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# "Design and Finite Element Analysis of Swing Jaw Plate of Jaw Crusher with Stiffener"

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**Abstract -** *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 (q ) 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 CatiaV5R15. The calculated dimensions are validated with the drawing of reputed manufacturers. Finite Element Analysis of jaw plates are carried out by using ALGOR V19 software. Computerization of the theoretical design calculations of jaw plates of the jaw crusher has been carried out. The computerized program facilitates for quick design of the plates of the jaw crusher.*
*The different comparisons of corrugated swing jaw plates behavior, calculated with the traditional and the new FEA failure models with stiffeners, shows that some 10-25% savings in plate weight may be possible.*

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

## I. 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.

 

## II. 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.

***Figure 1* – Jaw Crusher *Structure***

## III. 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, 2) Dodge Type Jaw Crusher

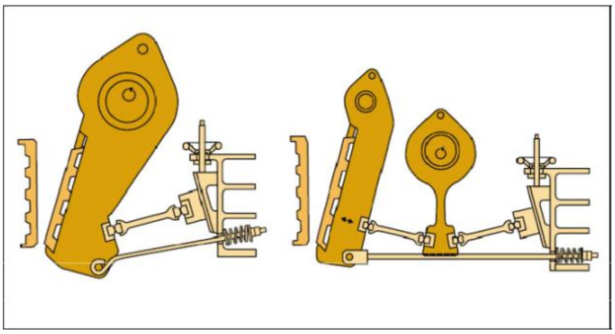

***Figure-2 Blake Type Jaw Crusher***

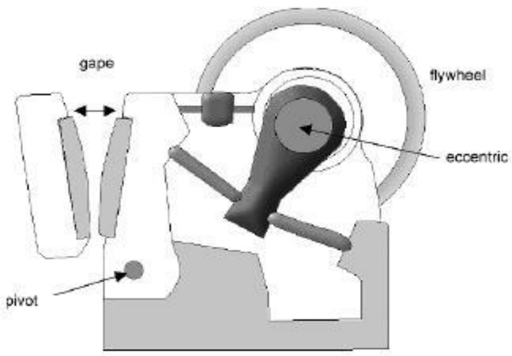


***Figure-3 Dodge Type Jaw Crusher***

## IV. INTRODUCTION TO FINITE ELEMENT METHOD

FEA has become common place in recent years. Numerical solution to even very complicated stress problems can now be obtained routinely using FEA, and the method is so important that even introductory treatments of mechanics of materials.FEA is a mathematical representation of a physical system comprising a part/assembly (model), material properties and applicable boundary conditions (collectively referred to as pre-processing), the solution of that mathematical representation (solving), and the study of results of that solution (post-processing).
The finite element analysis usually consists of three principal steps:

1. Pre-processing : In this process FEA software typically uses a CAD representation of the physical model and breaks it down into small pieces called finite 'elements'. This process is called as meshing. Higher quality of mesh, the better mathematical representation of physical model.
2. Analysis: FEA software constructs and solves a system of linear or nonlinear algebraic equations.
3. Post-processing: it is used to create graphical displays that show the distribution of stresses, strains, deformations, temperatures, and other aspects of the model.

 

## V. OBJECTIVE OF PRESENT

The objective of the present work is to strive for a design and analysis of commercially available swing jaw plates (including stiffening elements), that is 0.9 m (36 in.) wide with 304 mm and 51 mm (12 in. and 2 in.) top and bottom openings of jaw crusher. The finite element method is applied to the analysis of the swing jaw plate. Also further study of swing jaw plate with stiffener is done using finite element analysis. The theoretical design calculations of jaw plates have been computerized. The design and modeling jaw plates of crusher is accomplished by using CAD i.e. parametric design package (CATIAP3V5R15). By using this package three dimensional model of jaw plates jaw crusher has been developed. Finite Element Analysis of jaw plates are carried out by using ALGOR V19 programming. This work is extended to improve the strength/weight ratio of swing jaw plate by adding different number of stiffener elements on the jaw plates.

## VI. EXPERIMENTAL DATA COLLECTION

**Point load deformability testing apparatus**

The deformability of point-loaded specimens is determined with the loading method suggested by Reichmuth. As shown in Fig.3.6, 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.

Two other tests were performed to characterize the rocks Line loading was performed between two plates according to ASTM standards except that wooden strips were not placed between the specimen and plates to ensure that the specimen's diametral deformation was equal to platen convergence. Unconfined compression (q ), tests were also performed according to ASTM standards to measure Young's modulus.

