Manufacturing with design and analysis of rotor shaft of hammer mill crusher

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Abstract— **Crushing means size reduction of the object. Crushers are so many types in this hammer mill crusher also one. Hammer crusher is assembled by several parts and compounds including frame, rotor, screen, and hammer. The working principle of hammer mill crusher, the motor drives the rotor to rotate at a high speed through the belt, and on the rotor there are series of hammers. When the materials get into the working area of hammers, the rotating hammers with high rotation speed are crushing them, the crushed products meeting the required size can be discharged by the outlet and become the final products, the large size products are brought back to the crushing area by the hammers for being re-crushed until they reached the required size. The aim of our project is to model and design and Analysis of Rotor Shaft of Hammer Mill Crusher. In this thesis work we are designing and also analyzing the different parts like Bearing Assembly, Hammer, Gland Seal etc. and also theoretical values are compared with ANSYS values. Modeling and Design done in 3D parametric software Pro/Engineer and Analysis are done in ANSYS software.**

Index Terms — **Hammer Mill Crusher, ANSYS, Pro-E.**

1) INTRODUCTION

A crusher is a machine designed to reduce large solid material objects into a smaller volume, or smaller pieces. Crushers may be used to reduce the size, or change the form, of waste materials so they can be more easily disposed of or recycled, or to reduce the size of a solid mix of raw materials (as in rock ore), so that pieces of different composition can be differentiated. Crushing is the process of transferring a force amplified by mechanical advantage through a material made of molecules that bond together more strongly, and resist deformation more, than those in the material being crushed do. Crushing devices hold material between two parallel or tangent solid surfaces, and apply sufficient force to bring the surfaces together to generate enough energy within the material being crushed so that its molecules separate from (fracturing), or change alignment in relation to (deformation), each other. The earliest crushers were hand-held stones, where the weight of the stone provided a boost to muscle power, used against a stone anvil. Querns and mortars are types of these crushing devices[1].

In industry, a crusher is typically a machine which uses a metal surface to break or compress materials. Mining operations use crushers, commonly classified by the degree to which they fragment the starting material, with primary and secondary crushers handling course materials, and tertiary and quaternary crushers reducing ore particles to finer gradations. Typically, crushing stages are followed by milling stages if the materials need to be further reduced. Crushers are used to reduce particle size enough so that the material can be processed into finer particles in a grinder. A typical circuit at a mine might consist of a crusher followed by a SAG mill followed by a ball mill. In this context, the SAG mill and ball mill are considered grinders rather than crushers.

There are four basic ways to reduce a material by impact, attrition, shear or compression and most crushers employ a combination of all these crushing methods.

1. Impact
2. Attrition
3. Shear
4. Compression

In crushing terminology, impact refers to the sharp, instantaneous collision of one moving object against another. Both objects may be moving, such as a baseball bat connecting with a fast ball, or one object may be motionless, such as a rock being struck by hammer blows.

There are two variations of impact gravity impact and dynamic impact. Coal dropped onto a hard surface such as a steel plate is an example of gravity impact. Gravity impact is most often used when it is necessary to separate two materials which have relatively different friability. The more friable material is broken, while the less friable material remains unbroken. Separation can then be done by screening The Attrition is a term applied to the reduction of materials by scrubbing it between two hard surfaces. Hammer mills operate with close clearances between the hammers and the screen bars and they reduce by attrition (shown in fig 1.3.2) combined with shear and impact reduction. Though attrition consumes more power and exacts heavier wear on hammers and screen bars, it is practical for crushing the less abrasive materials such as pure limestone and coal.

Attrition crushing is most useful in the following circumstances

-When material is friable or not too abrasive Shear consists of a trimming or cleaving action rather than the rubbing action associated with attrition[2][5]. Shear is usually combined with other methods. For example, single-roll crushers employ shear together with impact and compression.

As the name implies, crushing by compression is done between two surfaces, with the work being done by one or both surfaces. Jaw crushers using this method of compression are suitable for reducing extremely hard and abrasive rock. However, some jaw crushers employ attrition as well as compression and are not as suitable for abrasive rock since the rubbing action accentuates the wear on crushing surfaces.

