

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

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Vol. 6, Issue 11, November 2017

Analysis and Optimization of Boiler Tube Failure Due To Erosion Using CFD Package

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ABSTRACT: In coal-fired power stations, about 20% of the ash produced in the boilers is deposited on the boiler walls, economizers, air-heaters and super-heater tubes. This deposited ash is subsequently discharged as slag and clinker during the soot-blowing process. The rest of the ash is entrained in the stream of flue gas leaving the boiler. These ash particles collide with the boiler steel components and cause extensive surface erosion.

Using software (CFD) analysis of boiler tube considering material of tube and velocity abrasive ash particle is done in main superheated tube. For the analysis differentiate between various modes of wear, and to understand which mode is the primary driver for tube failures,

A model of tube was developed and effect of erosion is investigated. An analysis of tube with different type velocity of fly ash, I have been carried out to reduce the erosive effect on water tube boiler with the help of CFD software we analyze and optimize the effect of erosion Using data analyze by CFD , mass removing rate to different velocity of fly ash

KEYWORDS: Computational fluid dynamics, boiler, economizers, air-heaters and super-heater tubes

I. INTRODUCTION

Failure of tube because of fly ash erosion, As ash is having abrasive action it erodes the outer surface of tube in Economizer, Re-heater regions. Typical location of the fly ash erosions are, gaps between tubes, banks and duct walls, gas by pass channels production of ferrous area close to large ash accumulation the major causes of fly ash erosions are, Temperature of flue gas ,high ash content in coal high flue gas velocity and high impingement angle of ash particle.[1]

Erosion is caused by the impact, cutting action, or abrasive wear of small solid particles freely immersed in the direction of fluid flow that frequently undercut portions of the material they strike Erosion is the progressive loss of original material from a solid surface due to mechanical interaction between that surface and the impinging fluid or solid particles

II. METHODOLOGY

In order to carry-out a research work for achieving the above mentioned objectives, the appropriate experiment has to be designed. Methodology of the experiment has been mentioned as under:

1. Selection of process parameters, variables and constants has to be done.
2. Based upon the process parameters, appropriate governing CFD models with valid assumptions have to be developed for determining each process parameters.
3. After the understanding of the physical process, an appropriate theoretical study based upon the governing CFD model has to be done.
4. An appropriate practical system (CFD models) has to be selected for designing the water tube

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5. Flow the fly ash at different velocity & calculate the erosion in tube walls.
6. Also create the Tungsten carbide CFD models & follow the process .then select which one tube is better to erosion resistant.

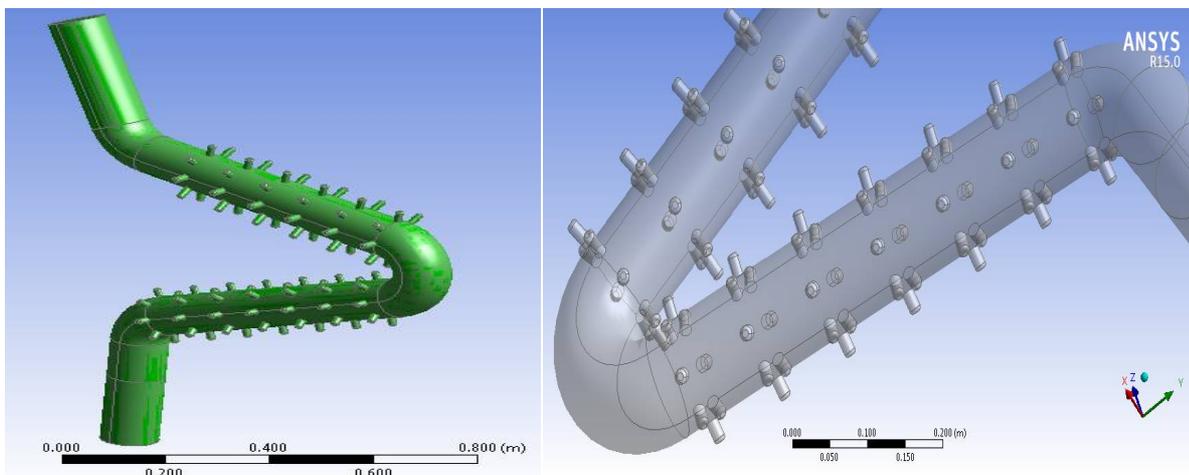


Fig.-CFD model of pipe

2.1 Basic Information and Data collection:

- Description of stainless steel water tube properties (SA210GR.A1)

