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REVIEW ON DESIGN AND ANALYSIS OF JAW PLATE OF JAW-CRUSHER

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ABSTRACT

A jaw crusher is a type of size reduction machine which is widely used in mineral, aggregates and metallurgy field's .Based on the analysis of the liner movement and the crushing parameters, force allotment along the swing jaw plate is obtained. The job is helpful for a design of new kind of swing jaw plate. The interaction between jaw plates and material particles brings the expected and serious wear to the jaw plates during the jaw crusher operation, which not only decreases the effectiveness, but also increases the cost and the energy consumption of the jaw crusher. Obtained results from the kinematic analysis of the moving jaw and the crushing force distribution analysis, the jaw plates wear is analyzed on a macroscopic level. It is helpful to design the crusher for improved performance .Efforts to decrease energy consumed in crushing have led to consideration of decreasing the weight of the swing plate of jaw crushers. Design of lighter weight jaw crusher will need a more precise accounting of the stress and deflections in the crushing plates than which is available with traditional technique. The design of swing jaw plate is carried out by using CAD i.e., jaw plate has been solid modeled by using unigraphics. FEA is applied to swinging jaw plate to maximize the crushing material quantity by varying the angle of swing jaw plate. The different comparisons of swing jaw plates behavior, calculated with the conventional and the new FEA failure models.

I. INTRODUCTION

A crusher is a device that is designed to reduce large solid chunks of raw material into smaller chunks. Crushers are commonly classified by the degree to which they fragment the starting material with primary crushers that do not have much fineness, intermediate crushers having more significant fineness and grinders reducing it to a fine power. Jaw crusher is a machine designed to reduce large solid particles of raw material intosmaller particles. Crushers are major size reduction equipment used in mechanical, metallurgical and allied industries. They are available in various sizes and capacities rangingfrom 0.2 ton/hr to 50 ton/hr. They are classified based on different factors like product sizeand mechanism used. Based on the mechanism used crushers are of three types namely Conecrusher, Jaw crusher and Impact crusher.

1.1 Introduction to Jaw Crusher

Fig1: Jaw Crusher

Jaw crushers are typically used as primary crushers, or the first step in the process ofreducing rock. They typically crush using compression. The rock is dropped between tworigid pieces of metal, one of which then move inwards towards the rock, and the rock iscrushed because it has a lower breaking point than the opposing metal piece.Jaw crusher movement is obtained by using a pivot point located at one end of the "swingjaw", and an eccentric motion located at the opposite end. [6]

1.2 Different Types of Jaw CrusherA crusher may be considered as primary, secondary or fine crusher depending on the size reduction factor.

a) Primary crusher – The raw material from mines is processed first in primary crushers.. The input of such crushers is relatively wider and the output products are coarser in size.

Example - Jaw crusher, Gyratory crusher.

b) Secondary crusher- The crushed rocks from primary crusher are sent to secondary crusher for further size reduction. Example - Cone crusher, reduction gyratory crusher, spring rolls, disk crushers etc.

c) Fine crushers- Fine crushers have relatively small openings, and are used to crush the feed material into more uniform and finer product.

1) Blake Type Jaw Crusher

In this the movable jaw is hinged at the top of the crusher frame so that the maximumamplitude is obtained at the bottom of the crushing jaws. Blake Crushers are operated bytoggles and controlled by a pitman. These are commonly used as primary crushers in themineral industry. The size of the feed opening is referred to as the *gape*. (a) Single toggle type: - In this the number of toggle plate is only one. It is cheaper and hasless weight compare to a double toggle type jaw crusher. The function of the toggle(s) is tomove the pivoted jaw.

(b) Double toggle type: - Here the number of toggle plate is two. Over the years many mineshave used the double-toggle style of crusher because of its ability to crush materials,including mineral bearing ores that were both tough and abrasive.

1. Larger, rough, blocky as well as sticky rock or ore lumps can be crushed.
2. Reinforcement of the crusher is possible with the help of high strength crusher frame tocrush very hard rock or ore lumps.
3. It is very simple to adjust to prevent much of wear and also very easy to repair,
4. Maintenance o the crusher is very easy.