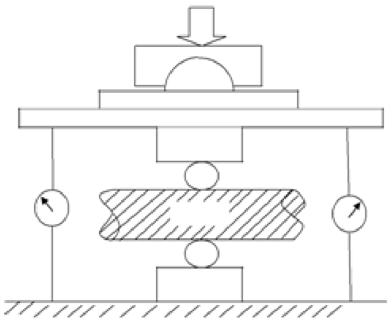

***Figure-4*** **Point-Load Testing Apparatus**

**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, dolomite limestone, taconite and amphibolites (closely banded gneiss) have shown in Table 1.1 with their major properties.

| Material | E (MPa) | q(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 Dolomite |
| Taconite | 41.4 | 234.4 | Massachusetts | siliceous, finely |
| Amphibolites | 33.6 | 124.1 | | grained crystalline. |

Table 1.1 Materials tested

 

## VII. SOLID MODELING OF SWING JAW PLATES

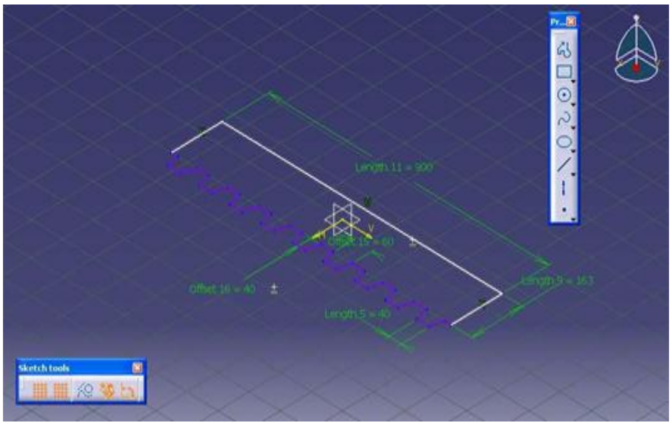

***Figure-5***
**Sketch of Swing Jaw Plates Base Feature**

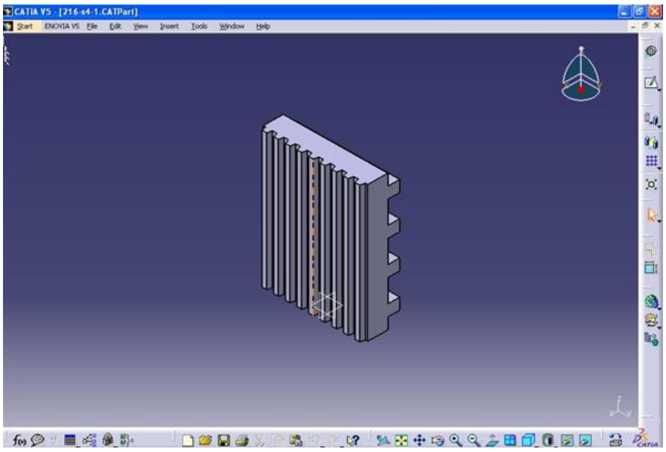

***Figure-6***
**Solid Modeling of Swing Jaw Plates with Stiffeners**

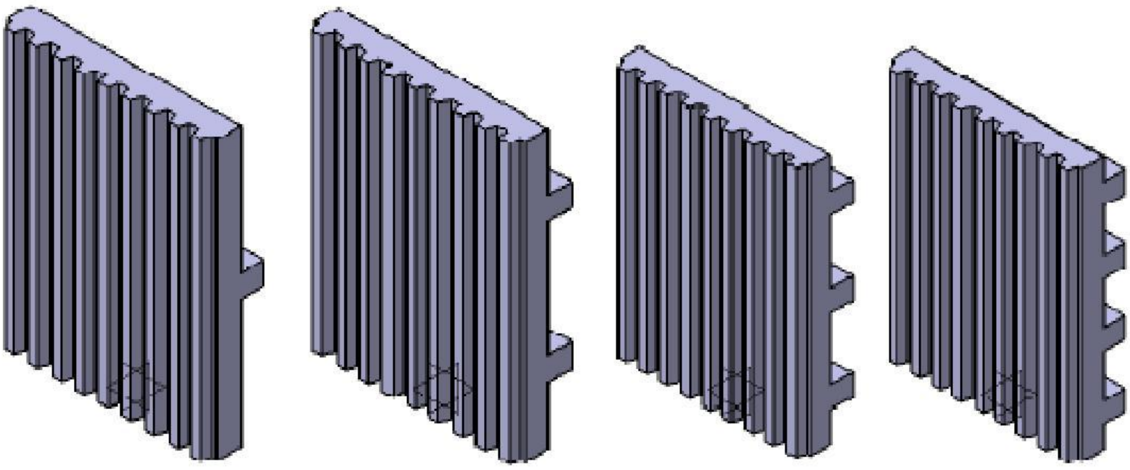

***Figure-7***

 