Mechanical Properties –

- Tensile (Maps) – 415 to 485
- Yield Strength (Maps) – 255 to 275
- Elongation (%) – 30

Chemical Properties –

- Carbon ≤ 0.35
- Si ≤ 0.1
- MN – 0.29 to 1.06
- P ≤ 0.035
- S ≤ 0.035

2.2 Tungsten Carbide Claddings:

If high erosion-resistant particles such as Tungsten carbide exist in low erosion resistant or soft matrix, the impacting particles can undercut and remove portions of the material. However, if the high erosion resistant particles are densely packed in a matrix material that causes the impacting particles to impinge on a greater percent of the hard particle, the erosion resistance increases dramatically.

So we are also analysis of tube with different type of fly ash velocity to use of tungsten carbide claddings I have been carried out to reduce the erosive effect on water tube boiler.[2]

- Description of Tungsten Carbide properties:

Physical-Chemical properties

- Melting point --2776 °C
- Boiling point at-- 1013 hPa 6000 °C
- Density --15.63 g/cm³ at 18 °C
- Water solubility < 0.1 mg/l at 20 °C
- Inflammable at > 300°C H. C.

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2.3 ANSYS Solution for Erosion Modeling:

- Typical variables affecting Erosion rate
- Angle of impingement
- Impact velocity
- Particle diameter
- Particle mass
- Collision frequency between particles and solid walls
- Material properties for particle and solid surface
- Coefficients of restitution for particle-wall collision

Particle erosion and accretion rates can be monitored at wall boundaries. The erosion rate is defined as

$$R_{erosion} = \frac{\sum_{p=1}^{N_{particles}} \dot{m}_p C(d_p) f(\alpha) v^{b(v)}}{A_{face}}$$

Where $C(d_p)$ is a function of particle diameter, α is the impact angle of the particle path with the wall face, $f(\alpha)$ is a function of impact angle, v is the relative particle velocity, $b(v)$ is a function of relative particle velocity, and A_{face} is the area of the cell face at the wall. Default values are $C=1.8 \cdot 10^{-9}$, $f=1$ and $b=0$. Note that C , f and b are defined as boundary conditions at a wall, rather than properties of a material, so the default values are not updated to reflect the actual materials being used

III. RESULTS & DISCUSSION

Some typical results of model predictions are presented in figures showing the variation of erosion rate with velocity, at impingement angle of 30° and boiler temperature for carbon steel and Tungsten Carbide respectively. It may be observed that there is an increase in erosion rate with increasing impacting particle velocity in both cases. In figure , the predicted result is verified with the published experimental data at boiler temperature which are superimposed on the theoretical predictions and found to be in good agreement.

3.1 Different velocity of Fly Ash erodes water Tube shown in figure:

- Different Velocity of fly ash erode Carbon steel tube : Fig1-4 when fly ash strikes on Carbon steel tube at 10,20,30,40m/s then material removing rate And erosion at tube surface show in figure

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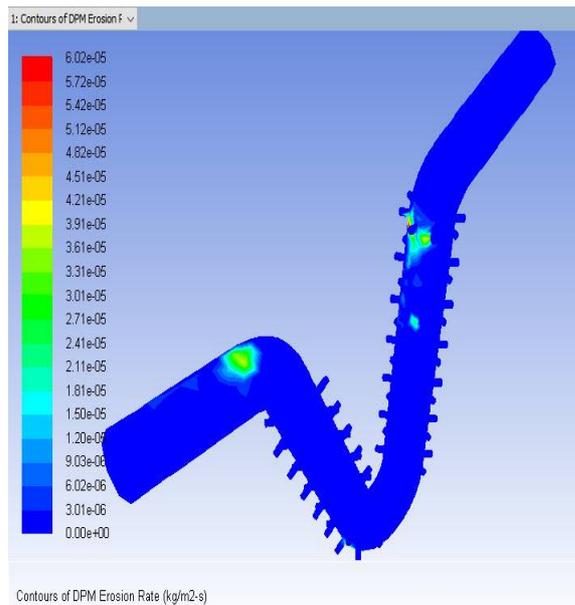


