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DESIGN AND ANALYSIS OF SWING JAW PLATE WITH AND WITHOUT RIBS

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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 [36]

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.

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.3.2 has been developed.

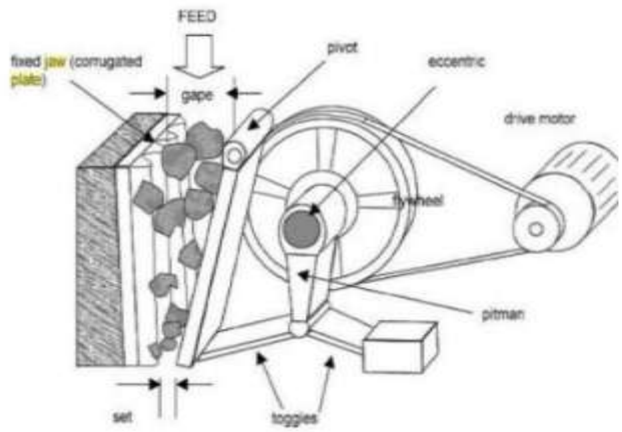
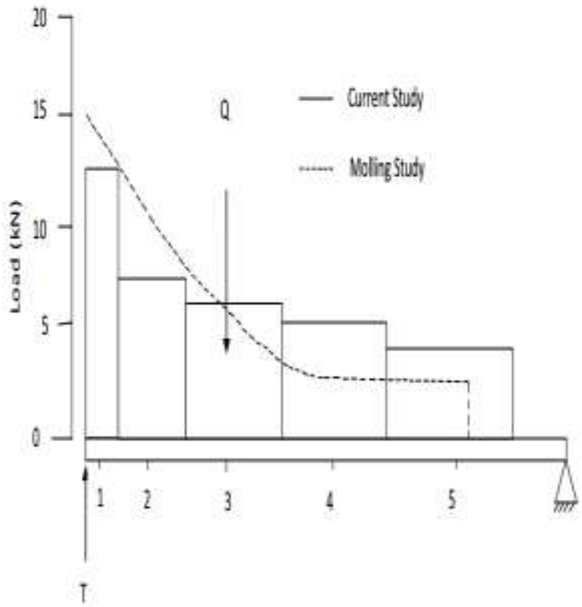


Fig.: Elevation View of Jaw Crusher

The load distribution

The parameter which most controls the design of the swing plate is the load distribution, shown. 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.



Load distribution along plate A only.

Normally, the stiffness and dimensions of swing plates are not changed with rock type and all plates are capable of crushing rock such as taconite with an unconfined compressive strength (q?) of up to 308 MPa. Only the facing of the swing plate is changed with rock type, to account for changes in abrasiveness or particle shape. For instance, ridged plates are employed with prismatic particles both to stabilize the particles and to ensure the point-loading conditions. Communications with manufacturers of jaw crushers have revealed that no consideration is currently given to force displacement characteristics of the crushed rocks in the design of swing plates.

Consideration of the two particles between the crusher plates in Fig.3.2 reveals the importance of the point-load failure mechanism. As a rock tumbles into position it will catch on a comer of a larger diameter and thus will be loaded at two 'points' of contact. Throughout the paper, 'point' describes contact over a small and limited region of the circumference of the particle. Should flat-sided contact occur, the ribbed face plates of most crushers will apply point loads to the particle. The particle will then fail either by two or three point loading. Thus, any design based upon both deformation and strength must begin with a point-load idealization.