Swing Jaw Plates (1200X900X140) with Stiffeners
Swing Jaw Plates (1200X900X152) with Stiffeners
Swing Jaw Plates (1200X900X165) with Stiffeners
Swing Jaw Plates (1200X900X178) with Stiffeners
Swing Jaw Plates (1200X900X191) with Stiffeners
Swing Jaw Plates (1200X900X203) with Stiffeners
Swing Jaw Plates (1200X900X216) with Stiffeners
Swing Jaw Plates (1200X900X224) with Stiffeners

## VII SWING JAW PLATES STATIC STRESS ANALYSIS WITH STIFFENERS

Below is a finite element representation of the stiffened plate shown above. The plate is thick, therefore thick plate theory applies. Square beam stiffeners are mounted as shown. The structure is simply supported and point loads at different nodes are applied to the surface of the plate. Because the centroidal axes of the stiffeners coincide with the mid-plane of the plate, need not to define the element properties for the stiffeners.

## VIII. MESHING AND ELEMENT TYPE

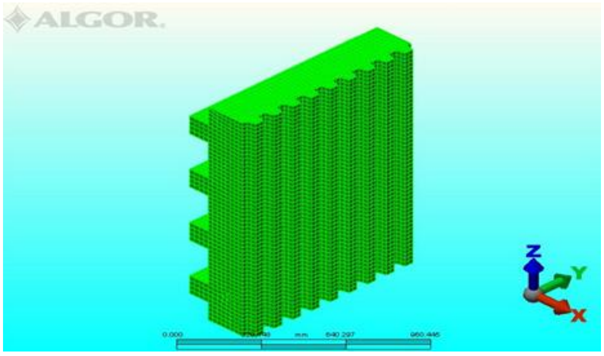


***Figure-7***
Stiffened Swing Jaw Plate Model Ready for Meshing

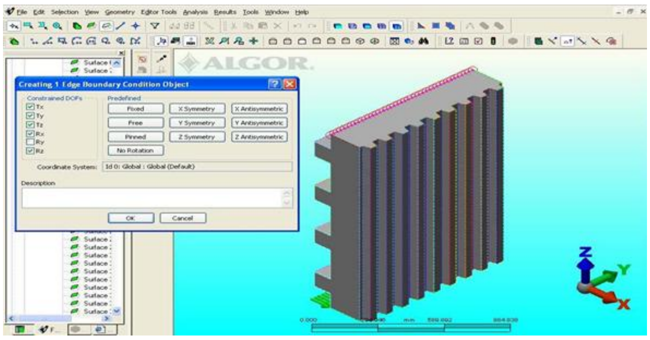


***Figure-8***
Showing Stiffened Swing Jaw Plate Boundary Condition

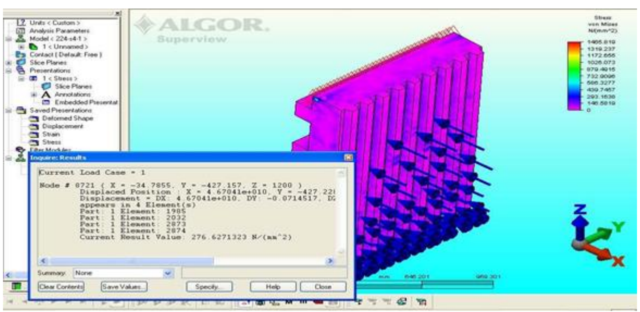


***Figure-9***
Showing Stiffened Swing Jaw Plate Stress Analysis

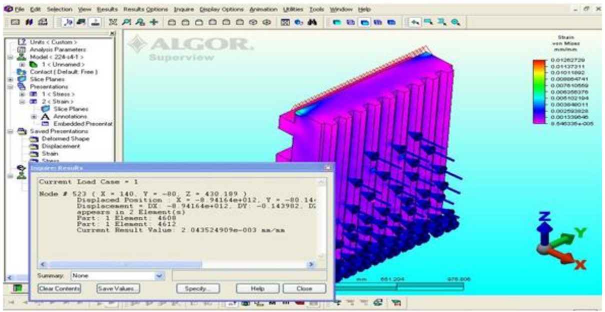


***Figure-10***
Showing Stiffened Swing Jaw Plate Strain Analysis

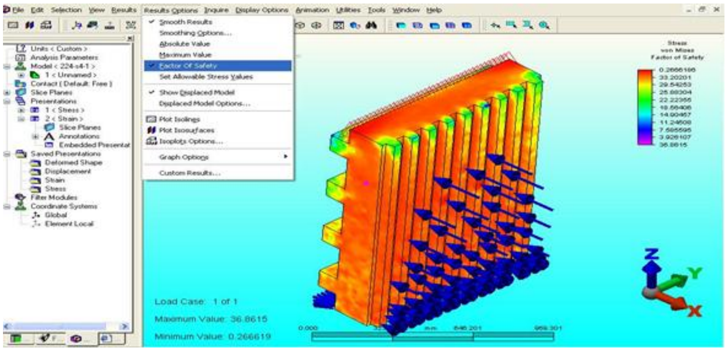

***Figure-11***
Showing Stiffened Swing Jaw Plate Factor of Safety Tool

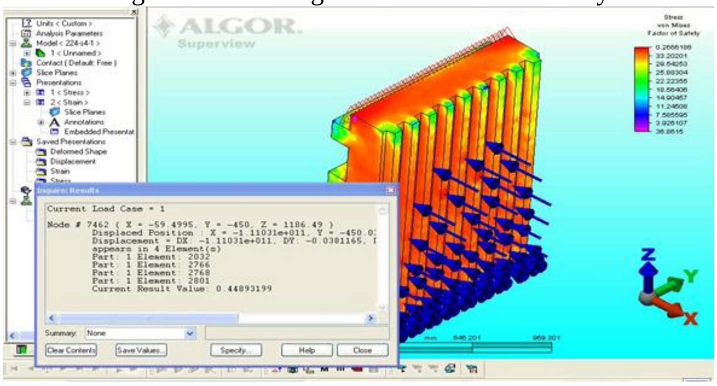

***Figure-12***
Showing Stiffened Swing Jaw Plate FOS Values

## IX. EFFECT OF STIFFENERS ON SWING JAW PLATES

| Thickness | | Stiffness(EI) ( kN) | | Number of Stiffeners | | | | Max Driving Force (MN) |
|---|---|---|---|---|---|---|---|---|