Fig-1 Erosion rate at velocity 10m/s

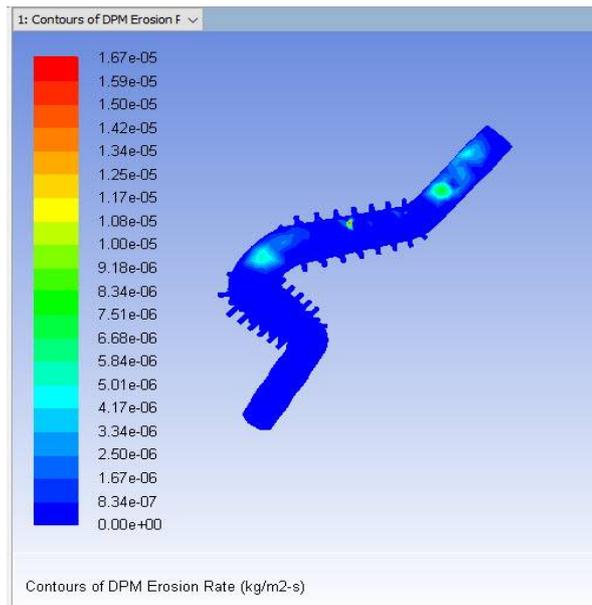


Fig-2 Erosion rate at velocity 20m/s

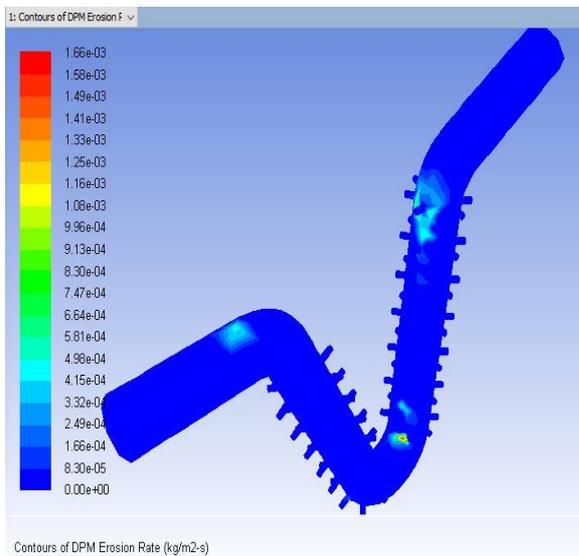


Fig-3 Erosion rate at velocity 30m/s

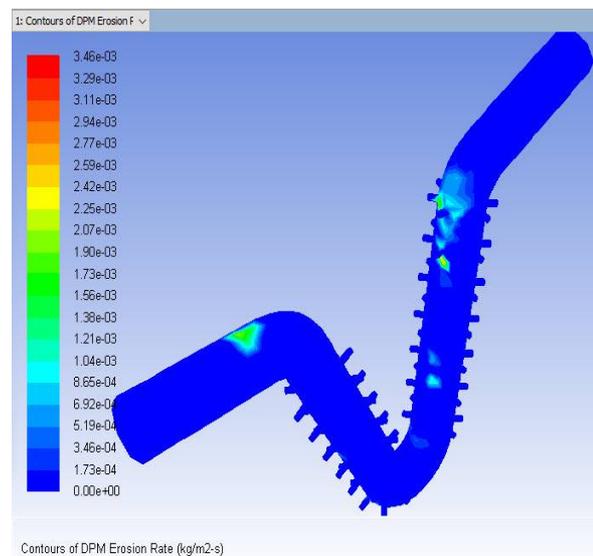


Fig-4 Erosion rate at velocity 40m/s

- Different Velocity of fly ash erode Carbon steel tube : Fig5-8 when fly ash strikes on Tungsten carbide cladding Tube at 10,20,30,40m/s then material removing rate And erosion at tube surface show in figure

