COMPUTER AIDED DESIGN AND ANALYSIS OF SWING JAW PLATE OF JAW

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ABSTRACT

Traditionally, stiffness of swing plates has not been varied with changes in rock strength. Rock strength has only been of interest because of the need to know the maximum force exerted by the toggle for energy considerations. Thus a swing plate, stiff enough to crush taconite with an unconfined compressive strength of up to 308 MPa, may be overdesigned (and, most importantly, overweight) for crushing a softer fragmental limestone, amphibolites. Design of lighter weight jaw crushers will require a more precise accounting of the stresses and deflections in the crushing plates than is available with traditional techniques. 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. In the present work the design of the swing jaw plate using point-load deformation failure (PDF) relationships along with interactive failure of rock particles as a model for such a weight reduction. The design of the corrugated swing jaw plate is carried out by using CAD i.e. jaw crusher plate has been solid modeled by using CERO.. Finite Element Analysis of jaw plates are carried out by using ANSYS software.The computerized program facilitates for quick design of the plates of the jaw crusher. The different comparisons with and without ribs of swing jaw plates are analyzed.

Keywords: Jaw Crusher, Computer Aided Design (CAD), Point-Load Deformations and Failure (PDF), Finite Element Analysis, Solid Modeling, Corrugated Jaw plate, Stiffened-Jaw Plate.

INTRODUCTION

Jaw crusher is a machine designed to reduce large solid particles of raw material into smaller particles. Crushers are major size reduction equipment used in mechanical, metallurgical and allied industries. They are available in various sizes and capacities ranging from 0.2 ton/hr to 50 ton/hr. They are classified based on different factors like product size and mechanism used. Based on the mechanism used crushers are of three types namely Cone crusher, Jaw crusher and Impact crusher.

The first stage of size reduction of hard and large lumps of run-of-mine (ROM) ore is to crush and reduce their size. Large scale crushing operations are generally performed by mechanically operated equipment like jaw crushers, gyratory crusher and roll crushers. For very large ore pieces that are too big for receiving hoppers of mechanically driven crushers, percussion rock breakers or similar tools are used to break them down to size. The mechanism of crushing is either by applying impact force, pressure or a combination of both. The jaw crusher is primarily a compression crusher while the others operate primarily by the application of impact.

Crushing is the process of reducing the size of the lump of ore or over size rock into definite smaller sizes. The crusher crushes the feed by some moving units against a stationary unit or against another moving unit by the applied pressure, impact, and shearing or combine action on them. The strain in the feed material due to sufficiently applied pressure, impact forces, or shearing effect when exceeds the elastic limit of the feed material, the fracturing will occur on them. The crushers are very much rugged, massive and heavy in design and contact surfaces have replaceable high tensile manganese or other alloy steel sheet having either flat or corrugated surfaces. To guard against shock and over load the crushers are provided with shearing pins or nest in heavy coiled springs. Many engineering structures consist of stiffened thin plate elements to improve the strength/weight ratio. The stiffened plates subjected to impact or shock loads are of considerable importance to mechanical and structural engineers. The main object of the present work is to propose an efficient use of modeling in the connection between the plate and the stiffener, and as part of it the constraint torsion effect in the stiffener.

Introduction to Jaw Crusher

The first stage of size reduction of hard and large lumps of run-of-mine (ROM) ore is to crush and reduce their size. Softer ores, like placer deposits of tin, gold, mineral sands etc. do not require such treatment. Large scale crushing operations are generally performed by mechanically operated equipment like jaw crushers, gyratory crusher and roll crushers. For very large ore pieces that are too big for receiving hoppers of mechanically driven crushers, percussion rock breakers or similar tools are used to break them down to size. The mechanism of crushing is either by applying impact force, pressure or a combination of both. The jaw crusher is primarily a compression crusher while the others operate primarily by the application of impact. [6]

Jaw crusher is one of the main types of primary crushers in a mine or ore processing plant. The size of a jaw crusher is designated by the rectangular or square opening at the top of the jaws (feed opening). For instance, a 24 x 36 jaw crusher has a opening of 24" by 36", a 56 x 56 jaw crusher has a opening of 56" square. Primary jaw crushers are typically of the square opening design, and secondary jaw crushers are of the rectangular opening design. However, there are many exceptions to this general rule. Jaw crusher is a primary type of crusher which has two jaws, out of which one is stationary attached rigidly with the crusher frame whereas the other moves between a small throw forward and retarded back successively to crush the ore or rock boulders. Jaw crushers are typically used as primary crushers, or the first step in the process of reducing rock. They typically crush using compression. The rock is dropped between two rigid pieces of metal, one of which then move inwards towards the rock, and the rock is crushed 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 "swing jaw", and an eccentric motion located at the opposite end.

