Innovation In Energy And Pollution Optimization In Steam Boilers

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ABSTRACT

The environmental laws in India have become strict and it is essential to operate steam boilers in a narrow band that optimizes energy efficiency and at the same time minimize the pollutants being emanated from the Stack. Energy Efficiency and Environmental regulation have often been considered to be at cross-purposes and operators have had a difficult choice to make.

This paper looks at some experimental data on a typical solid fired boiler and then looks at the Correlation between Dust concentration and Excess Oxygen. It also looks at relatively new research that is being worked on to help minimize dust concentrations at lower excess air levels.

Online Boiler Efficiency systems with integrated SPM control and abatement systems form the core of any Boiler house operation. New innovations in Cyclones and ESP systems can also be deployed to optimize energy and environmental performance.

Introduction

Solid fired steam boilers across India have varying degrees of Thermal efficiency and employ different grate technologies for different fuels. However this results in Boilers that differ in performance on Thermal efficiency and pollution parameters. Thus no standardization of performance is easy and detailed performance analysis is required. The Boiler design and its Energy efficiency and pollution control devices also need a detailed assessment. Thus Pollution abatement devices have been deployed from simple cyclones to bag filters and now ESP technology to help keep dust concentrations within statutory limits.

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Through a combination of new technologies that include special hybrid cyclones and compact high efficiency ESP systems and with real time Thermal efficiency and integrated SPM measurement and control systems, steam boilers in pulp and paper industry can benefit from higher operating thermal efficiency and lower dust concentrations.

Typically boiler efficiency is affected by excess air levels passing through the Boiler furnace. Thus it is common to find excess air levels between 6-11 % in boiler stacks. A high level of excess oxygen results in lower energy efficiency, In order to reduce stack loss due to excess oxygen, operators tend to reduce ID or FD fan speeds or dampers which then affects combustion which in turn changes the volatiles and particulate matter discharged from furnaces.

We did some experiments on solid fired boilers and while this needs to be further validated, initial data shows that controlling excess air through the correct method, results in lower dust concentrations combined with the right type of dust abatement device.

Objective behind this analysis is to assess the variation in SPM levels with change in O_2% by controlling ID/FD/Load and to ascertain the optimum oxygen percentage at which the SPM and efficiency compensated.

Experiment conducted at a Paper mill

A) Boiler Details:

I. Make: XYZ Ltd
II. Type: Solid Fired Fluidized bed grate
III. Capacity: 21TPH
IV. Fuel: Husk / Husk (70%) + coal (30%)
V. Max Pressure: 15bar
VI. MDC: Cyclone Separator-6Nos
Bag Filter-1Nos (435 bags, 3mtr Length)
VII. Heat Recovery Systems: APH and Economizer
*All the systems are controlled manually.

B) Plant Operating Conditions:

I. The boiler is operated at a pressure of 13 bar (g) and the steam consumption is 18TPH
II. The boiler is operated at full load most of the time
III. The furnace pressure was maintained at -1 to -3 mmWC.
IV. The bed temperature of the furnace was maintained at 690-750°C.
V. The maximum fuel flow rate is 5670 kg/h. for husk and 6600 kg/h. for mixture of husk and coal
VI. The ID and FD fans were operated at a frequency of 40-50Hz.

ID	FD	O2 %	SPM	Furnace Pr.
Variable	Constant			
41.2	*43.3*	*5.3*	*35*	*-1.46*
41.2	*43.3*	*5.3*	*39*	*-1.38*
45	*43.3*	*5.3*	*58*	*-4.16*
45	*43.3*	*5.5*	*58*	*-4.49*
45	*43.3*	*5.5*	*67*	*-4.3*
45	*43.3*	*5.5*	*58*	*-4.53*
45	*43.3*	*5.5*	*43*	*-4.92*
45	*43.3*	*5.3*	*51*	*-5*
48	*43.3*	*5.7*	*62*	*-7.17*
48	*43.3*	*5.9*	*81*	*-8.11*
48	*43.3*	*5.9*	*68*	*-8.19*
48	*43.3*	*5.7*	*72*	*-7.92*