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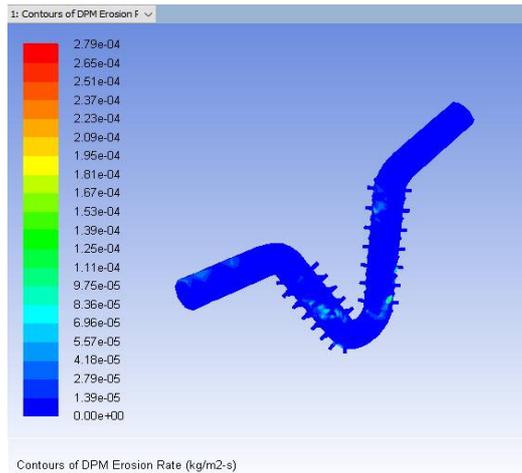


Fig-5 Erosion rate at velocity 10m/s

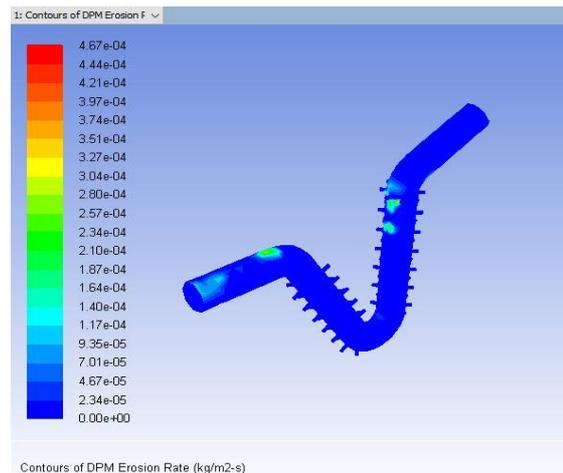


Fig-6 Erosion rate at velocity 20m/s

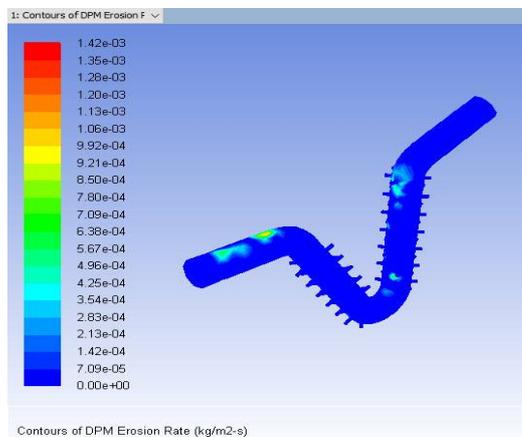


Fig-7 Erosion rate at velocity 30m/s

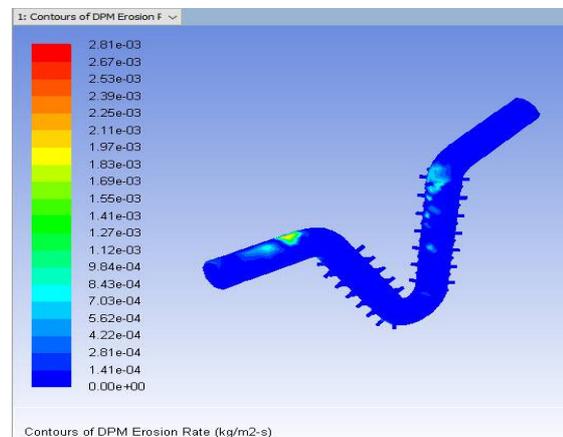


Fig-8 Erosion rate at velocity 40m/s

3.2 Graph representation of Erosion rate:

- carbon steel tube:

Table- velocity & erosion rate

S No	velocity	Erosion Rate
	m/s	Kg/m2-s
1	10	6.02E-06
2	20	1.67E-05
3	30	1.61E-03
4	40	3.46E-03
5	50	6.27E-03