Fig Typical Jaw Crusher

Different Types of Jaw Crusher

Jaw crusher can be divided into two according to the amplitude of motion of the moving face. The different types of Jaw Crushers are:

1) Blake Type Jaw Crusher

In this the movable jaw is hinged at the top of the crusher frame so that the maximum amplitude is obtained at the bottom of the crushing jaws. Blake Crushers are operated by toggles and controlled by a pitman. These are commonly used as primary crushers in the mineral industry. The size of the feed opening is referred to as the gape. The opening at the discharge end of the jaws is referred to as the set. The Blake crushers are single or double toggle drives. The function of the toggle(s) is to move the pivoted jaw. The retrieving action of the jaw from its furthest end of travel is by springs for small crushers or by a pitman for larger crushers. As the reciprocating action removes the moving jaw away from the fixed jaw the broken rock particles slip down, but are again caught at the next movement of the swinging jaw and crushed. This process is repeated until the particle sizes are smaller than the smallest opening between the crusher plates at the bottom of the crusher (the closed set). For a smooth reciprocating action of the moving jaws, heavy flywheels are used in both types of crushers. Blake type jaw crusher may be divided into two types.

Single toggle type: - In this the number of toggle plate is only one. It is cheaper and has less weight compare to a double toggle type jaw crusher. The function of the toggle(s) is to move the pivoted jaw.

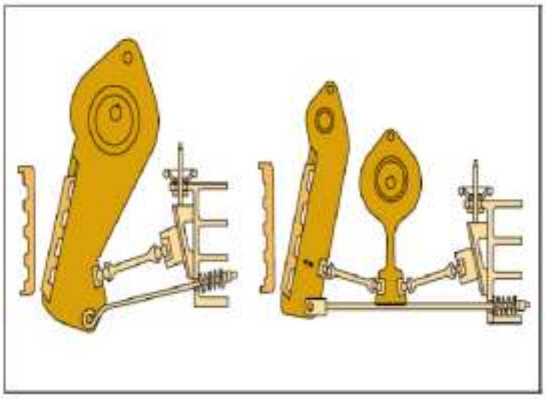
(b) Double toggle type: - Here the number of toggle plate is two. Over the years many mines have used the double-toggle style of crusher because of its ability to crush materials, including mineral bearing ores that were both tough and abrasive. While many aggregate producers have used the overhead eccentric style. There are many factors that should be considered when deciding which style would be best for your application. For larger material crushing, always larger Blake type jaw crushers are selected. The characteristics of this type of crusher are as following

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 to crush 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.



Types of Blake Type Jaw Crusher

Dodge Type Jaw Crusher

The moving plate is pivoted at the bottom and connected to an eccentric shaft. In universal crushers the plates are pivoted in the middle so that both the top and the bottom ends can move. The movable jaw is hinged at the bottom of the crusher frame so that the maximum amplitude of motion is obtained at the top of the crushing jaws. They are comparatively lower in capacity than the Blake crushers and are more commonly used in laboratories.

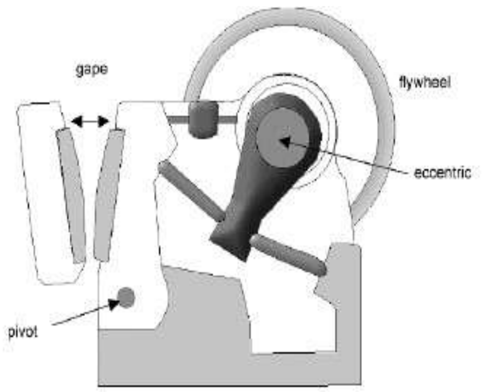


Fig: Dodge Type Jaw Crusher [6]

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. Generally this is accomplished by pressing it between jaws or rollers that move or turn together with proper alignment and directional force. The jaw crusher squeezes rock between two surfaces, one of which opens and closes like a jaw. Rock enters the jaw crusher from the top. Pieces of rock those are larger than the opening at the bottom of the jaw lodge between the two metal plates of the jaw. The opening and closing action of the movable jaw against the fixed jaw continues to reduce the size of lodged pieces of rock until the pieces are small enough to fall through the opening at the bottom of the jaw. It has a very powerful motion. Reduction in size is generally accomplished in several stages, as there are practical limitations on the ratio of size reduction through a single stage.

