Stress Analysis and Optimization of Grinding component for Bowl Mills

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Abstract— Bowl and Bowl Hub Assembly is a major component of a Bowl Mill, which is considered as the grinding component, where in the raw coal lumps are crushed to the desired micron level upon the Bowl and then fed to the boilers for efficient combustion. The prime purpose of this paper is to focus upon the stress analysis for the Bowl and Bowl Hub Assembly and to check whether the design lies within the safe working load conditions, and further optimize the Design. The component has been analysed for the failure criteria – Von Mises Stress. The software packages used for 3D modelling of the component was Solid Works, for the stress analysis the software package used was ANSYS-14.

Key words: Bowl and Bowl Hub Assembly, Von-Mises Stress, Coal Mill, Solid Works, ANSYS-14

I. Introduction

Bowl and Bowl Hub Assembly is the core component of the coal mill where the raw coal is crushed by the grinding rolls onto the Bowl surface. The function of the Bowl & Bowl Hub Assembly is to provide a grinding surface for the grinding of the raw coal coming from the coal feed pipe. The grinding roll of the journal shaft assembly crushes the raw coal to the required micron level and then due to the turbulence action of the hot air the grinded coal particles are lifted through the vane wheel assembly attached to the Bowl & Bowl Hub Assembly to the dynamic classifier for further segregation.

Bowl and Bowl Hub Assembly is manufactured from grey cast iron, located in the Mill Side Assembly and is connected to the gearbox output coupling. Bowl and Bowl Hub Assembly will be rotating at the rate of 37 RPM in clockwise direction. Rocks, pyrites, tramp iron and other non-crushable particles will be rejected and dropped at the mill side with the help of scrapper assembly.

Due to the centrifugal action of the bowl and bowl hub assembly it provides a shearing action to the grinding roll which provides an efficient crushing system. Hot air at 400°C from the primary air duct from the mill side passes through hot air chamber and which is in-turn streamlined into nuzzling effect while passing through the rotating Bowl and Bowl Hub Assembly. These velocities are well adequate to lift the ground coal then convey the coal-air mixture through the classifier and further transport the final coal product mixture to the furnace or to the dust collectors. The Bowl Hub is subjected to a temperature of 400°C, hence the Bowl Hub is provided with the insulation to prevent the thermal stresses entering into the casted material.

There were many research works carried out for the development of the most technically advanced mill and its optimized components like. Some of the major persons who were responsible for this development and their scope of work were:

A. Harun Bilirgren [1]:

Harun Bilirgren proposed the coal flow control mechanism concept for the HP mill. This coal air flow control mechanism plays a major role for the proper functioning of the HP mill. Harun Bilirgren developed an externally adjustable coal flow control mechanism design based upon the flow structures developed within the pulverizer. This coal flow control mechanism design is used to guide and control the coal flow distribution at the outlet ports

B. Inerio, V.Cortes, L.Canadas, J.L. Albaladejo and P.Otero [2]:

These scientists carried out their research work for the optimization of the milling system, thereby targeting the operating and maintenance cost. They also focussed upon the environmental impact of thermal power plants in order to incorporate its hazardous effects and globally increasing competitiveness in the field of power generation sector

C. C.Bhasker [3]:

This scientist mainly focused upon the performance parameters improvements for the coal-fired thermal power plants. His work includes the computational domains which are obtained through CFD/CAD software packages. Through these software packages he gave a clear understanding and improvement for the coal-air flow mixture within the mill.

D. Mounika, Kandi.Reddy, C.H. Priyanka [4]:

These scientists provided a major contribution for the designing of classifying equipment's for the coal mill. The classifying equipment's are the key components of the coal mill to allow only the micron level crushed coal particles to pass through the outlet port. Their work focused upon the most existing pulverizers which includes both vertical shaft type and ball mill types.

II. Proposed Methodology

The software packages used for the 3D Modeling and Static Analysis are:

- Solid Works V-12.
- ANSYS V-14.

A. Solid Works V-12

Solid Works is .the most widely used 3D modeling software which is used in many applications where accuracy is desired.

Solid Works is basically applied as solid modeling software, which uses some constraints in order to determine the shape or geometry of the model and assembly. Constraints used for modeling such as Dimensions, tool standards etc.