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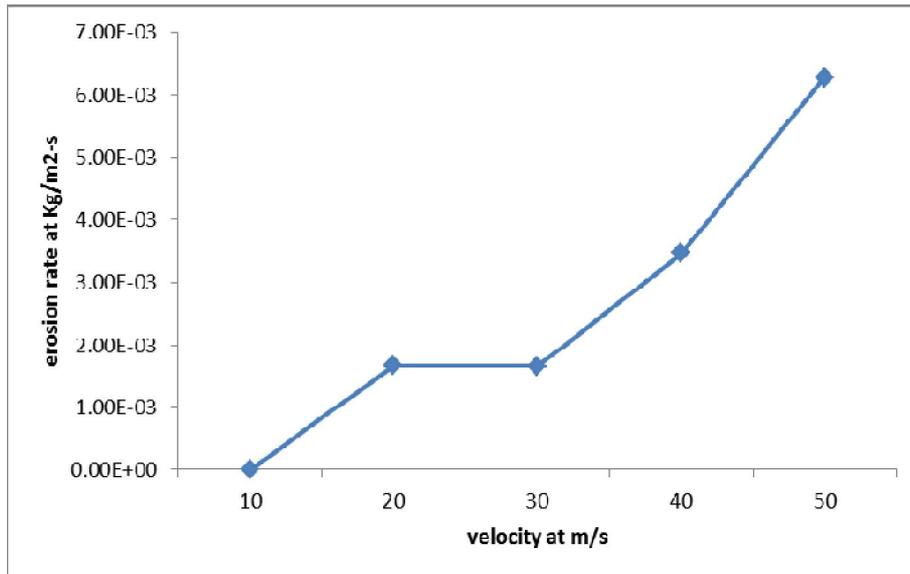


Fig- 9 Graph represent of erosion rate (Carbon steel)

- **Tungsten carbide cladding Tube:**

Table-5 velocity & erosion rate

S No	velocity	Erosion Rate
	m/s	Kg/m2-s
1	10	2.79E-04
2	20	4.67E-04
3	30	1.42E-03
4	40	2.81E-03
5	50	4.63E-03

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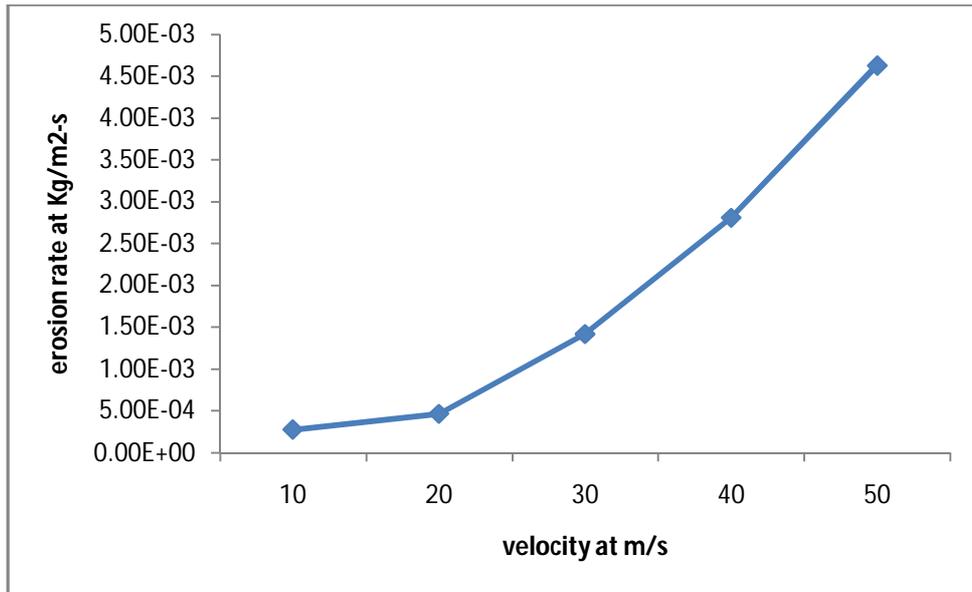


Fig- 10 Graph represent of erosion rate(Tungsten carbide cladding Tube)

➤ **Comparison to material removing rate between Carbon Steel and Tungsten Carbide cladding tube :-**