1.3 Major Components of a Jaw Crusher

Crusher Frame: Crusher Frame is made of high welding. As a welding structure, it has been designedwith every care so as to ensure that it is capable of resistant to bending stress even whencrushing materials of extremely hard.

Jaw Stock: Jaw Stock is also completely welded and has renewable bushes, Particular importancehas been given to jaw Stock of a design resistant to bending stresses. All jaw stocks areprovided with a renewable steel Alloy or manganese steel toggle grooves.

Jaw Crusher Pitman: The pitman is the main moving part in a jaw crusher. It forms the moving side of the jaw, while the stationary or fixed jaw forms the other. It achieves its movement through then eccentric machining of the flywheel shaft. This gives tremendous force to each stroke.

Manganese Dies in the Jaw Crusher: The jaw crusher pitman is covered on the inward facing side with dies made of manganese, an extremely hard metal. These dies often have scalloped faces. The dies are usually symmetrical top to bottom and can be flipped over that way.

Jaw Crusher Fixed Jaw Face: The fixed jaw face is opposite the pitman face and is statically mounted. It is also covered with a manganese jaw die

Eccentric Jaw Crusher Input Shaft: The pitman is put in motion by the oscillation of an eccentric lobe on a shaft that goes through the pitman's entire length. This movement might total only 1 1/2" but produces substantial force to crush material. This force is also put on the shaft itself so they are constructed with large dimensions and of hardened steel.

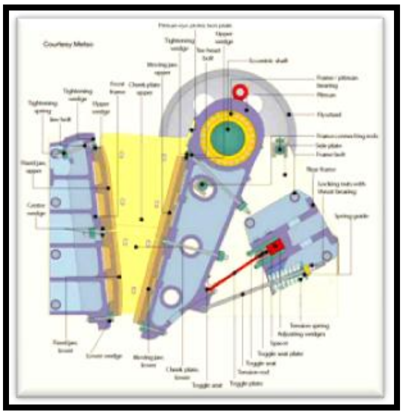


Fig2: Sectional view showing Components and functions of a Jaw Crusher

Jaw Crusher Input Sheave/Flywheel: Rotational energy is fed into the jaw crusher eccentric shaft by means of a sheave pulley which usually has multiple V-belt grooves.

Toggle Plate Protecting the Jaw Crusher: The bottom of the pitman is supported by a reflex-curved piece of metal called the toggle plate. It serves the purpose of allowing the bottom of the pitman to move up and down with the motion of the eccentric shaft as well as serve as a safety mechanism for the entire jaw.

Tension Rod Retaining Toggle Plate: Without the tension rod & spring the bottom of the pitman would just flop around as it isn't connected to the toggle plate, rather just resting against it in the toggle seat. The tension rod system tensions the pitman to the toggle plate. The toggle plate and seats. Thetoggle plate provides a safety mechanism in case material goes into the crushing chamberthat cannot be crusher.

Jaw Crusher Sides Cheek Plates: The sides of the jaw crusher are logically called cheeks and they are also covered with high-strength manganese steel plates for durability.

Jaw Crusher Eccentric Shaft Bearings:

Jaw Crusher Adjustment: Closed Side Opening Shims

1.4 Materials Used For Different Parts Body:

1. Body	Made from high quality steel plates and ribbed heavily in welded steel construction
2 Swing jaw Plate	Manganese steel
3. Fixed jaw plate	Manganese steel
4. Pitman	Crushers have a light weight pitman having White-metal lining for bearing surface
5. Toggle	Double toggles, for even the smallest size crushers give even distribution of load
6. Flywheel	high grade cast iron
7. Tension Rod	Pullback rods helps easy movement, reduces pressure on toggles and machine vibration
8. Hinge plate	Strong hinge pin made from steel are used for crushing without rubbing
9. Shaft and bearings	Massive rigid eccentric shafts made from steel along with roller bearing ensures smooth running