ID	FD	O2 %	SPM	Furnace Pr.
Constant	Variable			
48	**45**	*6*	*77*	*-4.11*
48	**45**	*6*	*81*	*-4*
48	**45**	*6*	*77*	*-3*
48	**45**	*6.3*	*72*	*-4.16*
48	**45**	*6.3*	*67*	*-4.02*
48	**45**	*6.4*	*85*	*-3.63*
48	**48**	*6.7*	*81*	*1.21*
48	**48**	*6.9*	*75*	*1.67*
48	**48**	*7.1*	*70*	*1.64*
48	**48**	*7.1*	*66*	*1.81*
48	**48**	*7.4*	*63*	*2.1*
48	**48**	*7.1*	*74*	*1.67*
48	**48**	*7.4*	*64*	*1.65*

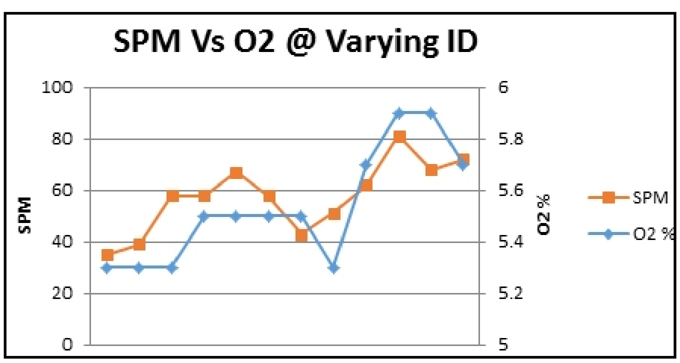

Fig - 1

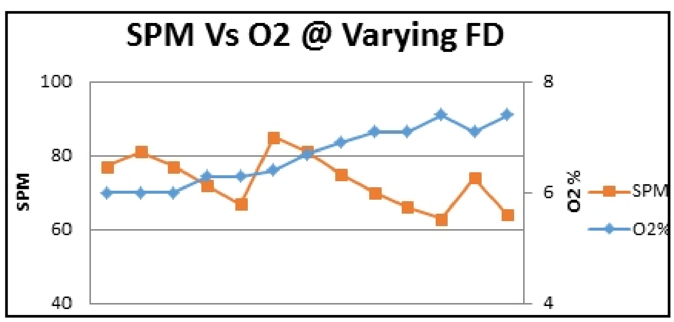

Fig - 2

To assess the variation in SPM levels with change in O_2% by controlling ID/FD/Load

Load & FD fan constant, Varying ID Fan:

I. As we vary the ID frequency the SPM will increase with increase in the O_2%.

Fuel Flow	ID	FD	O2 %	SPM	Furnace Pr.
Constant	Variable	Variable			
3000	**42**	44.3	4	38	-0.22
			4.2	31	-0.57
			4.5	42	-0.85
			4.9	43	-0.57
			5.1	43	-0.48
			5.3	40	-0.1
			5.3	37	-0.1
			5.6	37	-0.65
			5.6	28	-0.39
			5.6	18	-0.3
			5.6	12	

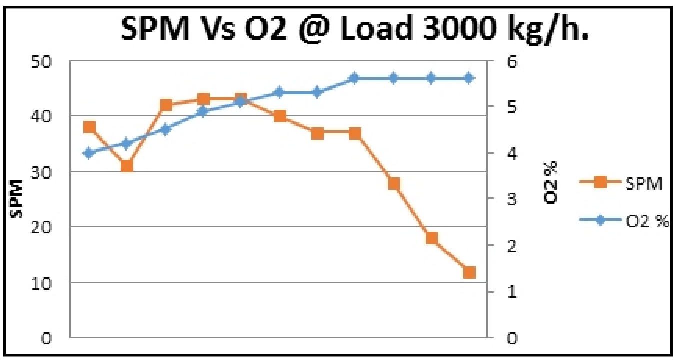

Fig - 3

Fuel Flow	ID	FD	O2 %	SPM	Furnace Pr.
Constant	Variable	Variable			
4548	45	45	3.8	89	-1
			3.8	70	-1.59
			3.7	75	-2.3
	45	45.5	3.8	68	-1.04
			3.8	60	-0.75