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. Lindqvist M.and Evertsson 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. Using a small jaw crusher, the wear of the crusher liners has been studied for different settings of the crusher. The experiments have been carried out using quartzite, known for being very abrasive. Crushing forces have been measured, and the motion of the crusher has been tracked along with the wear on the crusher liners. The test results show that the wear mechanisms are different for the fixed and moving liner. If there were no relative sliding distance between rock and liner, would yield no wear. This is not true for rock crushing applications where wear is observed even though there is no macroscopic sliding between the rock material and the liners. For this reason has been modified to account for the wear induced by the local sliding of particles being crushed. The predicted worn geometry is similar to the real crusher. A jaw crusher is a machine commonly used in the mining and aggregates industry. The objective of this work, where wear was studied in a jaw crusher, is to implement a model to predict the geometry of a worn jaw crusher.

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. This is due to the discharge gap being almost vertical or sharply inclined so that a large part of the material is crushed only to a size corresponding to the maximum width of the gap between the jaws at the crusher exit. A new design has a gently sloping gap between the movable and stationary jaws .This causes material to move slowly and be subjected to repeated crushing. In addition the movement of the movable jaw relative to the stationary one is such that its stroke is equal both at the inlet and outlet of the discharge gap. When the eccentric moves in different quadrants. The power consumption of this jaw crusher is low since the work of crushing is distributed between two quadrants. The precrushed material falls under its own weight onto the movable jaws which are lowered by the movement of the eccentric through the third and fourth quadrants. During this movement the material moved down slightly along the gap between the jaws and comes in contact with the movable jaws at approximately the time when they are furthest removed from stationary jaws. The material is again crushed as the eccentric continues to move through the first and second quadrant. The material thus undergoes repeated crushing when it passes through the gap between the jaws. Efforts to intensify the crushing process and to increase throughput capacity of crushers sometimes leads to interesting solutions of kinematic systems. The jaw crusher has six movable and three stationary two-sided jaws with a planetary drive. The high throughput capacity is achieved by a significantly more complicated construction. Analysis of crusher operation leads to the conclusion that development of their design is proceeding both along the path of improved design and development of fundamentally new efficient kinematic systems.

DESIGN AND MODELLING

Recently, concern for energy consumption in crushing has led to the consideration of decreasing the weight (and consequently the stiffness) of the swing plate of jaw crushers to match the strength of the rock being crushed. An investigation of the energy saving of plate rock interaction when point load deformability and failure relationships of the rock are employed to calculate plate stresses. Non simultaneous failure of the rock particles is incorporated into a beam model of the swing plate to allow stress calculation at various plate positions during one cycle of crushing. In order to conduct this investigation, essentially two studies were required. First, point load-deformation relationships have to be determined for differing sizes of a variety of rock types. Even though much has been written about the ultimate strength of rock under point loads, very little has been published about the pre and post-failure point load-deformation properties. Therefore, some 72 point, line and unconfined compression tests were conducted to determine typical point load-deformation relationships for a variety of rock types. Secondly, a numerical model of the swing plate A as shown in Fig. has been developed.