1.5 Jaw Crusher Working Principle

The working principal of Jaw Crusher is based on modern design "CRUCHING WITHOUTRUBBING" The machine consists, two Jaws, one fixed and the other moving. The openingbetween them is smaller at the bottom and wider at the top. The pitman moving on an eccentricshaft on bearing, swing lever (Moving Jaw) swing on center pin. The Rock held in between twoJaws and crushed by mechanical pressure. The mechanism of jaw crusher is to crush using impact on the upper parts of the jaw, with a little shear towards the bottom. Jawcrushers consist of two jaws. One fixed and the other reciprocating. The opening between themis largest at the top (gape) and decreases towards the bottom (set). The jaw moves on an eccentric shaftand the lower part is hinged on the toggles.

The rock is thrown between two jaws and crushed by mechanical pressure. This makes the attached jaw to approach and leave the other jaw repeatedly, to crush, rub and grind the feed. Hence the material moves gradually towards the bottom and finally discharges from the discharge end. The fixed jaw mounted in a “V” alignment is the stationary breaking surface.The swinging jaw exerts impact force on the material by forcing it against the stationary plate. The space at the bottom of the “V” aligned jaw plates is the crusher product size gaper size of thecrushed product from the jaw crusher. The rocks are crushed until they are small enough to pass through the gap at the bottom of the jaws.The ores are fed to the machine from the top where the jaws are atthe maximum distance apart.As the jaws come closer the ores are crushed into smaller sizes and slip down the cavity in thereturn stroke. In following cycle, further reduction of size is experienced and the ore moves down further. The process is continued till particles size is reduced to less than the bottom opening. The toggle is used to guide the moving jaw. The retrieving motion of the jaw from its furthest end of travel is by springs for small crushers or by a pitman for larger crushers. For a smooth movement of the moving jaws, heavy flywheels are used.

1.6 Problem Identification:-

The problem of the present available swing jaw plates are more wear rate while working. The wear rate reduces the production of crushing quantity. To improve the production quantity of crushing we are using various techniques to modify the swing jaw plate. The techniques include analysis by using CAD/CAE and mathematical models. The work also concentrates on modification of new jaw plate without affecting the cost of production and material.

1.7 Objectives

a. To reduce the wear rate of a Swing Jaw plate.

b. To find out the effects of the wears on a swing jaw plate.

c. To maximize the crushing quantity by varying the angle of swing jaw plate.

d. To reduce the shut down time due to maintenance of swing jaw plate.

II. LITERATURE REVIEW

Jaw crushers are used to crush material such as ores, coals, stone and slag to particle sizes. Jaw crushers operate slowly applying a large force to the material to be granulated.The jaw crushers are used commercially to crush material at first in 1616 as cited by Anon [1].It is used to simplify the complex engineering. Problem those were prevailing in Mining and Construction sector. An important experimental contribution was made in1913 when Taggart [2] showed that if the hourly tonnage to be crushed divided by Square of the gape expressed in inches yields a quotient less than 0.115 uses a jaw crusher.

LindqvistM.andEvertsson C. M. [3] worked on the wear in rock of crushers which causes great costs in the mining and aggregates industry. Change of the geometry of the crusher liners is a major reason for these costs. Being able to predict the geometry of a worn crusher will help designing the crusher liners for improved performance. Tests have been conducted to determine the wear coefficient

DeDiemar R.B. [4] gives new ideas in primary jaw crusher design and manufacture of Jaw crusher utilizing open feed throat concept, power savings and automation features. Jaw crushers with two jaw openings can be considered to be a completely new design. Jaw crushers are distinguished by reciprocating and complex movement of the moving jaw. Jaw crushers with hydraulic drives produced in France and jaw crushers with complex movement of two-sided jaws produced have advantages as well as a common shortcoming.

For a smooth reciprocating action of the moving jaws, heavy flywheels are used in both types of crushers. Russell A.R., Wood D. M.[5] helps in failure criterion for brittle materials is applied to a stress field analysis of a perfectly elastic sphere subjected to diametrically opposite normal forces that are uniformly distributed across small areas on the sphere's surface.