The 3D Models prepared for the Bowl and Bowl Hub Assemblies Old Design and Optimized Design are:

1) *Old Design*

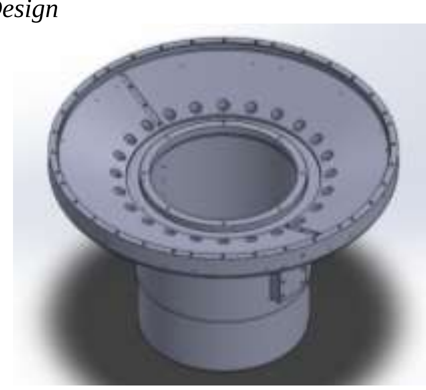

Fig. 1: Bowl and Bowl Hub Assembly (Old Design)

2) *Optimized Design*

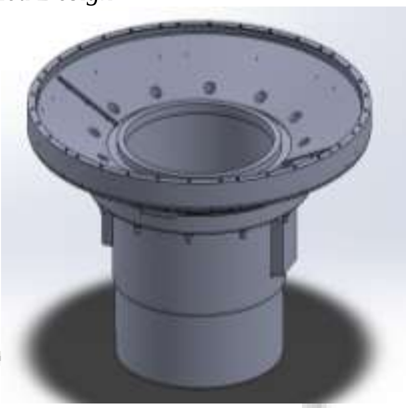

Fig 2: Optimized Bowl Design

3) *Comparison of Old Design and Optimized Design*

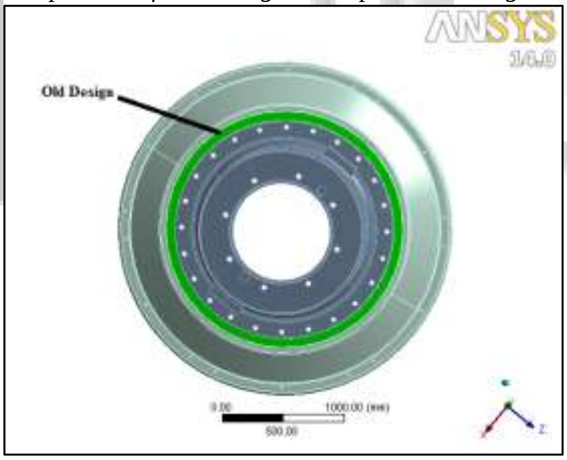

Fig. 3: Old Design

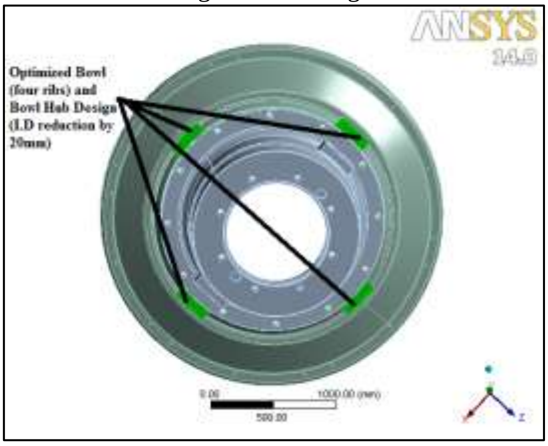

Fig 3: Optimized Bowl Design (four ribs) and Bowl Hub internal diameter reduction by 20mm

B. ANSYS V-14

ANSYS Simulation as a design imperative which are capable to provide the users partial feedback while designing and manufacturing the real world systems.

ANSYS Simulation is a very powerful tool which allows the engineers to predict, to test the created or existing designs in numerous virtual iterations in a short period of time there by avoiding the cost of prototype and physical testing's, in order to innovate faster, compact and smarter designs.

ANSYS plays a major role in product development and takes it to the next level though multi-physics simulation and can be easily employed

III. ANALYSIS MODELS & BOUNDARY CONDITIONS

The Models considered for Static-Structural Analysis were simplified in order to suit the analysis compatibility and also due to the complexity of the models.