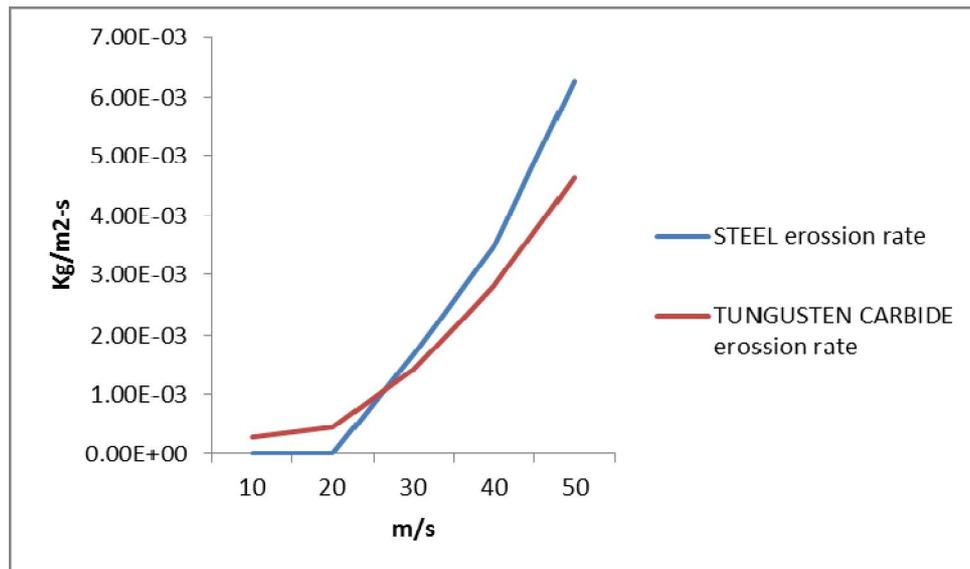
S No	velocity	STEEL	TUNGUSTEN CARBIDE	difference
	m/s	erosion rate Kg/m ² -s	erosion rate Kg/m ² -s	
1	10	6.02E-06	2.79E-04	-2.73E-04
2	20	1.67E-05	4.67E-04	-4.50E-04
3	30	1.66E-03	1.42E-03	2.40E-04
4	40	3.46E-03	2.81E-03	6.50E-04
5	50	6.27E-03	4.63E-03	1.64E-03

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It is cleared from the above result mass removal rate and erosion rate are increases with increases velocity of fly ash. The above result is performed for the different velocity of fly ash and plot the graph of erosion rate and comparison both material carbon steel and tungsten carbide cladding tube which one is better for high erosion-resistant .

From the above result is clear that –

- If we are proper maintain fly ash velocity in boiler so 5-10% reduce the erosion rate.
- Tungsten carbide is high erosion-resistant materials as exist in low erosion resistant or soft matrix, the impacting particles can undercut and remove portions of the material. However, if the high erosion resistant particles are densely packed in a matrix material that causes the impacting particles to impinge on a greater percent of the hard particle, the erosion resistance increases dramatically , so Tungsten carbide is better compare to other material .

IV. CONCLUSION

A model to predict the erosion rate for fly ash particle impingement on boiler component surface has been developed and the variation of erosion rate with various parameters& velocity and found to be in good agreement with the experimental data. It is seen that the erosion rates on steel surfaces subjected to a stream of fly ash particles vary with the particle velocity. For low values of fly ash velocity, erosion rate increases with increase in velocity, with the maximum erosion rate occurring at an maximum velocity. Thereafter, erosion rate decreases with further decreases in fly ash velocity. All the steel grades investigated in this study show increase in erosion rates with velocity

Variation of erosion rate shows monotonic rise with ash particle impact velocity. Tungsten carbide is high erosion-resistant materials as exist in low erosion resistant or soft matrix, the impacting particles can undercut and remove portions of the material. However, if the high erosion resistant particles are densely packed in a matrix material that causes the impacting particles to impinge on a greater percent of the hard particle, the erosion resistance increases dramatically.so Tungsten carbide is better compare to other material.

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