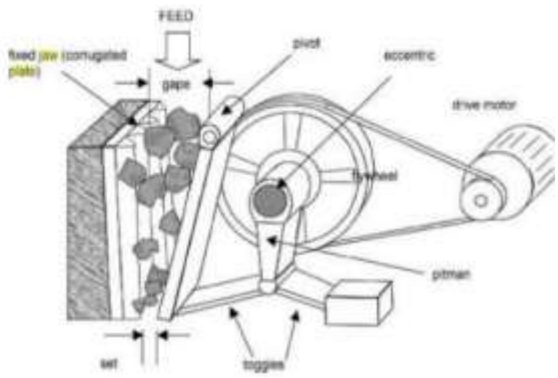
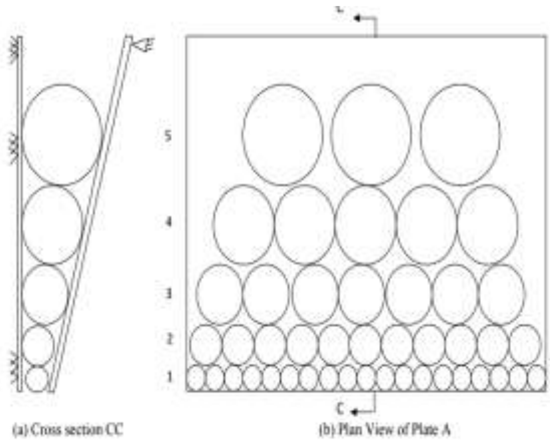


Fig: Elevation View of Jaw Crusher

The swing plate A is idealized as shown in Fig. (a) as a unit width beam loaded at a number of points by different sized particles. Each row of uniformly sized particles in Fig.(b) is idealized as one point load on the unit width model of the swing plate. Because of the interactive nature of this model, the failure of any row of particles permits redistribution of stresses within the beam.



The load distribution along the swing plate

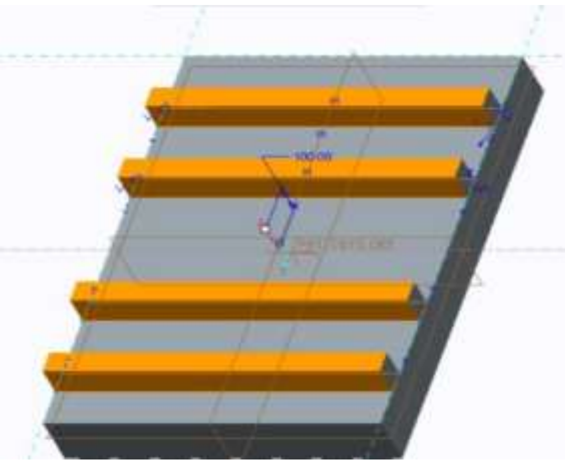
The parameter which most controls the design of the swing plate is the load distribution, shown in Fig.4.This hypothetical distribution, was only concerned with the total loading force (Q). Instrumentation of toggle arms in Germany has since led to correlation of measured Q with rock type. The most complete consideration of the effect of rock properties on Q and the toggle force (T). 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 (q?). The hypothetical toggle forces based upon the sum of forces necessary to crush a distribution of regular prisms fractured from an initial cubical rock particle. These approaches involved both maximum resistance and simultaneous failure of all particles and thus neither can lead to an interactive design method for changing stiffness (and weight) of the swing plate.

Point load deformation and failure (PDF) data for materials

Point load deformation and failure (PDF) data were obtained for the five materials: sand-cement mortar, fragmental limestone, dolomitic limestone, taconite and amphibolites (closely banded gneiss) have shown in Table with their major properties.

Table 3.1 Materials tested [7]

Material	E (MPa)	q_u (Mpa)	Location	Mineralogy, Texture
Mortar	9.7	20.7	Made in laboratory	Sand and cement
Fragmental limestone	30.3	54.5	Chicago Lyons, IL	mixture fragmental,
Dolomitic limestone	48.3	151.7	Northern Minnesota	porous Dolomitic
Taconite	41.4	234.4	Massachusetts	siliceous, finely
Amphibolites	33.6	124.1		grained crystalline.