A. ANSYS Model (Old Design).

Fig. 4: ANSYS Analysis Model (Old Design)

B. ANSYS Model (Optimized Design).

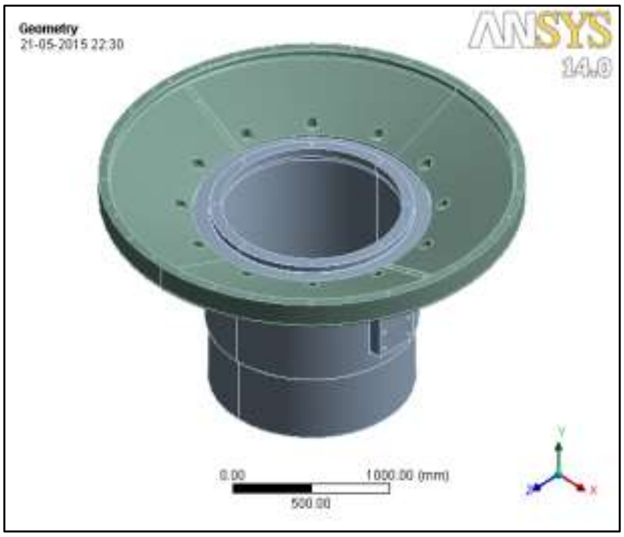

Fig. 5: ANSYS Analysis Model (Optimized Design)

C. Meshed Models

1) Old Design

Fig 6 (a): Meshed Model (Old Design)

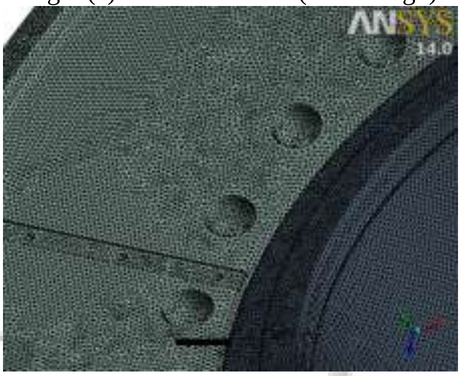

Fig 6 (b): Meshed Model detail view (Old Design)

2) Meshed Model details (Old Design).

Mesh Type	Relevance Centre	Body Sizing (mm)	Number of Elements	Number of Nodes
Tetrahedron	Fine	10	11726199	1637643

Table 1: Observations for Meshed Model (Old Design)

3) Optimized Design

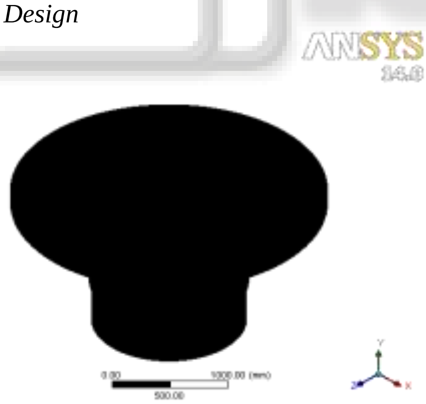

Fig 7 (a): Meshed Model (Optimized Design)

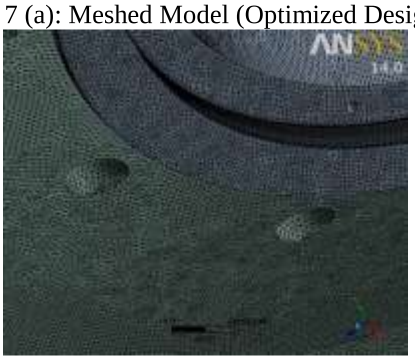

Fig 7 (b): Meshed Model detail view (Optimized Design)

4) Meshed Model details (Optimized Design).

Mesh Type	Relevance Centre	Body Sizing (mm)	Number of Elements	Number of Nodes
Tetrahedron	Fine	10	11737262	16381615

Table 2: Observations for Meshed Model (Optimized Design)

D. Boundary Conditions considered for the Static-Structural Analysis for the Bowl and Bowl Hub Assemblies.

1) Old Design:

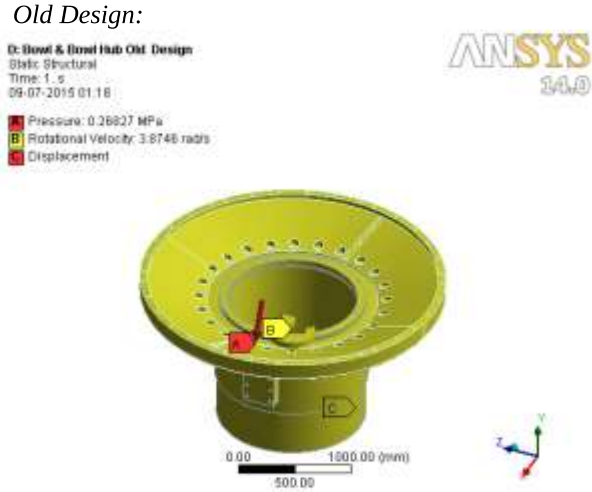

Fig 8: Boundary Conditions (Old Design)

