Productivity Enhancement of Jaw Crusher Using Composite Material

Neeraj Pateriya[1], Dr. B.R Rawal[2]

[1]PG Scholar (CAD/CAM/CAE), Dept of Mechanical Engineering, SGSITS Indore, MP, INDIA
[2]Assistant professor, Dept of Mechanical Engineering, SGSITS Indore, MP, INDIA

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Abstract - *Jaw crushers are heavy and slow speed machine which are used to reduction of large quantities of solids into smaller particle. The performance of jaw crusher is mainly determined by the crushing capacity with respect to power consumption during the crushing process. A swing plate stiffs enough that can crush taconite with a compressive force 308 Mpa. Swing plate strong enough to crush solids like taconite, on other hand swing plate assembly(plate & holder) made of martensite steel which is consume more power due to heavy weight, hence weight of the swing plate assembly is necessary to reduced. This work carried out comparative analysis of different composite material used in jaw plate holder. Basically swing jaw plate is a component of jaw crusher machine, in this respect geometrical modeling, finite element analysis and theoretical analysis of swing jaw plate presented, which allow studying effective strength to weight comparison, deformation, equivalent stress. A swing jaw assembly of martensite steel and composite material is taken for weight reduction. Generated geometric model was imported in finite element software ANSYS 15.0 workbench and static structural analysis was used to determination of equivalent stress and total deformation. From the result of static analysis observed that was composite material jaw plate assembly is lighter and more economical than the conventional martensite steel swing jaw holder with similar design and specification. Theoretical analysis shows that composite material consumes approximate half power compare to conventional material.*

***Key Words*:** swing jaw assembly, composite material, static analysis, theoretical analysis, power consumption.

1.INTRODUCTION

A jaw or toggle crusher consists of a set of vertical jaws, one jaw being fixed and the other being moved back and forth relative to it by a cam or pitman mechanism. The jaws are attached apart at the top than at the bottom, forming a tapered chute so that the material is crushed to smaller size as it travels downward till it escapes from the opening at bottom. De Diemer[1] according to the research work introduced the new idea in primary jaw crusher design and utilizing the power saving by open feed throat concept and automation features.jaw crusher with two jaw opening can be considered completely new design. discharge gap being almost sharply inclined & vertical so that large art of material crushed. The power consumption of the jaw crusher also reduced due to crushing work distributed between two jaws. Lindqvist,Evertssan & all[2] research work study a performance of a jaw crusher against the wear rate. The test result shows the wear rate is different for fixed and moving jaw linear. The objective of this paper wear rate had studied in crusher. Gupta & Yan[3] the research work is reduce the development cycle and improve the design quality of the jaw crusher. For this plate is made by hardened steel and bolted with heavy block called holder. In universal crusher plate is fixed in middle so top and bottom can be move the result of this improve productivity of jaw crusher. Yuming,Zhito & All[4] work on modeling simulation and kinetic analysis base on PRO –E for jaw crusher mechanism and also dynamic analysis of jaw crusher configuration. Whittles & all[5] worked to optimize of the efficiency of crushers is desirable in terms of reducing energy consumption, increasing throughput and producing better downstream performance as a result of improved size specification. The mechanism of rock fragmentation within crushers is dominated by compression at high strain rates. Research presented in this paper has investigated the relationship between strain rate, impact energy, the degree of fragmentation and energy efficiencies of fragmentation. M Gabor[6] the study of stiffened plate models which leads to reduction in plate weight and indicates that the design of new energy efficient system of the crushed materials. In case stiffened jaw plates as the number of stiffeners increases the strength/weight ratio of the jaw plate increases making it stronger than that of without stiffener. Kadid Abdelkrim[7]Carried out investigation to examine the behavior of stiffened plates subjected to impact loading, he worked to determine the response of the plates with different stiffener configurations and consider the effect of mesh dependency, loading duration, and strain-rate sensitivity. Numerical solutions are obtained by using the finite element method and the central difference method for the time integration of the non-linear equations of motion.

From the above literature it has been observed that various testing and analysis have been performed on jaw crusher design, thickness, wear and stiffeners. Jaw crusher weight reduction optimization using composite materials not done yet.

