrical energy for continuous use and distribution across a wide geographic area.

Figure 1.1: View of thermal power plant

Whilst a fuel-lean mixture, including water vapour, inert gases, and remaining of PC, is delivered to the inert burner ducts (upper burners). Computational fluid dynamics (CFD) modelling studies can comprehensively provide a wide range of information for the design of furnace and burner that can reduce the cost of time-consuming experimental investigations.

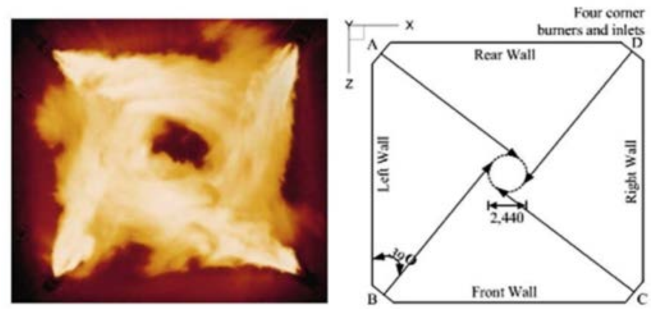


Figure 1.2: Central vortex & four corner burner's furnace configuration

The majority use variations of the SIMPLE algorithm and the k–e gas turbulence model, or some derivatives, like RNG k–e model or k–e– kp two phase turbulence model. Gas phase conservation equations are mostly time-averaged. A two-phase flow is usually described by Eulerian–Lagrangian approach and PSI-Cell method for coupling of phases, with some exceptions using Eulerian–Eulerian approach, or two-fluid trajectory model. Most of the combustion submodels given in treat particle devolatilization, char oxidation and additional gas phase reactions separately.

Yuegui Zhou, TongmoXu, ShienHui, Mingchuan Zhang [2009][5], Present the paper "Experimental and numerical study on the flow fields in upper furnace for large scale tangentially fired boilers", in this examined the

Experimental and numerical study on the aerodynamic field has been carried out in a tangentially fired boiler model of a 600MW unit. The results show that there exists residual swirl intensity of nearly 20% at the entry of the plate zone in upper furnace for large scale tangentially fired boilers.

Audai Hussein, Al-Abbas, Jamal Naser , David Dodds[2012][1], present paper on "CFD modelling of air-fired and oxy-fuel combustion in a large-scale furnace at Loy Yang A brown coal power station"**,** explained the study of oxy-fuel combustion in a large-scale tangentially- fired boiler is important prior to its implementation in real-life power plant. The simplified approach of the chemical kinetics has been modelled to calculate the fuel and the thermal NO_x formation.

Choeng Ryul Choi, Chang Nyung Kim[2009][6], discussed about "Numerical investigation on the flow, combustion and NO_x emission characteristics in a 500 MWe tangentially fired pulverized-coal boiler" in this paper The characteristics of the flow, combustion, temperature and NO_x emissions in a 500 MWe tangentially fired pulverized-coal boiler are numerically studied using comprehensive models, with emphasis on fuel and thermal NO_x formations..

Cristiano V. da Silva, Maria Luiza S. Indrusiak, Arthur B. Beskow[2010][7], explains in the paper "CFD Analysis of the Pulverized Coal Combustion Processes in a 160 MWe Tangentially-Fired-Boiler of a Thermal Power Plant." that to reduce CO_2 emissions through increasing efficiency. Also NO_x and SO_x emissions should be reduced to environmentally acceptable levels.

Aruna Devadiga, Prof. Dr. T. Nageswara Rao[2013][8], investigated about "Optimizing Bunsen burner Performance Using CFD Analysis", in which shows Improvements in burner energy efficiency and performance can have significant impacts in a continuous operation. To make improvements, it is critical to understand the dynamics of the fuel fluid flow and the flame and its characteristics. Computational Fluid Dynamics offers a numerical modelling methodology that helps in this regard. The products obtained in the combustion process, adiabatic flame temperature, flame length, degree of diffusion flame, are all a direct function of the stoichiometry.