Modeling irregular particle behavior with that of cylinders

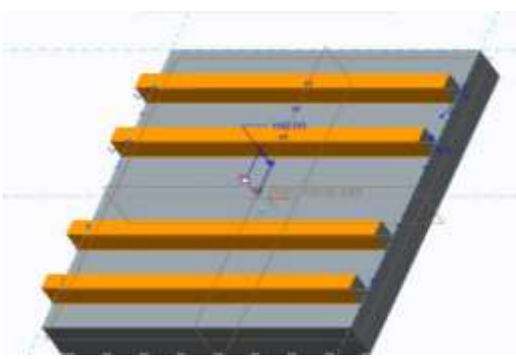
In this study point-loading of cylinders (or discs) are undertaken to model behavior of irregular rock particles. Modeling irregular particle behavior with that of cylinders can be shown to be appropriate by consideration of work presented by Hiramatsu and Oka .From photoelastic studies of plate-loaded 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 shown in Fig..

These results compared with disc and irregular particle point-load strengths from tests on andecite, dolomite, sandstone and shale and found the point load strength of the disk and irregularly shaped particles to be equal. Thus, the properties determined from point-loading of discs or cylinders are appropriate for the point-loading of irregular particles. The photo elastic 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. Thus, any deformation measured between the two points of contact will have two components:

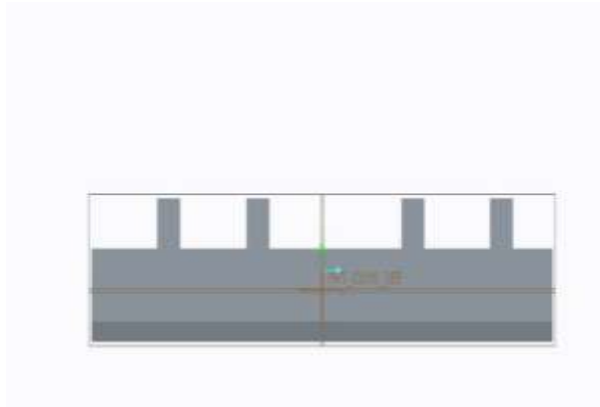
(1) Elastic over the middle 70% of the particle and

(2) Plastic (as a result of local crushing) immediately beneath the point of load application.

The deformbility of point-loaded specimens is determined with the loading method suggested by Reichmuth. As shown in Fig., cores were compressed with 19 mm diameter steel rods (oriented transversely to the long axis) by a universal testing machine. Diametral displacements were recorded with the two dial gages shown in the figure to eliminate any effects of tilting of the upper platen. Force-displacement data were recorded at equal load intervals throughout compression, and the loading rate was set so that the total time to failure was ten minutes or less. Failure was defined by a sudden loss of load capacity or the appearance of a fracture. When sudden brittle failure occurred, displacements at failure were extrapolated from the previously recorded values according to the maximum compressive load. No post-failure data were recorded. Unconfined compression , tests were also performed according to ASTM standards to measure Young's modulus.



3D MODEL



Solids represent a large variety of objects we see and handle. Curves and surfaces are intended to form the basis for solid or volumetric modeling. Solid modeling techniques have been developed since early 1970's using wireframe, surface models, boundary representation (b-rep), constructive solid geometry (CSG), spatial occupancy and enumeration. A solid model not only requires surface and boundary geometry definition, but it also requires topological information such as, interior, connectivity, holes and pockets. Wire-frame and surface models cannot describe these properties adequately. Further, in design, one needs to combine and connect solids to create composite models for which spatial addressability of every point on and in the solid is required. This needs to be done in a manner that it does not become computationally intractable. Manufacturing and Rapid Prototyping (RP) both require computationally efficient and robust solid modelers. Other usage of solid modelers is in Finite Element Analyses (as pre- and post processing), mass property calculations, computer aided process planning (CAPP), interference analysis for robotics and automation, tool path generation for NC machine tools, shading and rendering for realism and many others.[33]