3D MODEL

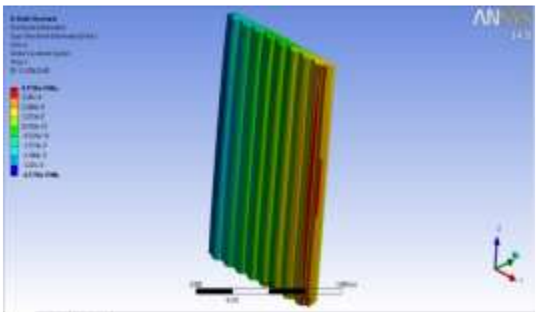
Computer Aided Analysis

Machine elements are required to operate in environmental conditions where they may be subjected to forces, extreme thermal conditions, and unfavorable weather conditionsa nd so on. The element must be designed to withstand the harmful effects of the environment and to operate satisfactorily. Hence, the designer must formulate a mathematical model for the element, represent the behavior or the response of the element using differential equations, and analyze for the response when subjected to environmental conditions. The stresses developed in the element due to the external forces under other unfavorable conditions must be obtained and compared with the maximum stresses that the element can withstand safely. The mathematical model for the element as well as mathematical model for the external forces must be formulated by the designer. There are several methods available to solve the resulting differential equations describing the behavior of the element or the system, of which the element is a part. The past experience in solving similar equations using all the available techniques may be store in an expert system which can suggest the best analysis method for the design problem. Alternatively; the designer can make a choice of the analytical method from the past experience in solving similar problems. Finite difference methods, transfer matrix methods, finite element methods are some of typical methods that can be used for the mathematical representation of the system and direct numerical integration or modal analysis techniques are some possible analysis techniques to obtain the system response when subjected to environmental excitations.

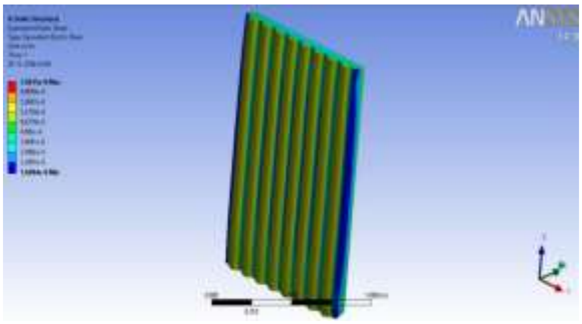
When the element being designed is quite complex or when the element behavior can be understood only by analyzing the complete system, of which the element is apart, then calculations done manually will be unmanageable and prone to errors. Computers can be very efficiently used for the routine and repetitive computations involved in all these analysis methods. [34]

Swing Jaw Plates Static Stress Analysis Using ANSYS

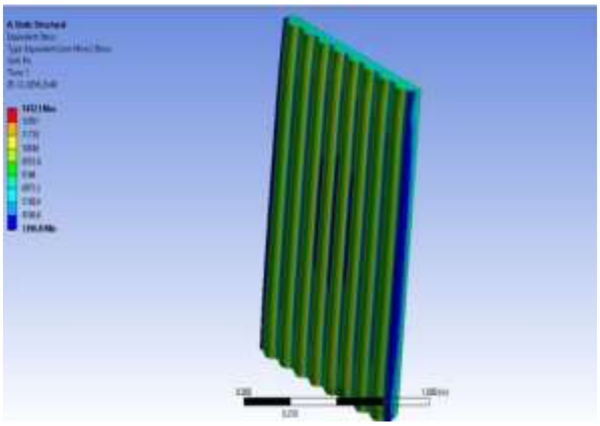
JAW PLATE WITHOUT RIBS



STATIC STRUCTURAL



EQUIVALENT ELASTIC STRAIN



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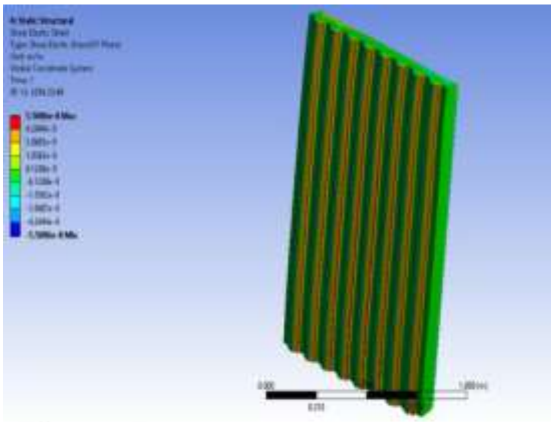