II. EXPERIMENTAL VALIDATION

Secondly, a wider range of test conditions and better control of the operating conditions in the facility are possible in a smaller facility that is controlled by the group conducting the test program. Thirdly, not only can the smaller furnace be carefully controlled, but also because of its size and access ports, the entire furnace volume can be traversed with small incremental steps, so that much more detailed data sets can be obtained.

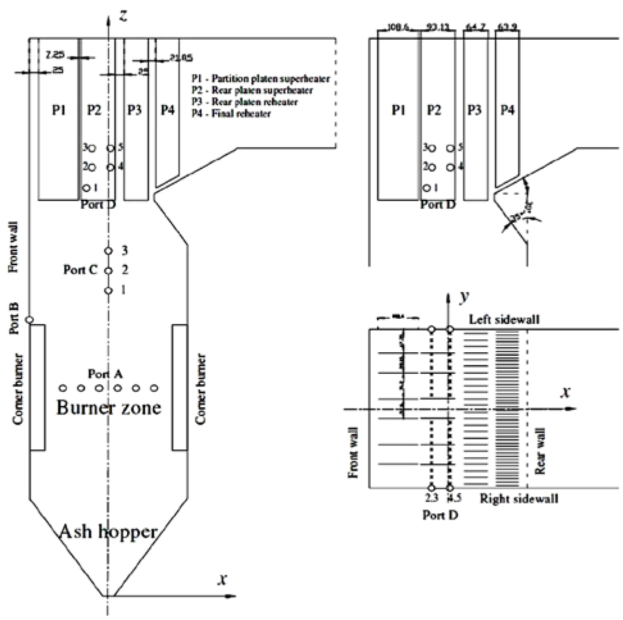
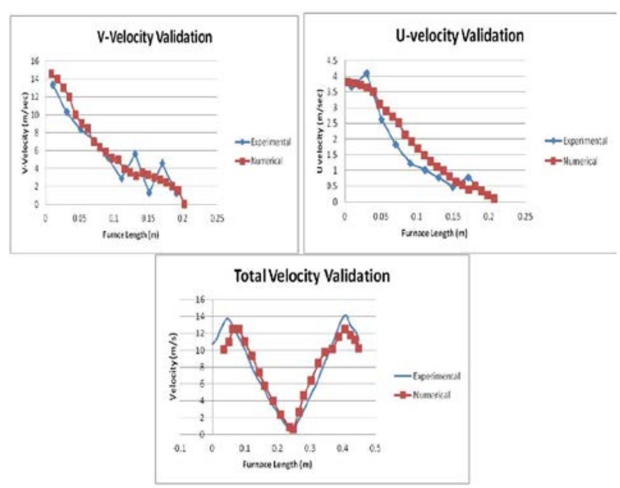


Figure 2.1: Schematic diagrams of TFF, its panel heaters, and measurement ports installed in the central furnace and behind the partition platen superheaters.



Graph 2.2: Validation of Numerical results with Experimental data

III. EFFECT OF PARAMETERS ON THE PERFORMANCE OF TANGENTIALLY FIRED FURNACE

- To design and optimize the furnace burner for 600MW plant
- To investigate the vortex strength of tangentially fired boiler, sustains the flame propagation for efficient combustion
- To investigate the effect of the following important parameters on vortex formation
  - ✓ Burner Angle
  - ✓ Inlet Velocity
  - ✓ Burner Size
  - ✓ Burner Mounting/configuration

3.1 Effect of Burner Velocity:

A jet is produced when a fluid is discharged through the nozzle. Spreading of the jet is due to entrainment of the surrounding. Due to entrainment of the surrounding, the axial velocity of the jet decreases. For any downstream axial distance, the maximum velocity is at the centre and minimum at periphery such that a parabolic profile is developed as shown in figure 3.1.

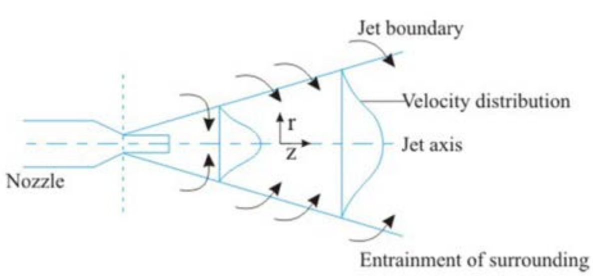


Figure 3.1 Jet dynamics from the burner as nozzle

3.1.1 Burner Velocity (V=8 m/sec)

The burner velocity is slowed down by reducing the mass flow rate for the given size of burner area from 14m/sec to 8m/sec. The contours of velocity magnitude and corresponding static and total pressure are shown in the Figur3.2.