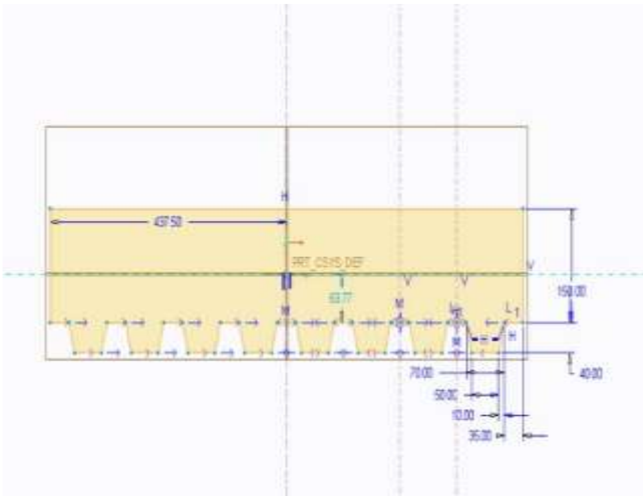


Fig. Picture Showing Corrugated Cast Steel Jaw Plates

Swing Jaw Plates Static Stress Analysis Using ANSYS

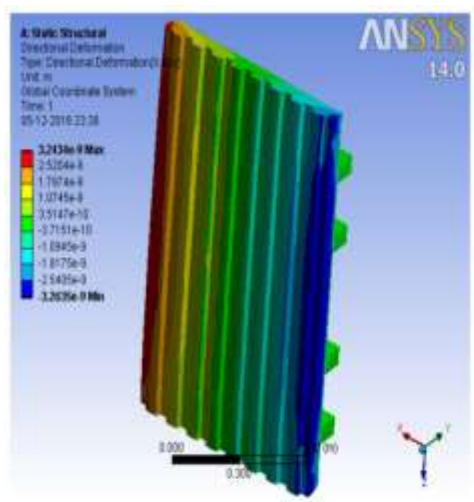
Assumptions

To simulate the stress behavior of corrugated jaw plate some assumptions and approximations are required. Here analysis was undertaken based on the assumption that the point load strength of the disk and irregularly shaped particles to be equal and tensile point loads of different particle sizes are acting normal to the plate.