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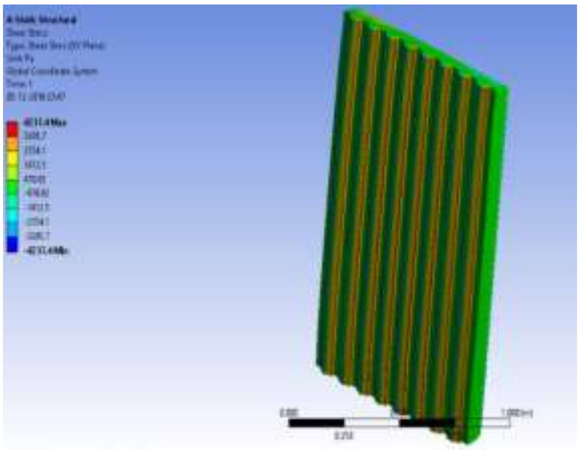
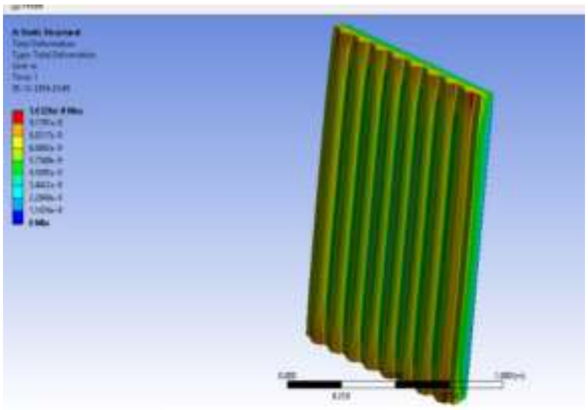


SHEAR STRESS



RESULTS, DISCUSSION AND CONCLUSION

Swing jaw plate with and without ribs esults are observed.The load distribution found with simultaneous failure as shown and compared with the load distribution curve assumed by Molling [6]. The stepwise pressure distribution was found by distributing the ultimate point load for that size particle over the distance midway between each of the two adjacent loads. The similarity of the two distributions further substantiates the size-strength relations and particle size distribution employed in this study. The FEA models using ANSYS are employed to calculate maximum tensile stresses and maximum toggle forces (T) for a variety of model plate thicknesses, using the rock properties of the amphibolites.

CONCLUSION

(1) Finite element analysis of swing jaw plates is carried out, using eight- noded brick element to predict the behavior when it is subjected to point loading under simply supported boundary conditions.

(2) The present jaw plate models accurately predict the various stresses for plates in both with and without rib models . As the present models are developed using a non-conforming element, the results can be further improved using a conforming element with improved mesh size thereby increased no of elements. Infact, FEM results approach the true solutions, with the increase in the number of elements.

(3) without rib plate models which leads to reductions in plate weight and indicates that design of new energy-efficient systems of the crushed material.

(4) The stiffened plate models which leads to 25% saving in energy, of course this 25% is an estimate.

(5) Consideration of the two particles between the crusher plates reveals the importance of the point-load failure mechanism. Thus, any design based upon both deformation and strength must begin with a point-load idealization.

(9) Design of lighter weight jaw crushers will require a more precise accounting of the stresses and deflections in the crushing plates than is available with traditional techniques.

(10) Rock strength has only been of interest because of the need to know the maximum force exerted by the toggle for energy considerations. Thus a swing plate, stiff enough to crush taconite, may be overdesigned for crushing a softer fragmental limestone.

(11) Design of crushers for specific rock types must consider the variability of point load strength and deformability implicit in any rock type name and quarry sized sampling region.

FURTHER SCOPE FOR STUDY

Further work is needed to apply the basic, non-simultaneous failure and rock-machine interaction theory with the following modifications and extensions.

(1) Varying packing arrangements from the simplified row assumption to random distributions found in actual operation can be applied to get more accurate results.

(2) Extend the size-peak crushing force and stiffness relationships to account for larger sized feed stock and the effects of jointing and blast-induced micro fissures.

(3) All the Rock names are given on the basis of composition and texture, not strength or deformability. Thus limestone, as shown by the comparison of fragmental and dolomitic limestone, can have widely varying strengths. Therefore crushers cannot be selectively designed with low factors of safety without testing the exact rock to be crushed.

(4) Rock strength will vary even within a specific quarry. Other work has shown that coefficients of variation of rock strength can be as much as 20 - 50% of the mean for are stricted sampling region.

(5) Line loading also produces deformation hardening behavior. Such loading conditions may be applicable for modeling the behavior of slabby material when loaded with ridged plates.

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