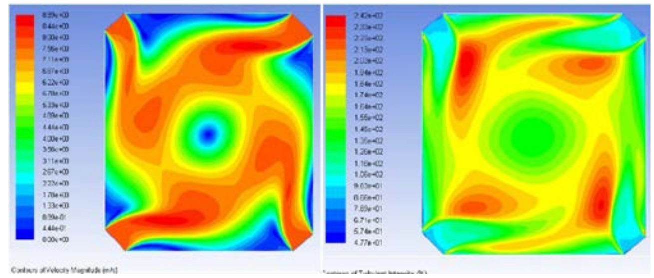


Figure 3.2: Contours of velocity magnitude and turbulence magnitude for Burner Velocity 8 m/sec

3.1.2 Burner Velocity (V=10 m/sec)

The burner velocity is decreased from the base case i.e. from 14m/sec to 10 m/sec for understanding the effect of Burner velocity on the turbulence dynamics in the Burner.

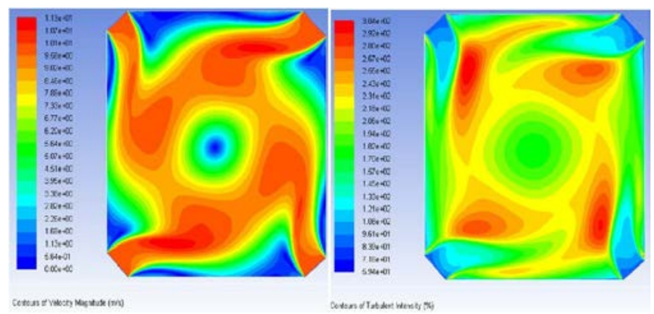


Figure 3.3: Contours of velocity magnitude and turbulence magnitude for Burner Velocity 10 m/sec

3.1.3 Burner Velocity (V=12m/sec)

The burner velocity is further increased from the previous cases to 12 m/sec by less than the base case velocity. The Contours are shown in the Figure 3.4

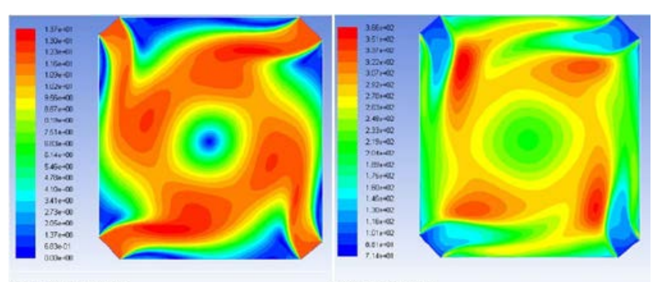


Figure 3.4: Contours of velocity magnitude and turbulence magnitude for Burner Velocity 12 m/sec