| (in) | (mm) | (×10) | | NOS=4 | NOS=3 | NOS=2 | NOS=1 | |
| 8.8 | 224 | 10 | | | | | | |
| 8.5 | 216 | 1.60 | | 193.24 | 209.51 | 217.41 | 225.45 | 1.17 |
| 8.0 | 203 | 1.33 | | 212.25 | 218.75 | 235.89 | 248.74 | 1.17 |
| 7.5 | 191 | 1.10 | | 223.98 | 239.52 | 252.78 | 265.23 | 1.17 |
| 7.0 | 178 | 0.90 | | 239.87 | 246.37 | 258.60 | 274.68 | 1.17 |
| 6.5 | 165 | 0.73 | | 245.36 | 257.45 | 269.63 | 284.66 | 1.17 |
| 6.0 | 152 | 0.55 | | 259.58 | 267.13 | 276.53 | 289.56 | 1.17 |
| 5.5 | 140 | 0.44 | | 280.92 | 283.15 | 289.91 | 296.71 | 1.17 |

## X. APPROXIMATE SAVINGS IN ENERGY USING STIFFENERS

If fatigue of the plate is of concern, then the maximum tensile stress is important. A comparison of data in Table shows that the maximum induced tensile stress for the 203 mm (8.0 in) thick model plate equals that induced for the 152 mm (6.0 in) plate. This difference is found because the particles do not fail simultaneously but fail at different stages.The reduction in the toggle force necessary to push the lighter, stiffened plates can be translated into an approximate savings in energy. If the peak acceleration (a) of the 203mm and 152 mm plates is assumed to be equal, then the force reduction resulting from a smaller plate is proportional to the acceleration times the change in plate mass. Since the mass is somewhat proportional to the thickness of the 203 and 152 mm models, the crushing energy absorbed by plate movement is reduced by approximately [(203 – 152)/203] = 25%. Of course this 25% is an estimate, as the model plates which are stiffened and leads to reductions in plate weight and indicates that design of new energy-efficient systems should include deformation (PDF) properties of the crushed material.

## ACKNOWLEDGEMENT

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