As a mechanical reduction method, compression should be used as follows

—if the material is hard and tough
—if the material is abrasive
—if the material is not sticky

—where the finished product is to be relatively coarse, i.e., 1 h/2 (38mm) or larger top size
—when the material will break cubically

2) PROPOSED METHOD

The Hammer Mill Crusher is manufactured by selecting appropriate bearings and shafts that are able to bear the stresses induced in them. The analysis is done using Pro-E and ANSYS software[3][4][5]. The analysis can be better understood by seeing fig1. Out of different industrial manufacturing methods, considering economical and time consumption processes we adopt the following manufacturing methods they are

- Gas cutting
- Hand grinding
- Drilling
- Welding
- Turning
- Grinding
- Milling
- Casting

Among the different cutting process we adopt oxy-acetylene gas cutting process for cutting thick metal sheets to required size. In **Oxy-acetylene cutting** the flame is used for cutting ferrous metals in which the preheating of the metal is accomplished with a flame produced by an oxyacetylene torch.

We use gas cutting process for different components like rotor disc, baseplate, hammers. Hand grinding is used for surface finishing the components like rotor disc, hammers, liner plates, base plate, and side plates. The drilling machine (drill press) is a single purpose machine for the production of holes. Drilling is easily the most common machining process. One estimate is that 85% of all metal-cutting material removed comes from drilling operations.

We use drilling process for rotor disc, hammers, base plate. The term welding is defined as joining of two or more surface (usually metals, but not always) under the influence of heat, so the product shall be nearly homogeneous union as possible. There are different types of welding process out of them we adopted arc welding because it is easy to weld thick materials and economical.

We use arc welding process for assembling rotor disc, base plates, and feeder, to the walls of hammer mill crusher.

Turning is the machining operation that produces cylindrical parts. In its basic form, it can be defined as the machining of an external surface. We use turning process for making steps on the rotor shaft. Grinding is a finishing process used to improve surface finish, abrade hard materials, and tighten the tolerance on flat and cylindrical surfaces by removing a small amount of material[9][10][11].

We use machine grinding process for surface finishing on shaft, hammers, rotor disc. A milling machine is equipment used to machine solid materials. Milling machines are often classed in two basic forms, horizontal and vertical out of these two processes we adopt horizontal milling for creating guide ways on the rotor shaft. Casting is a manufacturing process by which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify[7][8].

Sand casting used for single piece moldings so we adopt sand casting process for manufacturing rotor shaft (see Figure1).

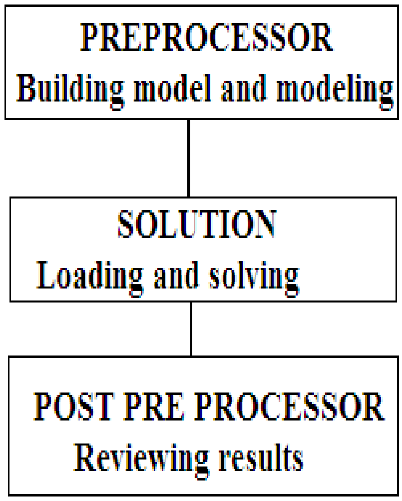


Fig 1: Basic Steps in Ansys (Finite Element Software)

3) DESCRIPTION

A.Pre processing (Defining the Problem)

The major steps in preprocessing are given below
Define key points/lines/ areas/volumes.
Define element type and material/geometric properties
Mesh lines/ areas/volumes as required.

B. Solution (Assigning Loads, Constraints, and Solving)

Here the loads (point or pressure), constraints (translational and rotational) are specified and finally solve the resulting set of equations.

C. Post processing

In this stage, further processing and viewing of the results can be done such as

- Lists of nodal displacements
- Element forces and moments
- Deflection plots

D. Element used for Analysis

BEAM3 is a uni-axial element with tension, compression, and bending capabilities. The element has three degrees of freedom at each node translations in the nodal x and y directions and rotation about the nodal z-axis. Other 2-D beam elements are the plastic beam(see Figure 2-6) and 3D (see Figure 7-10).