Gupta Ashok and Yan D.S. [6] worked in design of jaw crushers which impart an impact on a rock particle placed between a fixed and a moving plate. The faces of the plates are made of hardened steel. Both plates could be flat or the fixed plate flat and the moving plate convex. The surfaces of both plates could be plain or corrugated. The moving plate applies the force of impact on the particles held against the stationary plate. Both plates are bolted on to a heavy block.

Dowding Charles H. [7] designed jaw plates to reduce efforts to decrease energy consumed in crushing have lead to consideration of decreasing the weight of the swing plate of jaw crushers for easily crushed material.

This paper presents the results of an investigation of the feasibility of using point load-deformation-failure (PDF) relationships along with interactive failure of rock particles as a model for such a weight reduction. PDF relationships were determined by point-loading various sizes of materials: concrete mortar, two types of limestone, amphibolites and taconite.Molling [7], who proposed this hypothetical distribution, was only concerned with the total loading force. The parameterwhich most controls the design of the swing plate is the load distribution. Instrumentation of toggle arms in has since led to correlation of measured with rock type. Ruhl [7] has presented the most complete consideration of the effect of rock properties on Q and the toggle force. His work is based upon the three-point loading strength of the rock, which he found to be one-sixth to one eleventh the unconfined compressive strength. Hiramatsu and Oka [8] worked to model irregular particle behavior with that of cylinders by appropriate consideration. From photoelasticstudies of plate-loaded spheres and point-loaded cubes, prisms and ellipsoids, they determined that the stresses produced in plate and point-loaded spheres of identical diameter are equal. Thus, the plate idealization may be replaced by the point load. Niles I. L. [14] showed that point-load failure of a sphere was equal to that of a point-loaded ellipsoid. Therefore, ultimate point loads on spheres will be approximately equal to ultimate point loads on cylinders (or discs). For both the ellipsoids and the cylinders, the excess volume outside the spherical dimensions does not change the circular failure surface parallel to the smallest dimensions of the body. This circular failure surface for the sphere and cylinder is shown by the jagged lines on the two shapes

Hiramatsu and Oka's [8] photoelastic studies and theoretical calculations reveal that point loads produce tensile stresses across the middle 70% of the axis between the point loads. However, the volume directly beneath the contact is found to be in a state of compression, which leads to early, local compression failure. Early work by Bergstrom et al. and Stevenson and Bergstrom presented measurements of the deformability of small iron ore pellets and glass beads when crushed between two plates.

Whittles D.N. et al [8] 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. For the investigation two laboratory test methods were used to generate compressive failure under different strain rates. The tests were namely a variable speed unconfined compressive strength test, and a laboratory drop weight test.

King R.P. [9] investigation largely improved our understanding of the mechanism of the particle fracture process. It is found that although the particle is loaded predominantly in compression, substantial tensile stresses are induced within the particle under various loading conditions. It is those tensile stresses that induce a major catastrophic splitting crack to be responsible for the particle breakage. Moreover, around the loading points there is progressive localized crushing caused by the high compressive stress? Therefore, two major failure mechanisms are recognized: catastrophic splitting and progressive crushing.

Briggs, C.A. and Bearman, R.A. [10] reported that the particle breakage is the fundamental mechanism in all industrial combination process. In this study, the breakage processes of particles with heterogeneous material property, irregular shape and size under various loading conditions are numerically investigated by the Rock Failure Process Analysis code from a mechanics point of view

Berry P. et al [11] studied the laws of mechanics and constitutive relations concerning rock breakage characteristics. The simulated results are consistent with the general description and experimental results in the literature on particle breakage. A descriptive and qualitative particle breakage model is summarized as the following: at the first loading stage the particle is stressed and energy is stored as elastic strain energy in the particle. A number of randomly distributed isolated fractures are initiated because of the heterogeneity.

Guangjun FAN, Fusheng MU [12] worked on the certain domain, called the liner domain, of the coupler plane is chosen to discuss the kinetic characteristic of a liner or a crushing interface in the domain. Based on the computation and the analysis of the practical kinetic characteristic of the points along a liner paralleling to the direction of coupler line, some kinematics arguments are determined in order to build some kinetic characteristic arguments for the computing, analyzing and designing.