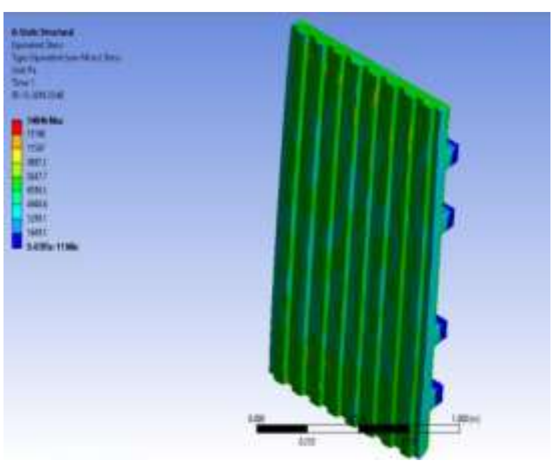
Applying Material Properties

Austenitic Manganese Steel is only when the manganese content exceeds about 0.08% that the steel may be classed as an alloy steel. When manganese content exceeds about 10%, the steel will be austenitic after slow cooling. One particular type of steel, known as Hadfield manganese steel, usually contains 12% manganese. Austenitic Manganese Steel-Standard and Specifications (ASTM 128 A/ 128M) .This specification covers Hadfield austenitic manganese steel castings and alloy modifications. Cast cross-section size precludes the use of all grades, and the buyer should consult us, as to grades practically obtainable for a particular design required. Final selection is to be based on consensus between the buyer and Acme Alloys. The wear resistant cast steel is generally, referred to as Hadfield manganese steel. Although the above mentioned ten grades of austenitic steels have chemical composition to the Hadfield's original composition, its primary reason for existence is the assurance it provides the user from unexpected failure in demanding applications where downtime cannot be accepted. Manganese steel is a low-strength, high-ductility material. But properly controlled heat treating by austenizing and followed by water quenching or controlled air cooling, the 12% manganese steel, ASTM 128 A, consists of a meta-stable austenitic phase having a face centered cubic (FCC) lattice with strengthening from interstitial carbon and substitutional manganese atoms. Another property of great significance is its ability to work-harden from an initial hardness of 240 BHN (23 Rc) to well over 500 BHN (51 Rc). The face centered cubic (FCC) lattice has 12 equivalent slip systems and deformations that result in conversion of some austenite to martensite. As this work-hardening deformation process continues, it increases hardness of the affected metal and eventually results in increasing abrasion resistance.Thus, manganese steels perform most efficiently when external conditions cause extensive work hardening of the wear component's surface. If cracking of the work hardened layer occurs, the crack propagation would quickly be checked and prevented by the tougher un-worked hardened core. Hence, in demanding applications such as primary rock crushing austenitic manganese steels are widely used. Mineral and mining equipment, grinding and crushing machinery, power shovel buckets, railway track work, cement plants- kiln and mill liners, stone crushers- jaw and gyratory crushers and ore processing. [26] Austenitic manganese steel material customer defined using isotropic material properties. Elastic Modulus (E) = 210 GPa, Mass Density (ρ) = 7838 kg/m3, Poisons ratio (ν) = 0.3, Shear Modulus (Φ) =80.76 GPa, Yield Strength (Ys) =550Mpa.