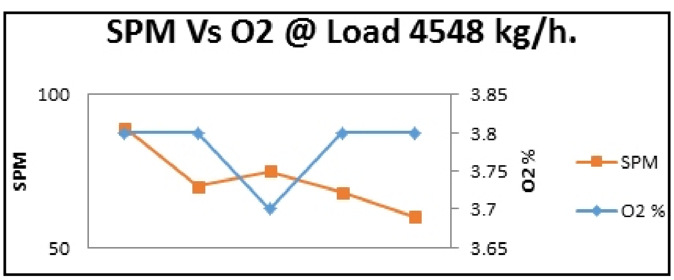

Fig - 4

Fuel Flow	ID	FD	O2 %	SPM	Furnace Pr.
Constant	Variable	Variable			
5000	**50**	44.5	4.3	131	-7.19
	50	47	4.9	117	-0.18
	50	47	5	101	-1.21

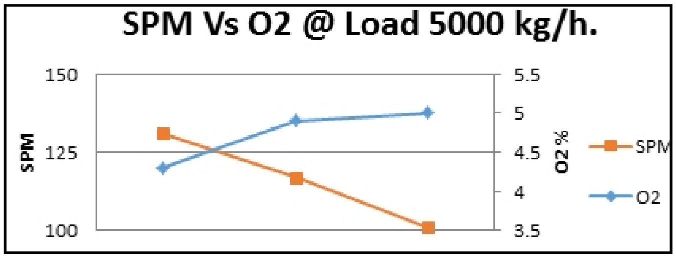

Fig - 5

Fuel Flow	ID	FD	O2 %	SPM	Furnace Pr.
Constant	Variable	Variable			
1000	**43.9**	45	8	131	
			9.6	111	-1.55
			9.8	93	-1.46
			9.8	88	-1.65
			9.8	82	-2.22

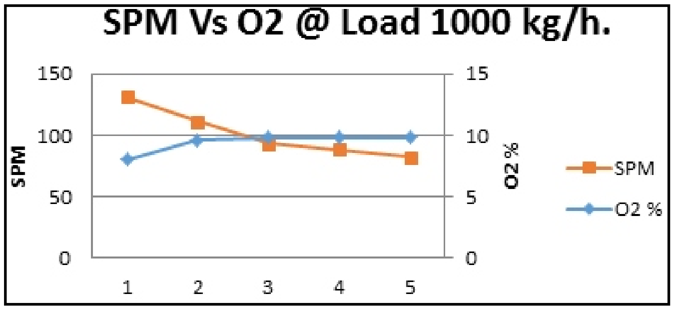

Fig - 6

Fuel Flow	ID	FD	O2 %	SPM	Furnace Pr.
Constant	Variable	Variable			
2200	43.9	45	3.8	96	-1.24
			4.3	104	-1.05
			4.5	110	-0.94
			4.6	115	-1.1
			4.8	115	-1.12
			5.5	105	-1.26
			5.6	101	-1.21
			5.7	111	-1.28
			6.3	98	-1.87
			6.6	89	-1.64
			6.6	86	-1.78

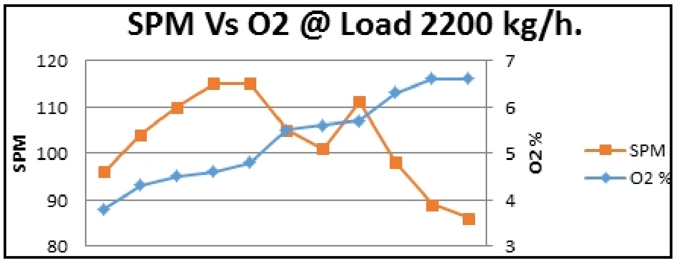

Fig - 7

Fuel Flow	ID	FD	O2 %	SPM	Furnace Pr.
Constant	Variable	Variable			
2400	**43.9**	45	8.9	123	-1.34
			8.7	126	-1.1
			8.5	100	-0.44