2 MATERIAL & METHOD:

The material which is composed of two or more different kind of composite which are insoluble in each other and maintain their physical and chemically separated by clear cut interface called composite. Specific properties of composite are listed below-

- Low density
- High specific strength
- High specific modulus
- High thermal conductivity
- Good fatigue modulus
- Control of thermal expansion

Composite material are basically classified at two distinct levels-

The first level of classification is usually made with respect to matrix constituent. The major composite classes include organic matrix composite (OMC), metal matrix composite (MMC) and ceramics matrix composite (CMC). The term organic matrix composite is generally assumed to include two classes of composites, namely polymer matrix composite (PMC) and carbon matrix composites commonly referred to as carbon-carbon composites.

The second level of classification refers to the reinforcement form-

Fiber reinforcement composites, laminar composites and particulate composites. Fiber reinforced composite can be further divided into discontinuous or continuous fiber (Milton C 2001)

2.1 Structural analysis of jaw plate assembly

Structural analysis is a common application of a finite element analysis. Structural analysis is done to find out the total deformation and maximum von-mises i.e. equivalent stress of jaw plate assembly.

Steps are followed in structural analysis-

Step 1- cad modeling of jaw plate assembly and then saved as IGES format and then this file can be imported into ANSYS software.

Step 2 - Material selection choose proper material which have to be consider for analysis. In this problem be can consider a epoxy fiber glass composite, epoxy carbon fiber composite, rein forced aluminum composite & martensite steel for jaw holder material.

Step 3- Meshing of jaw crusher plate assembly, generally fine meshing are used for obtaining good result.

Step 4- Boundary condition fixed support at bottom of the assembly, provide displacement top of holder, force is applied in the jaw assembly is 8700 N in the face and toggle force is applied in back side of holder.

Step 5- Result and discussion

Figure 1 & 2: For martensite steel

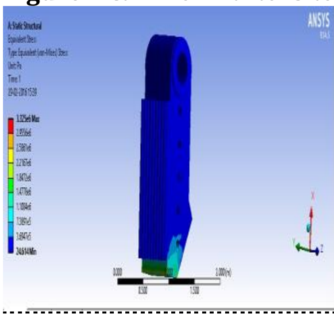

Fig (1)

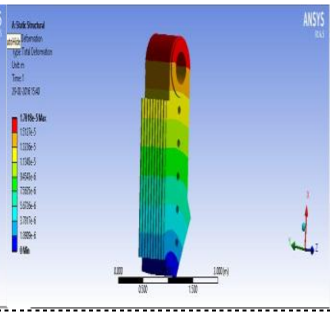

Fig (2)

Figure 3 & 4: for reinforced aluminium

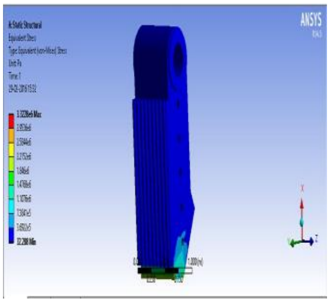

Fig (3)

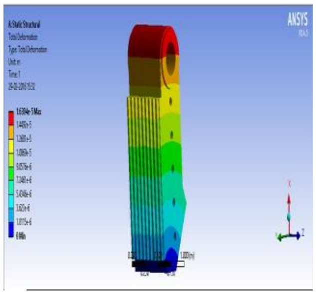

Fig (4)

