Investigation of Effect of Without Stiffener on Swing Jaw Crusher Plate by Finite Element Analysis

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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 (qu) 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 propose work the design of the swing jaw plate using point-load deformation failure relationships along with interactive failure of rock particles as a model for such a weight reduction. The design of the corrugated swing jaw plate will carry out by using CAD i.e. jaw crusher plate has been solid modelled by using Solid Works 2013. The calculated dimensions are validated with the drawing of reputed manufacturers. Finite Element Analysis of jaw plates are carried out by using ANSYS 14.5 software. The theoretical design calculations of jaw plates of the jaw crusher have been carried out.

Key words: Stiffener; Jaw Crusher; Swing Jaw Plate; ANSYS 14.5; Solid Work 2013

I. INTRODUCTION

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. [11]

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. [11]

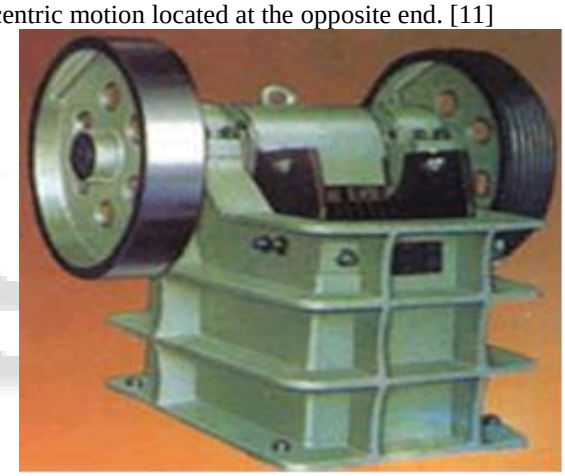


Fig. 1: Typical Jaw Crusher [10]

II. EXPERIMENTAL SETUP

A. Techno Enterprise-Company Who Manufacturing Jaw Crusher:

Techno Enterprise is one of the renowned organizations that are engaged in the manufacture, export & supply of pulverizers & grinding machines. Techno Enterprise is specializing in the manufacture of wide range to ensure the diverse requirements of different clients are satisfactorily met. The machines and grinders that we are providing are extensively used in different industries like chemical, mineral, dyestuff, paints, food processing and also in fertilizers, insecticides, etc our product range. Techno Enterprise is Located in the most advanced industrial area of Vatva (Gujarat, India).

We have a strong infrastructure base that enables us to execute our orders on time. Further, our R & D unit continuously works upon optimizing our range of machines with advantageous technical features which makes them an ideal choice in the contemporary market. We are one of the well recognized Manufactures, Exporter and Suppliers of Rotary Dryer, Drum Dryer-Flaker, Tray Dryer, Hot Air

Generator Bet Dryer, Fluid Bed Dryer, Vibrating Screen, Rotary Screen, Gyro Screen, Air Classifier Material Separator, Jaw Crusher, Pre Crusher, Screen Pulveriser, Impact Pulveriser, Micro Pulveriser, Ball Mill, Dry Granding Ball Mill System, Wet Grinding Ball Mill System, Cone Crusher , Material Handling Equipment- Belt Conveyor, Screw Conveyor, Bucket Elevator, Screw Feeder, Pneumatic Conveying System, Dust Collection System, Ribbon Blender, Magnetic Drum, Trommel, Vessel, Reactor, Auto Clave Main Turn.

Fig. 2: Workshop of Techno Enterprise at Vatva, Ahmadabad.

B. Technical Specification of Jaw Crusher (Model -TEJC-22"X13"):

Fig. 3: Jaw Crusher (Model-TEJC-22"X13")

It can be used to crush material, whose compression strength is not more than 320MPa. PE series is used in primary crushing, while Techno series is used in secondary crushing and fine crushing.