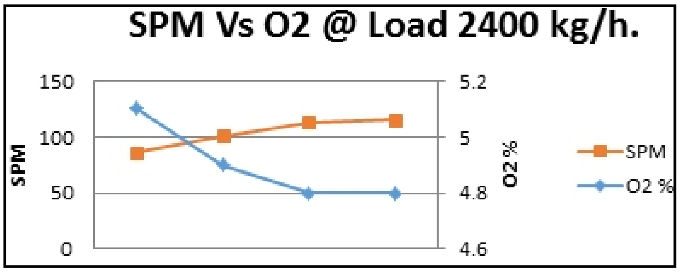

Fig - 8

Fuel Flow	ID	FD	O2 %	SPM	Furnace Pr.
Constant	Variable	Variable			
4000	43.9	45	5.1	86	-0.84
			4.9	101	-0.82
			4.8	113	-1.12
			4.8	115	-1.12
	43.9	47	4.9	101	3.53
			5.1	82	3.58
			5.1	77	3.9
			5.1	71	4.37

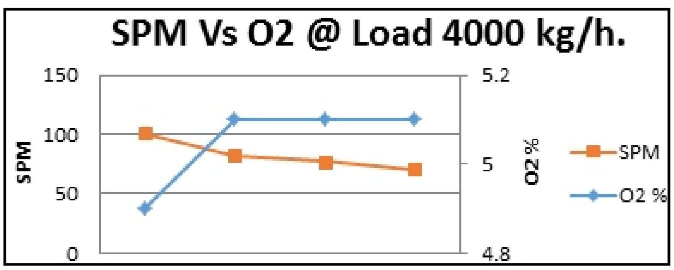

Fig - 9

Fuel Flow	ID	FD	O2 %	SPM	Furnace Pr.
Constant	Variable	Variable			
5300	43.9	45	6.4	121	-0.51
			5	130	
			4.8	140	
			4.6	145	
			4	148	-0.83

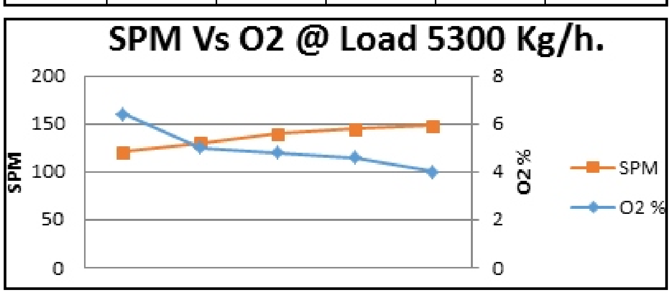

Fig - 10

II. The reason behind this is that as the ID pressure increases, the suction effect will come into effect. This causes the ash particles to go away with the flow of air thereby increasing the SPM levels in the stack (Fig 1).

Load & ID fan Constant, Varying FD fan

I. As we vary the FD frequency the SPM will decrease with increase in O_2%.

II. Initially when we increase the O_2% the SPM will shoot up and then start to decrease.

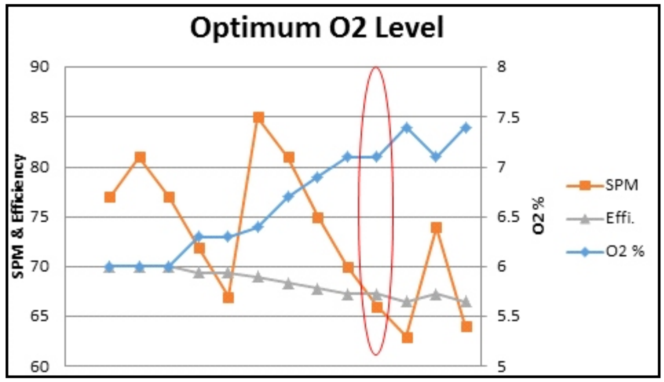

Fig - 11

As the FD increases the increase in the O_2% will give a sudden push to the system thereby increasing the SPM initially and then when the system gets stabilized the SPM starts dropping down with increase in the O_2% (Fig 2).

At Varying Load Conditions:

I. At the varying load conditions with the increase in the O_2% the SPM level decreases.

II. With the increase in the load the SPM level also will increase, but with the oxygen level also increased proportionally, the SPM will depreciate.

III. Two different kind of fuel being used on the site, tests were carried out for both the fuels.

IV. The same kind of trend is observed for both fuels (husk alone and husk + coal mixture). Fig. 3, Fig. 4 and Fig. 5 depict the result of tests carried out with Husk as a fuel at different load conditions.

V. Similarly Fig. 6, Fig. 7, Fig. 8, Fig. 9 and Fig. 10 depict the result of tests carried out with mixture of Husk & coal as a fuel at different load conditions.