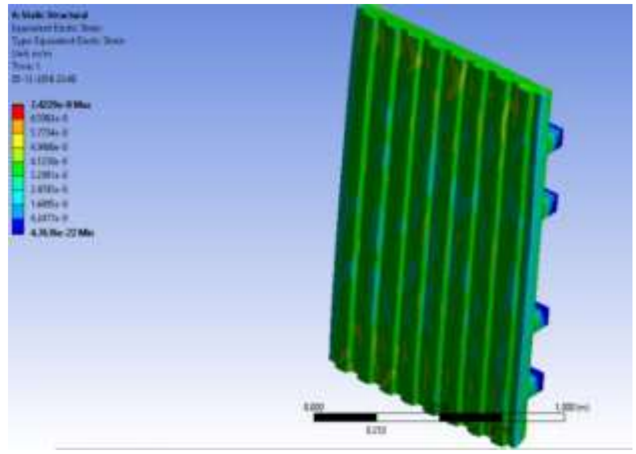
JAW PLATE WITH RIBS AND WITHOUT RIB ANALYSIS



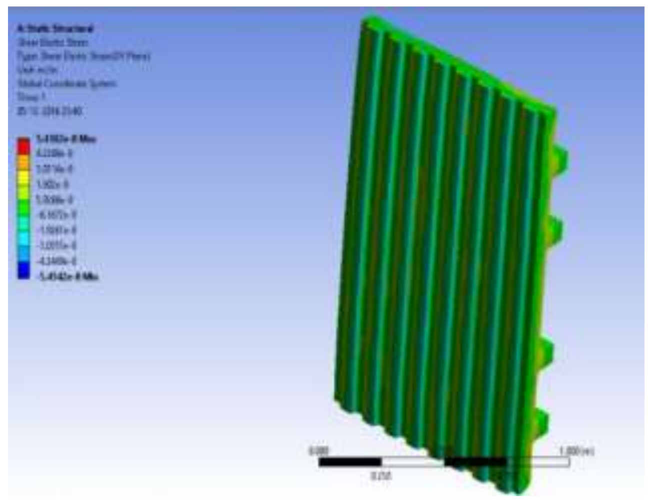
Directional Deformation



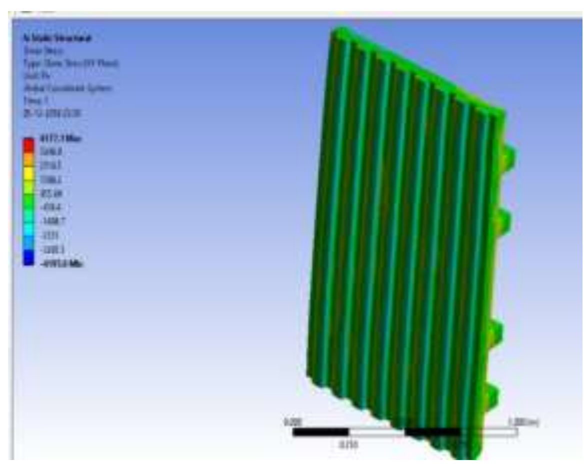
Static Structural



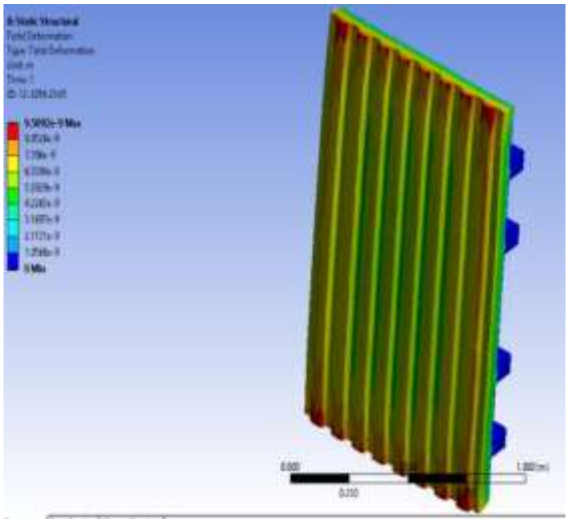
Equvilent Strain



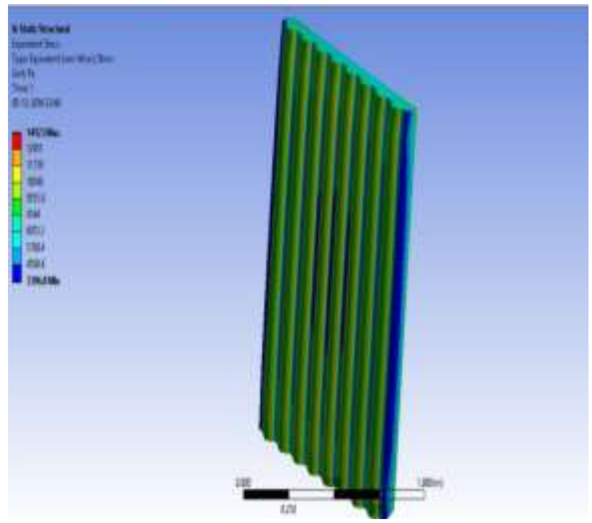
Shear Elastic Strain



Stress Along X-Y Axis

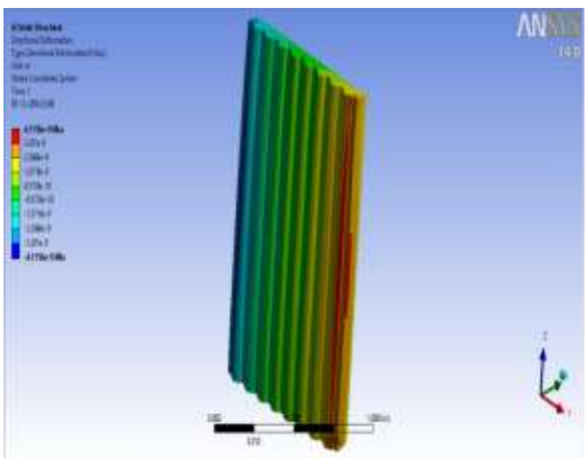


Total Deformation