2) Optimized Design

Fig 9: Boundary Conditions (Optimized Design)

3) Boundary Conditions considered for the Static-Structural Analysis for the Bowl and Bowl Hub Assemblies in brief:

a) The Dimension System considered for the Static-Structural Analysis for the Bowl and Bowl Hub Assemblies is.

Unit System	Metric (mm, t, N, s, mV, mA) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Table 3: Observations for Dimension System.

b) Connections

Since the Bowl is assembled to the Bowl Hub with the help of bolts, and the entire Bowl and Bowl and Bowl Hub Assembly is rotating at the rate of 37RPM therefore a frictional contact exists between the Bowl and Bowl Hub.

Sl. No	Contact Body	Target Body	Connection type	Coefficient of Friction
1	Bowl	Bowl Hub	Frictional	0.275

Table 4: Observations for Connections considered.

c) Constraints Considered.

Since the entire Bowl and Bowl Hub Assembly will be placed at the gear box such that the bottom face of the Bowl Hub is bolted to the gear box and the entire Bowl and Bowl Hub Assembly will be rotated by the gear box at the rate of 37RPM thus a Displacement is applied at the Bottom face of the Bowl Hub by constraining all degrees of freedom.

d) Loading Conditions

1) Pressure

Since there are three grinding rolls crushing the coal at the Bowl surface, each grinding roll applies a load of 314KN upon the Bowl °. Since the entire Bowl and Bowl Hub Assembly will be rotating at the rate of 37RPM thus the load is uniformly distributed upon the Bowl. Thus a uniformly distributed load of 942KN will be acting upon the Bowl. This load is considered as uniformly distributed pressure acting upon the Bowl by converting it by:

$$P_1 = \frac{F}{A} \quad \text{...... (1)}$$

Where,

P = Pressure.

F = Force= 942KN.

A= Cross Sectional Area.

P_1 = 0.26827MPa.

2) Rotational Velocity.

Since the Bowl and Bowl Hub Assembly is placed upon the gearbox such that the bottom faces of the Bowl Hub is bolted to the gearbox. The gearbox rotates the entire assembly at the rate of 37RPM.

Thus the rotation of 37RPM is considered for the Analysis by converting it into Rotational Velocity by:

$$\omega = \frac{2\pi N}{60} \quad \text{... (2)}$$

ω = 3.8746 rad/s

4) Boundary Conditions

Connection type	Displacement	Pressure MPa	Rotational Velocity rad/s
Frictional =0.275	X=Y=Z=0	0.266	3.87

Table 5: Observations for Boundary Conditions

IV. FEA RESULTS

A. Bowl and Bowl Hub Assembly (Old Design)

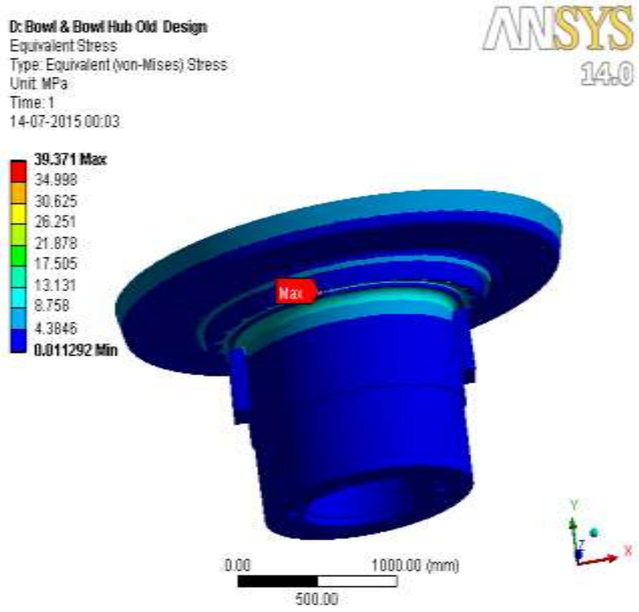

Fig 10: Von-Mises Stress (Old Design)