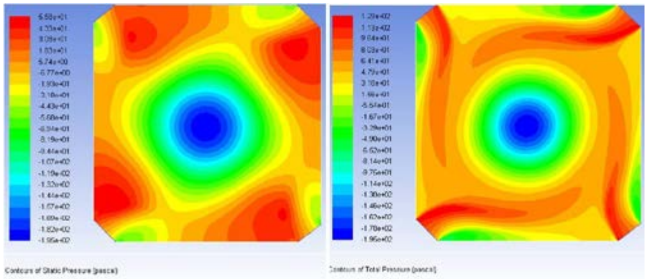


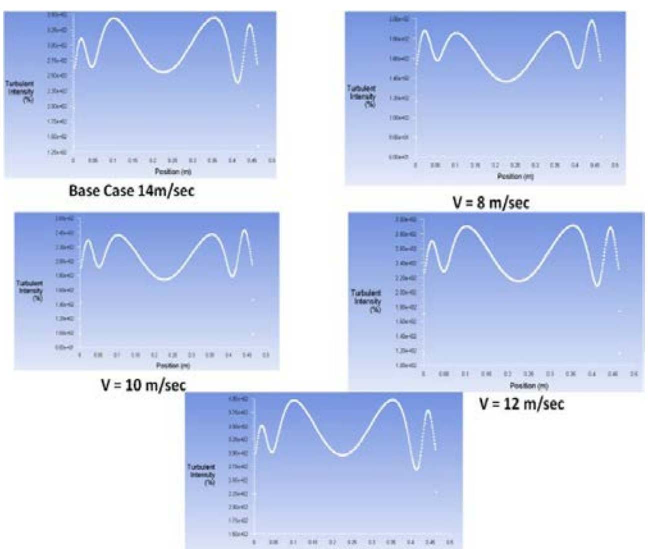
Figure 3.5: Contours showing Static and Total Pressure for Burner Velocity 12 m/sec

IV. RESULTS AND DISCUSSION

The furnace burner is designed and analysis is performed for different key parameters like burner velocity, burner angle, burner size and its configuration. The analysis of the above parameters are combined for the best combination of parameters with the objective function to maximize mixing efficiency in the burner which ultimately produces efficient combustion and reduces the losses in the mixing stage. The efficient combination of parameters produces cost saving design for better performance of overall plant.

4.1 Effect of Burner Velocity:

The turbulence intensity is checked for all the design variables for the velocity i.e. 8, 10, 12, 14, and 16 m/sec.

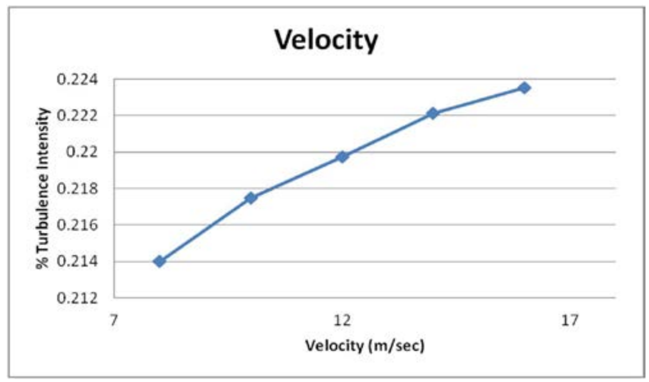


V=16 m/sec

Graph 4.1: % of Turbulence intensity at different positions for different velocities

Table 4.1: Turbulence intensity (%) for different velocity

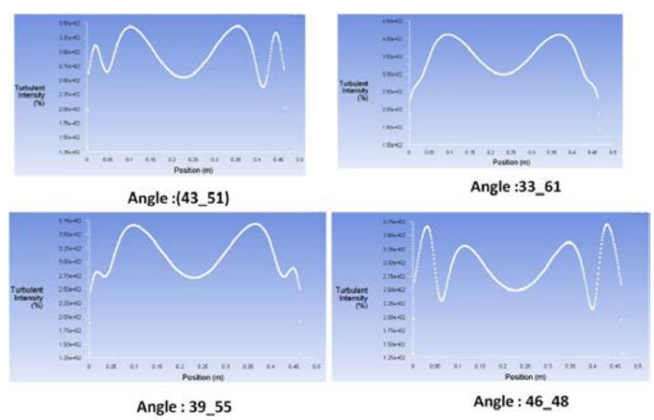
Velocity (m/sec)	Avg. Turbulence Intensity	Max(Circle region)	Total	%
10	2.07	215.54	991	0.217
12	2.52	265	1206	0.219
14	2.96	315	1418	0.222
16	3.42	365	1633	0.223



Graph 4.2: % of Turbulence intensity at different velocities

4.2 Effect of Burner Angle:

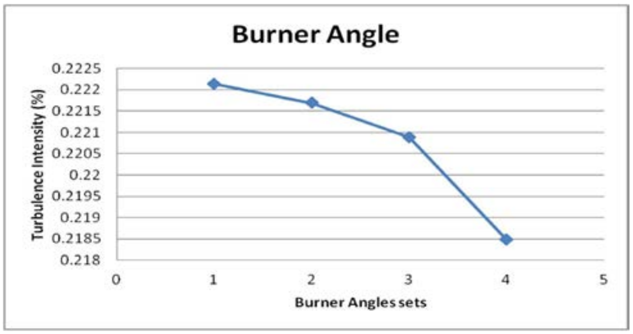
The turbulence intensity is checked for all the design variables for the Burner Angle i.e. (33^0,61^0),(43^0,51^0), (39^0,55^0) and (46^0,48^0). Out of which the results are compared with the Base case results i.e. (43,51). The turbulence plots for different angles are shown as below.