Weiss N.L. [13] work is helpful for a design of new prototype of this kind of machine on optimizing a frame, designing a chamber and recognizing a crushing character. A liner of jaw crusher is an interface for analyzing the crushing force, on which the crushing force occurs, in other words, the directly contact and the interaction between the material and the liner occur there. So the interface has great effect on the crushing feature of jaw crusher. The liner is one of the curves in the crosssection of the couple plane, which is also given a definition as one of the coupler curves in a four bar crank-rocker model.

III. STATIC FORCE AND KINEMATIC ANALYSIS

3.1 Static Force Analysis

T2 is the torque driving the crank

T3 = is the torque, acting about the swing jaw axis 03

F2and F3and are the forces in links 2 and 3 respectively, all assumed to be compressive

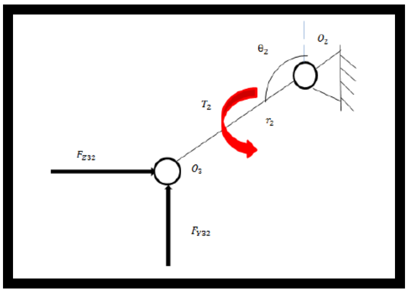


Fig3: Free body diagram about o2

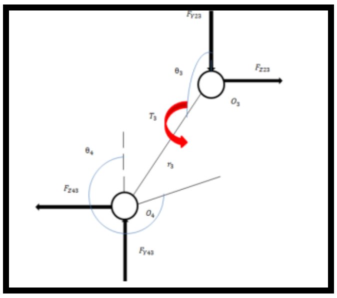


Fig4: Free body diagram about o4

And the angles,

Θ3 is angle of swing jaw plate

Θ2 is the angle of crank

The Equilibrium of moments on the crank about joint O_2 leads to the following results

$0 = -F_{y32} \text{ x } r_2 \sin\Theta_2 + F_{z32} \text{ x } r_2 \cos\Theta_2 + T_2$

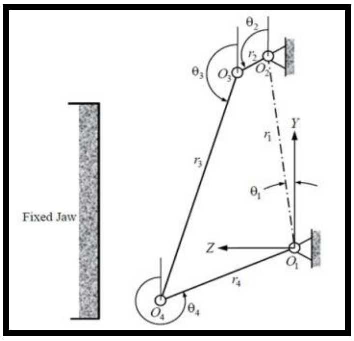
$T_2 = (F_{y32} \text{ x } \sin\Theta_2 - F_{z32} \text{ x } \cos\Theta_2) r_2$

A relationship between T_2 and T_3

$\frac{T_3 X r_2}{T_2 X r_3} = \frac{\sin 2\theta_3}{\sin(\theta_2 + \theta_3)}$

3.2 Kinematic Analysis

In analysis of the kinematics of the above crusher, an understanding of the motion of the rocker, relative to the fixed jaw as the crank rotates through a complete cycle is mandatory. All angular displacements are taken counter clockwise, relative to the Y direction.



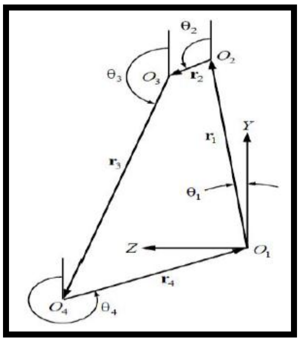


Fig5:Kinematic Model of a Single Toggle Jaw Crusher Fig6:Vector Loop Closure Method

Position and Displacement analysis The analysis of the position and displacement can be accomplished through use of the wellknown vector loop closure method, which is illustrated in figure below.