1) Feature:

- Rugged steel body
- Jaw plates of wear-resistant manganese steel
- Special steel eccentric shaft with heavy duty
- Double-Toggle attachment superior load distribution
- Spray oil lubrication system guarantees safe operation at high speeds
- Requires lower horse power cheaper squirrel cage
- Maximum crushing range- 13mm to 62mm

2) Advantages:

A substantially longer jaw life is achieved as a result of the unique jaw geometry. The centerline of crushing zone is aligned with the hinge pin center and the material to be crushed is held firmly by the straight line crushing action of the jaws. This principle uses pure compression to crush, eliminating rubbing within the crushing chamber. Double toggle action ensures crushing even on the down stroke and provides maximum mechanical advantage to the eccentric. Lighter pitman and toggles reduce inertia and enables a greater throughput to be achieved.

3) Application:

Gravel-Ferro Alloys-Blast Furnace Slag-Bauxite-Quartz Granite-Feldspar-Barytes-Iron Ore-Betonies-Coal & Coke-Magnesite-Stone-Rock Phosphate-Lime Stone-Soap Stone Dolomite.

4) Specification:

Model	Input mm	Output mm	TON/PH	HP
TEJC-22"X13"	260	60	42	40

C. Detail of Swing Jaw Plate:

Engineering components can be of various forms (sizes and shapes) in three dimensions. A Solid can be thought of as composed of a simple closed connected surface that encloses a finite volume. The closed surface may be conceived as an interweaved arrangement of constituent surface patches, which in turn, can be individually considered as composed of a group of curves. It then behooves to discuss the generic design of curves, surfaces and solids in that order. Even before, it may be essential to understand how three dimensional objects or geometrical entities are represented on a two-dimensional display screen, and how such entities can be positioned with respect to each other for assembly purposes or construction operations.

Fig. 4: Picture Showing Corrugated Cast Steel Jaw Plate

III. CAD MODELING AND FEA OF SWING JAW PLATE

A. CAD Tool-Solid Work 2013:

Solid Works 2013 is 3D mechanical design system built with adaptive technology and solid modeling capabilities.

The Solid Works 2013 software includes features for 3D modeling, information management, collaboration, and technical support with DSS you can:

1) Create 3D models and 2D manufacturing drawings.
2) Create adaptive features, parts, and subassemblies.
3) Manage thousands of parts and large assemblies.
4) Use third-party applications, with an Application Program Interface (API).
5) Use VBA to access the Autodesk Inventor API. Create programs to automate repetitive tasks. On the Help menu, choose Programmer Help.
6) Import SAT, STEP, and AutoCAD and Autodesk Mechanical Desktop (DWG) files for use in

Autodesk Inventor. Export Autodesk Inventor file to AutoCAD, Autodesk Mechanical Desktop, and IGES formats.

7) Collaborate with multiple designers in the modeling process.
8) Link to web tools to access industry resources, share data, and communicate with colleagues.

Use the integrated Design Support System (DSS) for help as you work

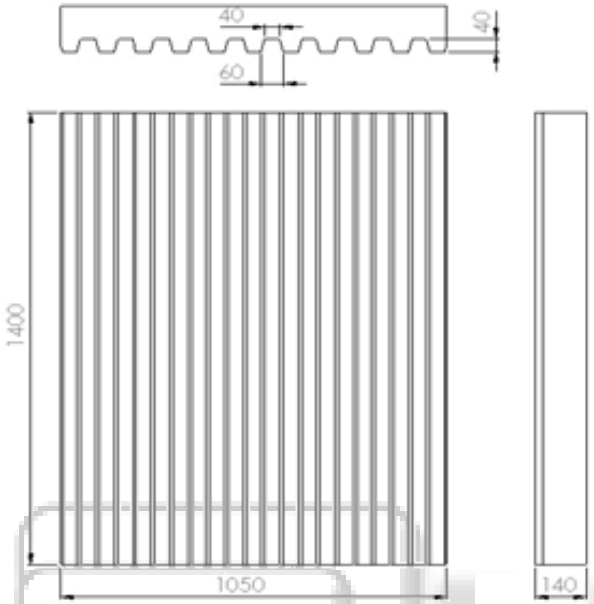


Fig. 1: Detail view of Swing Jaw Plate [1]

As shown in Figure 2 to 6, there are different orientations of 3D model of Swing Jaw Plate. Such as isometric view, front view, top view, side view and back view.