Graph 4.3: % of Turbulence intensity at different positions for different burner angle sets.

Table 4.2: Turbulence intensity (%) for different Burner Angles

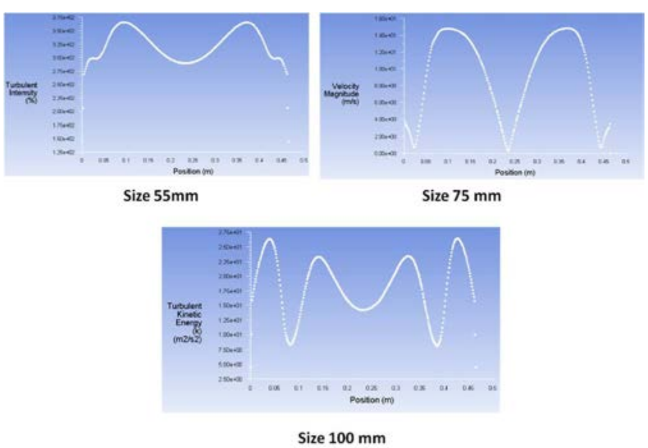
SET	Burner Angle	AvgTurb Intensity	Max (Circle region)	Total	%
1	43_51	2.96	315	1418	0.222144
2	33_61	3.46	366.9	1655	0.221692
3	39_55	3.12	330	1494	0.220884
4	46_48	2.92	305	1396	0.218481



Graph 4.3: % of Turbulence intensity at different burner angle sets

4.3 Effect of Burner Size:

Burner Size decides the mass flow rate of air and fuel coming into the furnace for efficient combustion for the same flow velocity. The different burner sizes are studied for maximization of turbulence intensity of the mixture i.e. the flame stability.[15]



Graph 4.5: % of Turbulence intensity at different positions for different burner sizes.

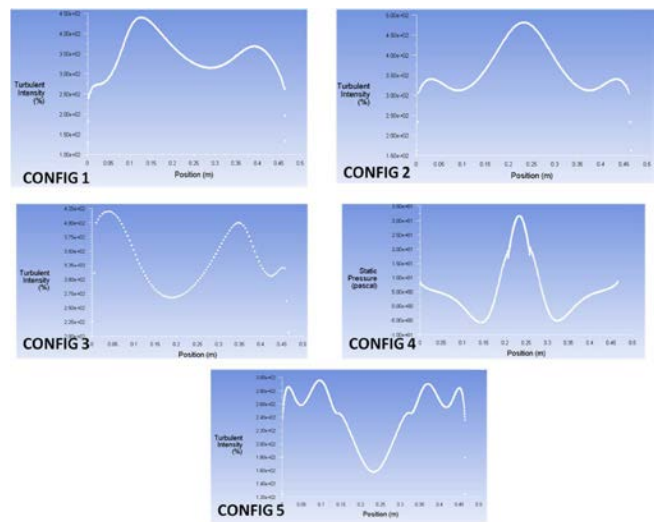
Table 4.3: Turbulence intensity (%) for different Burner Size

Size (mm)	Average Turbulence Intensity	Max. (Circle Region)	Total	%
56	3.2	216	929	0.23
75	3.32	245	1000	**0.26**
100	3.47	259	1394	0.19

Graph 4.6: % of Turbulence intensity at different burner size (mm)

Increase in burner size increases the average turbulence intensity but doesn't fetch better mixing in the center, due to which the intensity increases then decreases, optimum burner size is selected a 75mm which is also available in manufacture's range.[16]