B. Bowl and Bowl Hub Assembly (Optimized Design)

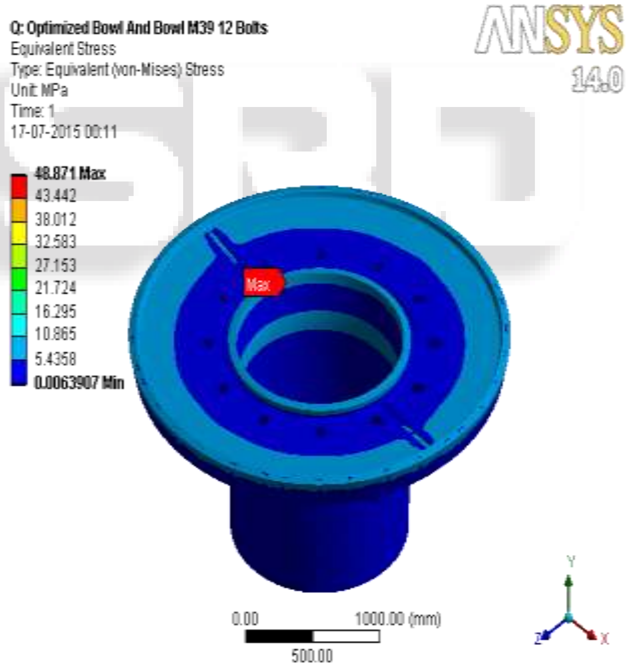

Fig 11: Von-Mises Stress (Optimized Design)

C. ANSYS Analysis results for the Bowl and Bowl Hub Assemblies.

Sl. No	Bowl and Bowl Hub Assemblies	Equivalent [Von-Mises] Stress. (MPa)
1	Old Design	39.371
2	Optimized Bowl Design	48.871

Table 6: Observations for Analysis Results

V. RESULTS AND DISCUSSIONS

A. Bowl and Bowl Hub Assembly (Old Design)

Sl. No	Parameters	Analytical Results	Analysis Results	% Error	Design Condition
1	Von-Misses Stress (MPa)	37.63	39.37	4.6	SAFE

Table 7: Observations for Results comparison (Old Design)

From the above observation table 7 we can observe that the Analytical results and ANSYS results obtained lies within the permissible limit of percentage error. The values obtained both from Analytical and ANSYS Analysis results for stress parameters of the Bowl and Bowl Hub Assembly (Old Design) lies within the maximum allowable stress limit of 82.737MPA.

B. Bowl and Bowl Hub Assembly (Optimized Design)

Sl. No	Parameter	Analytical Results	Analysis Results	% Error	Design Condn
1	Von-Misses Stress (MPa)	46.56	48.87	4.95	SAFE

Table 8: Observations for Results comparison (Optimized Design)

From the above observation table 8 we can observe that the Analytical results and ANSYS results obtained lies within the permissible limit of percentage error. The values obtained both from Analytical and ANSYS Analysis results for stress parameters of the Bowl and Bowl Hub Assembly (Optimized Design) lies within the maximum allowable stress limit of 82.737MPA.

VI. CONCLUSION

The Finite Element Analysis carried out for the Bowl and Bowl Hub Assembly (Old Design) such that the Maximum Equivalent (Von-Mises) Stress result is 39.371MPa, which lies within the Maximum Allowable Stress Limit of 82.74MPa, as per the design standards. Thus we can conclude that the results obtained from the Finite Element Analysis carried out for the Bowl and Bowl Hub Assembly (Old Design) is appropriate and the design lies within the REAL SAFE working load conditions and the design can be further optimized.

The Finite Element Analysis carried out for the Optimized Design, with four ribs on the Bowl and internal diameter reduction of the Bowl Hub by 20mm such that, the Maximum Equivalent (Von-Mises) Stress result is 48.871MPa, which lies within the Maximum Allowable Stress Limit of 82.74MPa, which is a standard value as per design standards of Bowl and Bowl Hub Assembly. Thus we can conclude that the results obtained from the Finite Element Analysis carried out on the Bowl and Bowl Hub Assembly (Optimized Design) is appropriate and lies within the REAL SAFE working load conditions.

Thus we can conclude that the design condition of the Bowl and Bowl Hub Assembly is real safe, hence the design can be further optimized and the factor of safety considered for the design can be reduced through FEA.

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