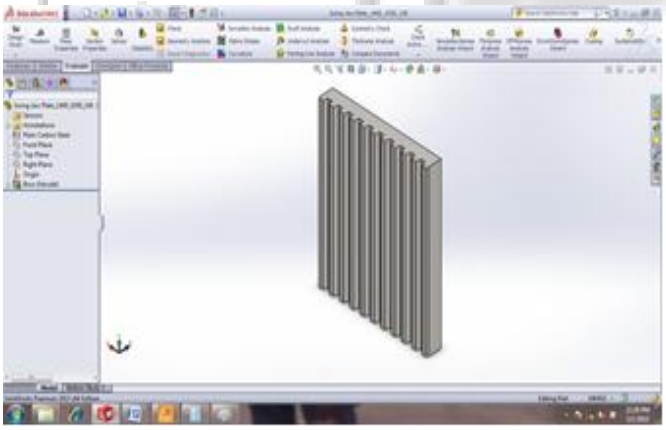


Fig. 2: 3D Model of Swing Jaw Plate

B. Swing Jaw Plate:

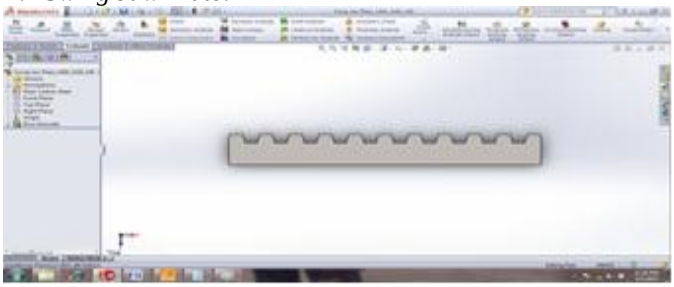
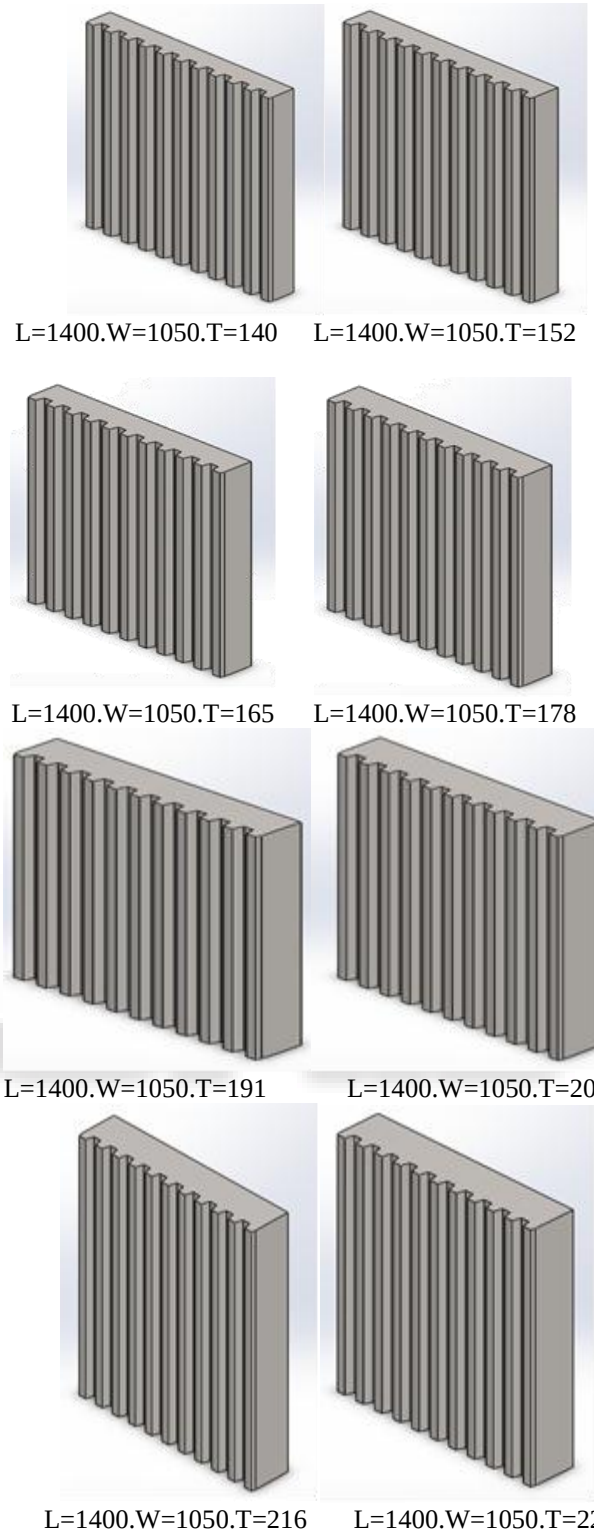