The vector loop equation can be written as follows

$r_1 + r_2 + r_3 + r_4 = 0$

r_1 mm(distancebetween toggle end and center of shaft)	r_2 mm (Eccentricity)	r_3 mm(Jaw Plate Length)	r_4 mm(distance between toggle end and jaw plate end)
660 mm	12.5 mm	800 mm	300 mm

3.3 Angular Displacement of the Swing Jaw

The angular displacement of swing jaw plate is given by:-

$2r_1 r_2 \cos\Theta_2 + 2r_1 r_3 \cos\Theta_3 + r_4^2 - r_1^2 - r_2^2 - r_3^2 = 2r_2 r_3 \cos(\Theta_3 - \theta_2)$

3.4 Design of Existing Crusher

We select the crusher 20”x10” crusher for the calculations (**JC1020)**

The given data for it is as below

The factors of importance in designing the size of primary crushers, like a jaw crushers, are:

Vertical height of crusher « 2 x Gape

Width of jaw > 1.3 x Gape

< 3.0 x Gape

Throw =$0.0502^{0.85}$ (Gape) Where the crusher gap is in meters.

3.5 Crusher Sizes and Power Ratings

Opening Gap for Crusher is 254 mm, Width of Jaw is W = 508 mm, Reduction ratio = 5:1, Maximum opening for jaw = 250 mm, Rock size maximum= 55 mm, Rock size minimum= 45 mm, From Rose And English formula

Critical Speed of crusher is given by

$V_c = 47\left(\frac{1}{L_T^{0.5}}\right) x \left(\frac{R-1}{R}\right)^{0.5}$

Where R= Reduction Ratio = 5 ,V_c= Critical velocity

$V_c = 47\left(\frac{1}{0.012^{0.5}}\right) x \left(\frac{5-1}{5}\right)^{0.5}$

= 384 R.P.M

Determination of crusher capacity (Q)

From Rose And English formula

Q = 36.86 T/H

$Q = 60 x L_T x V_c x W x (2 x L_{min} + L_T) x \left(\frac{R-1}{R}\right)^{0.5}$

Where

L_T = Length of throw = 0.012 meter, V_c= Critical Speed = 384 RMP, W=Width of jaw plate = 0.508 meter

L_{min} = Minimum size of rock = .045 meter, R= reduction ratio = 5By putting value we get

3.6 Power Consumption for Crusher

Given data

Work IndexW_i for rock is 16 from standard chart

D_{pb} = Mean product size of stone= 45 mm, D_{pa} = Mean feed size of stone= 254 mm,

$P = Q x 0.316 x W_i x \left(\frac{1}{\sqrt{D_{pb}}} - \frac{1}{\sqrt{D_{pa}}}\right)$x factor of safety

$P = 36.86 \text{ x } 0.316 \text{ x}16 \text{ x } \left(\frac{1}{\sqrt{45}} - \frac{1}{\sqrt{254}}\right) \text{ x}2$

= 32.17 KW

= 43 HP ~ 45 HP

3.7 Design of Jaw

From Rose and English Formula

The torque developed on jaw plate is 60 times at critical speed.

Hence from

T_2= Px60/2 x π x V_c

Where P= 32.17 kw

V_c = 384 PRM

Putting Values in equation we get

T_2 = 800 Nm

Putting

T_3= 60 xT_2

= 48000 Nm

Appling Beam theory

$\sigma_y = \frac{M \, X \, t_b}{2 \, X \, I}$

M = bending moment in the jaw.

I_b = Second moment of area of jaw

$$I_b = T_3 X \frac{t_b^3}{12}$$

$$\frac{\sigma_y}{2} = \frac{250 \, X \, 10^6}{2} = \frac{48000 X \, 12}{2 \, X \, 0.508 \, X \, t_b^2}$$

= .067 meter

= 67 mm

Where t_b = Thickness of Jaw, σ_y = yield strength of material = 250 MPa

IV. CONCLUSION

The study shows that the production rate of the crusher machine depends upon the swing jaw plate. As the wear rate reduced the production capacity of the crusher machine increases. In this paper we studied the capacity calculations of crusher machine. From this study we can conclude that the wear of swing jaw plate plays a major role in production capacity of machine. We also studied crusher machine components and material used for manufacturing them. The wear rate may be reduce by applying variousoptimization method such as Taguchi method.

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