VI. Plots for Fuel as Husk at different load conditions:

VII. Plots for Fuel Husk + Coal mixture at different load conditions:

To ascertain the optimum oxygen percentage at which the SPM and efficiency compensated

Optimum Oxygen Percentage level

I. The optimum percentage of oxygen level below that the SPM level will not decrease and beyond which the efficiency cannot increase is ascertained.
II. From Fig. 11 it is observed that, with increase in the level of the O_2% there is reduction in the SPM level, but initially due to the effect of sudden push SPM level will shoot-up & start decreasing.
III. In observed case we can defined optimum O_2% level @ 7.1 were SPM was 66 mg/Nm^3 & Efficiency Was 67.26%.
IV. We can still increase the Efficiency by reducing O_2% upto 4% without increasing SPM level above 130 mg/Nm^3
V. The optimum point will change with the load conditions, so it's necessary to define the different optimum point at different load conditions.

Results & Benefits of integrating/interpreting online efficiency monitoring with SPM Monitoring:

I. Controlling excess air and at the same time trying to minimize SPM with optimum thermal efficiency is better than a blind control on either energy or environment. Trying it to control SPM by varying the O_2% level (By increasing FD Fan Speed), there might be chances of backfire incase if furnace Pressure goes in positive band as shown in Fig. 12

II. SPM Monitoring with Online Boiler Efficiency helps to maintain the SPM level by varying the O2% & simultaneously keeping track on Furnace Pressure by changing the ID fan speed.
III. With this complete package it is possible to maintain the SPM level, with boiler safety & optimum Efficiency.

Innovations in Solid Fired Boilers

Depending on capacity of boiler and type of fuel being fired, Indian pulp and paper mills should consider any of the following new technology equipment:

I. Boilers up to 4 TPH consider hybrid cyclones that show higher dust collection efficiency, the hybrid nature comes from a cyclonic action coupled with Momentum transfer effect of water sprays. The wet powder at the bottom gets removed at the bottom using an automated ash removal valve and conveyor.
II. Beyond 4TPH, the traditional use of Bag filters can now be rethought by the availability of High efficiency Electro static separators which are compact and also have a novel way of collecting dust and consuming lower levels of electrical power with higher degree of safety.
III. The management of the combustion system of the boiler through an integrated real time Boiler Efficiency system and at the same time measuring SPM Levels and interpreting and diagnosing problems becomes a invaluable tool in optimizing energy and environmental performance.
IV. The core of the combustion system is the Grate. A boiler with the right type of grate design and providing for complete combustion with least amount of excess air with low Volatiles and accurate band control of furnace temperatures ensures that Energy and Environmental control of boilers becomes that much mores simpler. Examples of good grate design includes dynamically air cooled grate or stepped grate are some recent innovations in Boiler grate technology.

Conclusions

The following can be concluded from the data collected from the Online Boiler Efficiency and SPM System

I. There is a reduction in the SPM levels when there is an increase on the O_2% and vice-versa.
II. The SPM levels decrease only when the O_2% is controlled by the FD fan frequency but not by the ID fan frequency as the data shows (Fig 1 & Fig 2).
III. Even in the presence of external dust arresters like Cyclone & Bag filter, the effect of the O_2 variation on SPM level was observed. . One also needs to investigate whether the SPM abatement devices were of the correct size and design.
IV. The optimum percentage of oxygen level can be maintained only at a particular load. When the load starts varying the oxygen percentage also starts varying. So it is difficult to define a fixed set point for the oxygen level at all load conditions.

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Further work

The experiment done at this pulp and paper mill needs to be further validated at different fuels and grate types and coupled with different dust abatement devices to find out the singular effects of each parameter on energy efficiency and dust concentrations. This paper thus lays down initial work that can lead to more innovation in dust abatement at combustion level itself rather than depending wholly on the dust abatement devices.

List Of Abbreviations

Acronym	Definition
SPM	*Suspended Particulate Matter*
ESP	*Electro-Static Precipitator*
ID	*Induced Draft*
FD	*Force Draft*
TPH	*Tons Per Hour*
MDC	*Mechanical Dust Collector*
APH	*Air Pre Heater*