4.4 Effect of Burner Configurations:



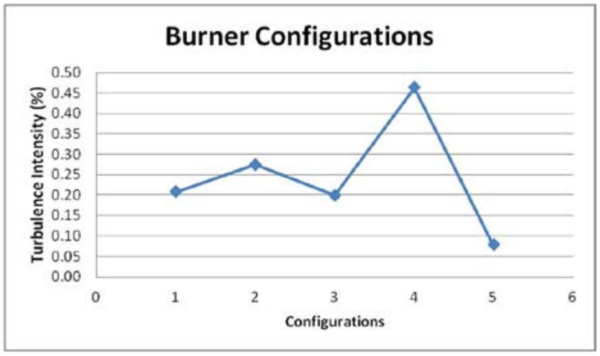
Graph 4.7: % of Turbulence intensity at different positions for different burner configurations.

Different burner's orientation is checked for understanding the flow pattern and flame stability compared to tangentially fired burners.

Table 4.4: Turbulence intensity (%) for different Burner Configurations

Configuration	Average Turbulence Intensity	Max (Circle Region)	Total	Pressure Loss (Pa)	%
1	3.46	335	1613	170	0.21
2	3.64	232	848	180	0.27
3	3.34	67	337	187	0.20

4	2.54	673	1453	192	0.46
5	2.57	221	2856	138	0.08



Graph 4.8: % of Turbulence intensity at different burner configurations

4.5 Optimum Burner Design:

From the above analysis of different parameters, optimum design parameters are selected which produces better results among the selected combinations, individually.[18] The study is performed to check the effect of different parameters on the burner efficiency which is directly related with the turbulence intensity.[19] The optimum parameters are analyzed sequentially and effect is checked separately keeping the others parameters constant for studying the single variable on flame stability. The optimum parameters are coupled together to analyze the optimum geometry effect.[20]

Table 4.5: Optimum Combination of parameters

Parameters	Optimum Range
Burner Size	75.1 mm
Burner Velocity	16.2 m/sec
Burner Angles	430, 510
Configuration	(No.1)Four Burners at Corners

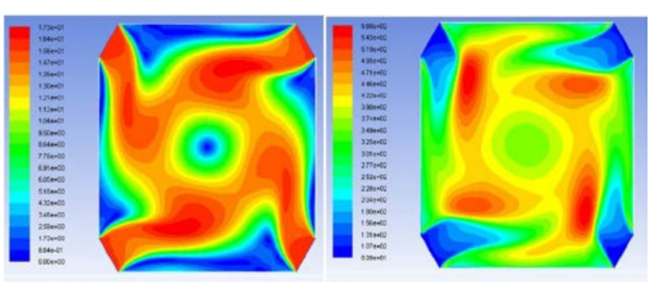


Figure 4.1: Contours showing velocity magnitude and turbulence magnitude for Burner Angle (43^0,51^0), Velocity 16m/s, size 75mm.

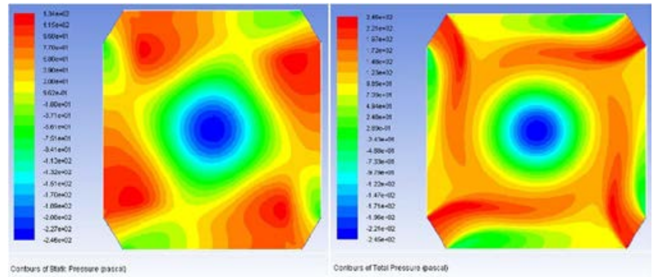


Figure 4.2: Contours showing Static and Total Pressure for Burner Angle (43^0,51^0),

CONCLUSION

The following key points are concluded from the above analysis,

- Thermal power plant burner for 600 MW is studied for maximum flame stability.
- The base design is studied for different design parameters with objective function of increasing the turbulence intensity which directly enhances the flame stability for proper mixing of fuel and air which leads to better combustion efficiency.
- The effect of different parameters are studied on the vortex strength formed at the middle of circle for tangentially fired boilers
- The optimum parameters are coupled and analyzed for the optimum configuration which gives better efficiency than the base case, the intensity i.e. efficiency increases from 22% to 27%.
- The proposed model is quite robust to work for any Reynolds number and any size and configuration of the burner.
- The above change in turbulence intensity makes the combustion process more effective and saves the cost of overall power generation process.

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