2.2 Theoretical analysis

Velocity analysis of jaw crusher-

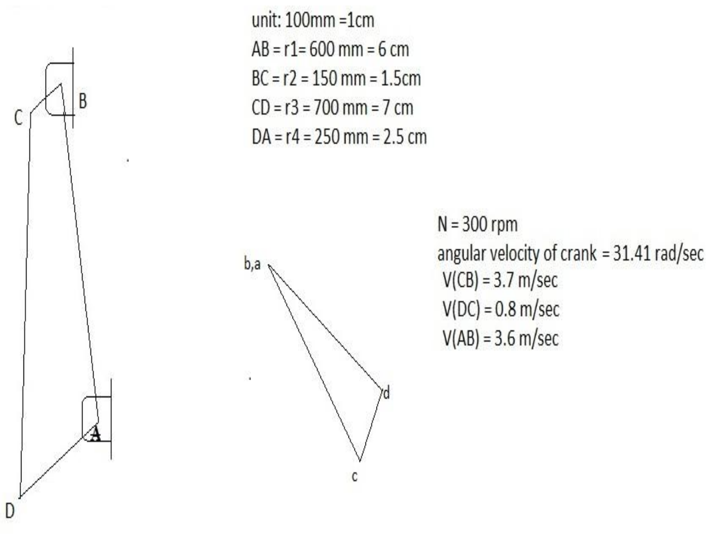

Fig (5)

Power calculation for jaw crusher:-

$$P=2\pi NT/60$$

For steel (both plate & holder) –

Torque (T) = F*r = m*a*r

Total mass of the assembly = mass of plate + mass of holder

$$=\rho(plate)*V(plate)+\rho(holder)*V(holder)$$

= 7720*(.15) + 7720*(1)

= 8878 kg

Acceleration of jaw assembly by velocity diagram from fig (5) is = 0.91m^2/sec

Torque (T) = 8878*0.91*0.7

= 5655.28 N-m

Angular velocity for plate assembly ω (DC) :

V (DC) = ω (DC)*DC

0.8 = ω (DC)*0.7= 1.14rad/sec

2πN/60= 1.14

N (DC) = 10.9 rpm

P = (2π * 10.9 *5655.28)/60 =6.455 KW

For fiber reinforced aluminum-

Torque (T) = F*r = m*a*r

Total mass of the assembly = mass of plate + mass of holder

$$=\rho(plate)*V(plate)+\rho(holder)*V(holder)$$

= 7720*(.15) + 3310*(1)

= 4477.26kg

Acceleration of jaw assembly by velocity diagram from fig (5) is = 0.91 m^2/sec

Torque (T) = 4477.26*0.91*0.7

= 2852.01 N-m

Angular velocity for plate assembly ω (DC):

V (DC) = ω (DC)*DC

0.8 = ω (DC)*0.7= 1.14rad/sec

2πN/60= 1.14

N (DC) = 10.9 rpm

Power = (2π * 10.9 *2852.01)/60 =3.255 KW

3 RESULT & DISCUSSION:

Static analysis of the jaw holder (martensite steel and composite material) is performed using ANSYS 15 software to find the von-mises stresses and deformation. The analysis involves the following discretization called meshing, boundary condition, loading. A virtual model of jaw plate and jaw holder modeled separately, than assembled together by using CREO2.0.

1. After taking all possible material result of martensite steel fig (1) much more similar of fiber reinforced aluminum. Maximum stress (von mises) are approximate similar for both the material. But the total deformation of martensite steel fig (2) is more than the fiber reinforced aluminum fig (3) & fig (4) shows maximum stress and total deformation

For martensite steel-
Equivalent stress = 3.325*10 ^ (6) pa
Total deformation= 1.7072*10 ^ (-5) m

For fiber reinforced aluminum-
Equivalent stress =3.322*10 ^ (6) pa
Total deformation=1.6302*10 ^ (-5) m

2. Theoretical analysis also shows power consumption for fiber reinforced aluminum approximately half than the martensite steel.

4 CONCLUSIONS:

The static analysis is performed for several composite material like epoxy fiber glass, epoxy carbon fiber and fiber reinforced aluminum. These materials which can replace the martensite steel as a holder material of jaw crusher. Above analysis it is found that the value of von mises stress for epoxy carbon fiber composite and martensite steel approximately same, but the deformation is high so the suggested material is fiber reinforced aluminum because the value of von mises is same as martensite but the deformation is less than the martensite steel.

Also doing the theoretical analysis it found that using the fiber reinforced aluminum as a material of jaw holder consume less power compare to martensite steel. It also find that the lesser weight of jaw plate assembly consume less power and work efficiently compare to previous one material working under same environmental condition.

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