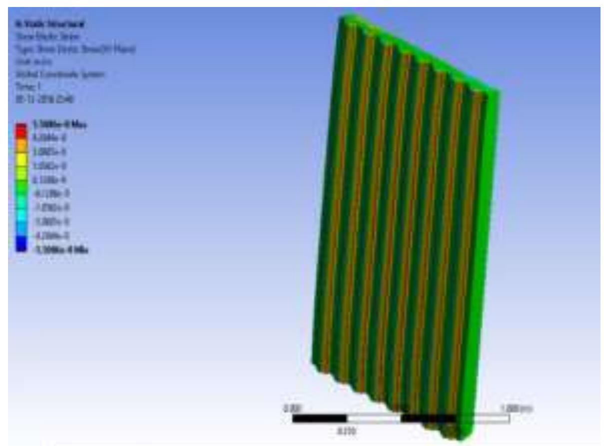


Static Structural

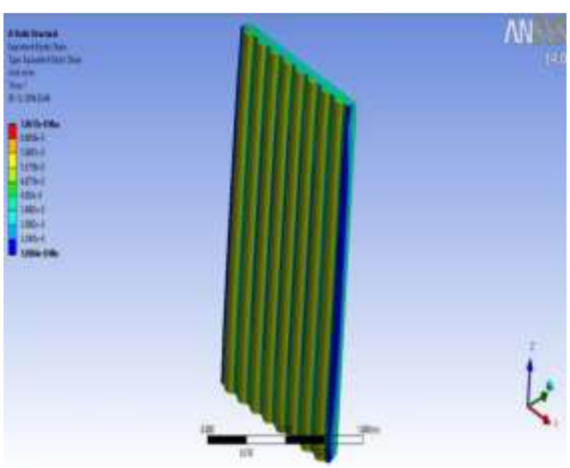
Jaw Plate Without Ribs



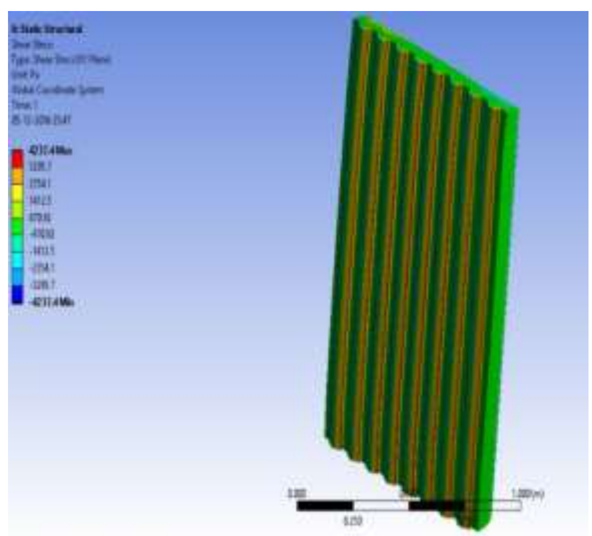
Static Structural



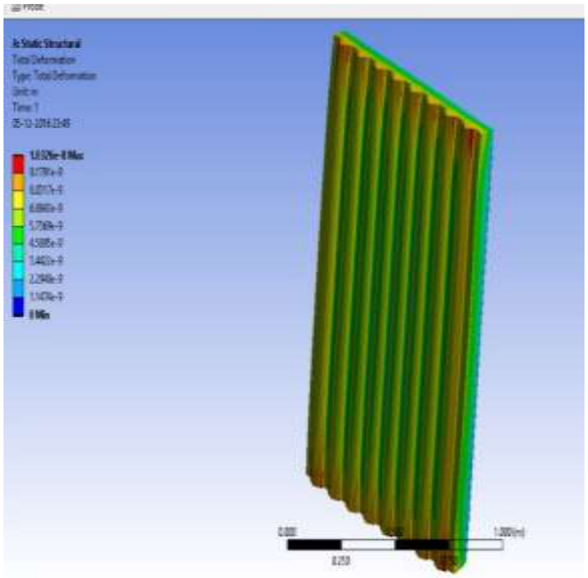
Elastic Strain



Equivalent Elastic Strain



Shear Stress



Deformation

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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