E. Results in Ansys

- Power transmitted by the shaft=85kw or 100hp
- Speed of the shaft =850 rpm
- Weight of the rotor shaft =2000kg``
- Beam length =165cm
- Shear stress =650 kg/cm²
- Bending stress =300 kg/cm²

1. 2D Beam Analysis:

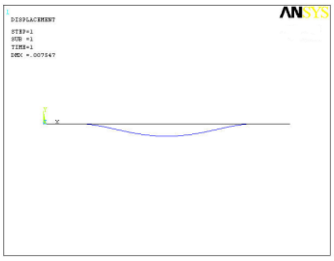


Fig 2: Deformed Shape

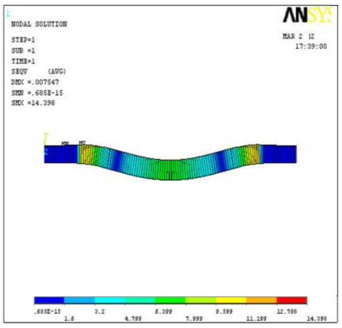


Fig 3: Von Mises Stress

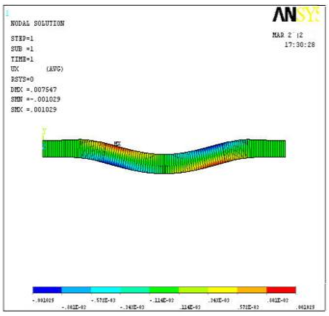


Fig 4: Deformation in X-direction

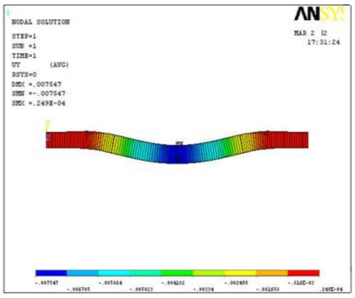


Fig 5: Deformation in Y-direction

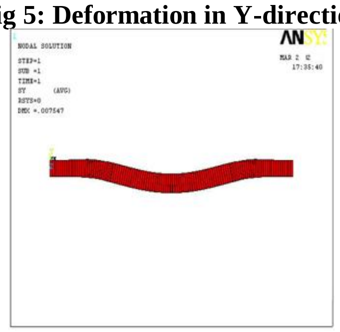


Fig 6: Stress along Y-Direction

2. 3D Shaft Analysis:

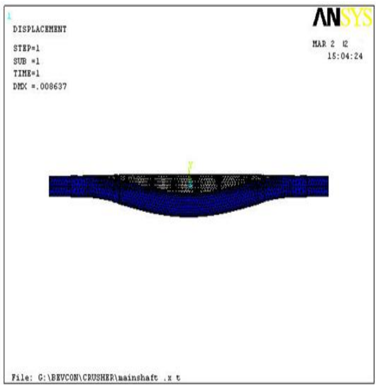


Fig 7: Deformed Shape

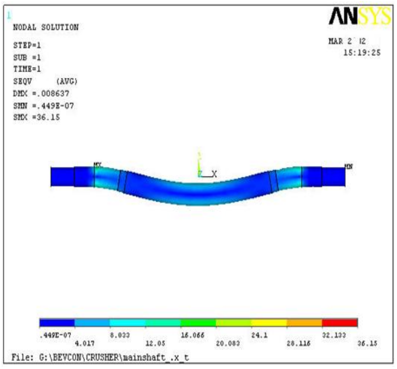


Fig 8: Von Mises Stress

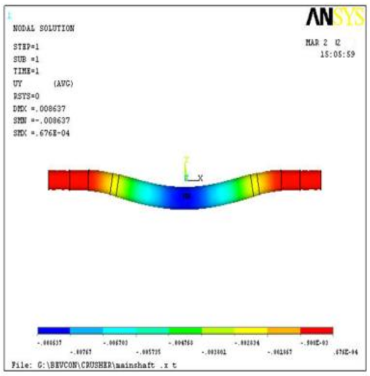


Fig 9: Displacement in Y-Direction

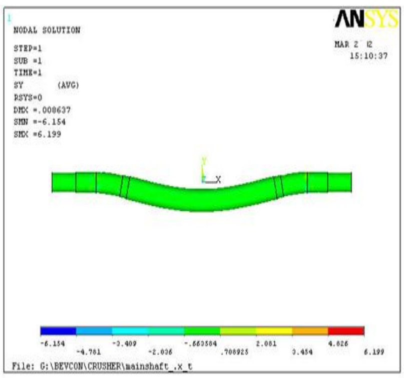


Fig 10: Stress along Y-direction

3. Rotor Shaft Assembly in ANSYS Workbench

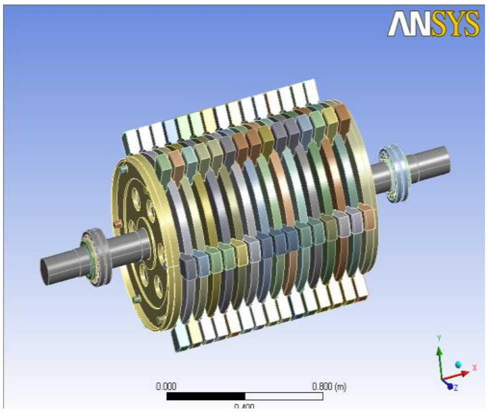


Fig 11: Assembled model in Ansys Workbench

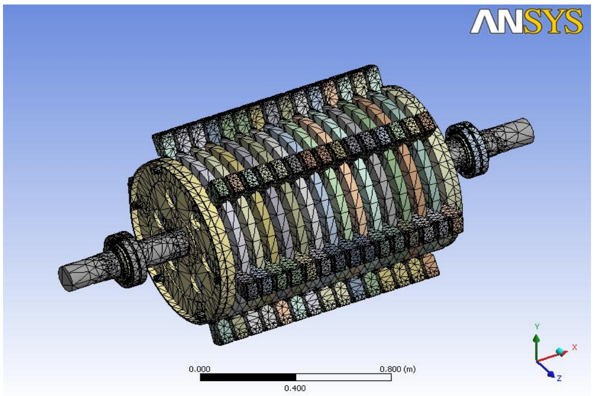


Fig 12: Rotor Shaft Assembly Mesh in Ansys

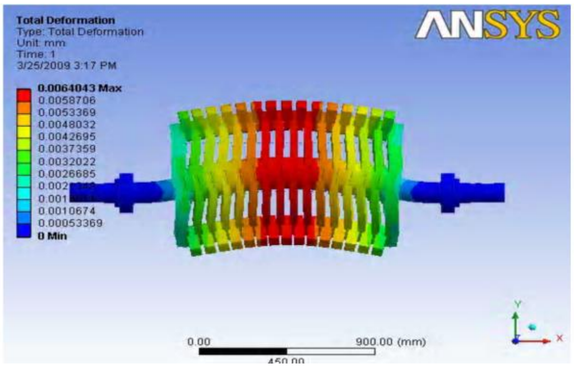
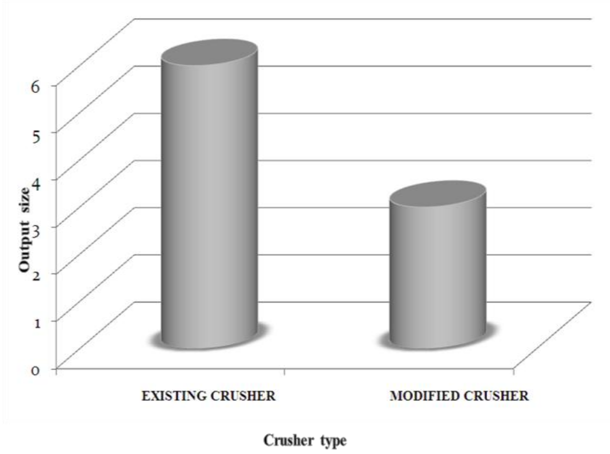


Fig 13: Deformation in Ansys

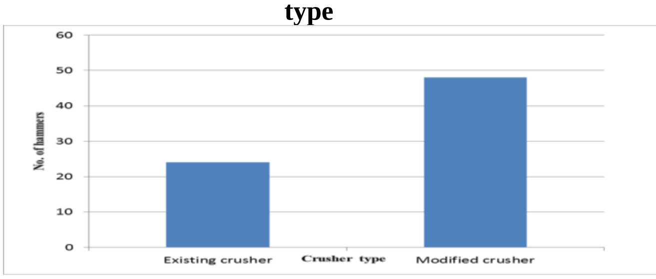
4) EXPERIMENTAL RESULTS

In this experiment the values are obtained by analyzing with ANSYS software. Hence the comparision between ANSYS and theoretical values are:

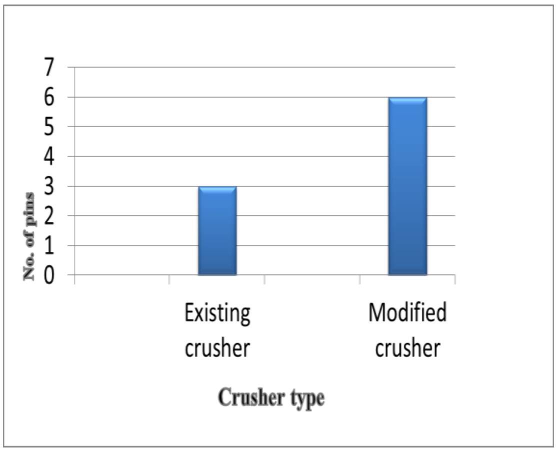
- Deformation obtained by theoretical is 0.089 mm
- Stress obtained is 11.34 N/mm^2
- And deformation obtained in Ansys is 0.0841mm
- Von-mises stress is 16.633 N/mm^2
- So analysis is correct



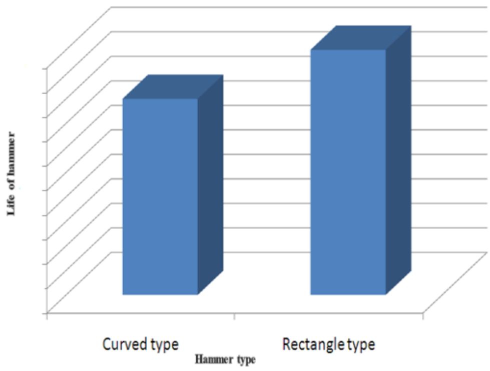
Graph 1: comparison between output size and crusher type



Graph 2: comparison between crusher type and no. of hammers



Graph 3: Comparison between no. of pins and crusher type



Graph 4: Comparison between hammer type and life of the hammer

4.Modifications

- As the existing hammer mill crusher contains 24 hammers with three pins on the rotor disc, if 'more fine grain size is required as output we need to increase the number of hammers which leads to the replacement of entire rotor disc assembly which is time taking and cost effective process.
- To overcome the above problem we increased number of hammer pins from 3 to 6 by this we can get an extra hammers without replacing the rotor disc by this we can acquire more fine sized output".
- "The existing hammer mill contains curved head hammers but we used flat head hammers which gives more hammer life compared to curved head".

Let us see the results in 2D and 3D. We have taken beam as element type and analysis is performed on it. We got maximum deflection of 0.08246mm which is very less compared to safe limit. The following figure shows the nodal solution(see Figure 14-15).

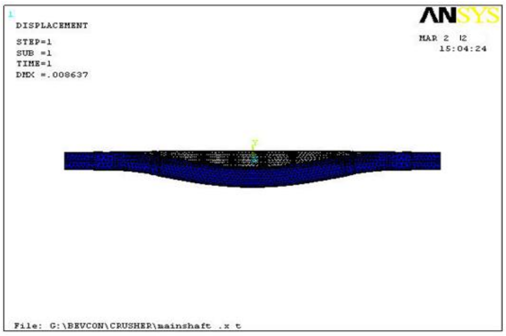


Fig.14 Deformed Shape

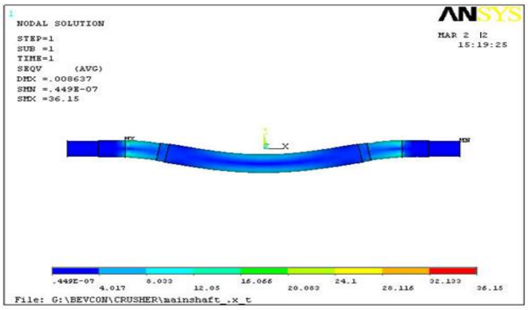


Fig. 15 Von Mises Stress

Now we can see the stresses in shaft. Maximum stress developed in shaft is 36.15 N/mm^2 which is far less than the yield strength of the material, which is 45 N/mm^2. So that shaft will not fail under these conditions.

5) CONCLUSION

Understood the crushing principles & crushers available based on the industry like power, Steel, Glass making, Stone crushing for construction…etc. Shaft diameter selected based on shaft deflection theory is 123 mm. Factor of safety on the selected diameter as 11. 3D models developed in Pro-E & exported to ANSYS for analytical results & proved that the deflection is 0.8296 mm.We conclude that the deformation obtained by the theoretical value is 0.089mm and analytical value is 0.0841mm. So the theoretical value greater than the analytical value. So the analysis is correct.

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