Fig. 3: Top View of Swing Jaw Plate



L=1400.W=1050.T=140 L=1400.W=1050.T=152
L=1400.W=1050.T=165 L=1400.W=1050.T=178
L=1400.W=1050.T=191 L=1400.W=1050.T=203
L=1400.W=1050.T=216 L=1400.W=1050.T=224

Fig. 4: Corrugated Swing Jaw Plate Models having Dimensions in mm

C. Design of Swing Jaw Plates:

The factors of importance in designing the size of jaw crusher's plate are:

Height of jaw plate (H) ≈ 4.0 X Gap
Width of jaw plate (W) > 1.3 X Gap
< 3.0 X Gap

Where the crusher gape is in meters [6].

These dimensions vary as individual manufacturers have their own specifications and design of individual makes. In

this case, we have top opening i.e. gape 350 mm and bottom opening 40mm.
Height of jaw plate (H) = 1400 mm
Width of jaw (W) = 1050 mm
Weight of Swing Jaw Plate = 1385.75 kilograms

D. Finite Element Analysis (FEA):

ANSYS 14.5 precision finite element model-building tool, offers many design scenarios and mesh enhancement capabilities. ANSYS 14.5 enables several design classes, including 2- and 3-D surface and solid models, beam or truss and plate/shell. ANSYS 14.5 also enables engineers to build compound models having mixed element types. ANSYS 14.5 provides access to Merlin Meshing Technology for automatic surface mesh enhancement or enables engineers to work directly on an FEA model surface for manual mesh enhancement. Engineers can choose tetrahedral, brick or hybrid (bricks outside and tetrahedral inside) solid FEA meshes.

ANSYS's linear static and dynamic stress analysis capabilities determine stresses, displacements and natural frequencies as well as predict dynamic response to static and dynamic loading. These capabilities are highlighted throughout this brochure. ANSYS's FEA, Mechanical Event Simulation, modeling and CAD/CAE interoperability tools are designed to help engineers develop products that are more reliable and less costly to produce with faster times-to-market. To provide the best cost/benefit solution for each customer, ANSYS's High Technology Core Packages and Extenders can be purchased at special combination pricing or separately to best fit individual needs while allowing for future growth and change.

The finite element method (FEM), sometimes referred to as finite element analysis (FEA), is a computational technique used to obtain approximate solutions of boundary value problems in engineering. Simply stated, a boundary value problem is a mathematical problem in which one or more dependent variables must satisfy a differential equation everywhere within a known domain of independent variables and satisfy specific conditions on the boundary of the domain. Boundary value problems are also sometimes called field problems. The field is the domain of interest and most often represents a physical structure.

The field variables are the dependent variables of interest governed by the differential equation. The boundary conditions are the specified values of the field variables (or related variables such as derivatives) on the boundaries of the field. Depending on the type of physical problem being analyzed, the field variables may include physical displacement, temperature, heat flux, and fluid velocity to name only a few. 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.

1) Preprocessing: Defining the Problem:
The major steps in preprocessing are:

- define key points/lines/areas/volumes,
- define element type and material/geometric properties,
- Mesh lines/areas/ volumes as required. The amount of detail required will depend on the dimensionality of the analysis, i.e., 1D, 2D, ax symmetric, and 3D.

2) Solution:
Assigning loads, constraints, and solving
Here, it is necessary to specify the loads (point or pressure), constraints (translational and rotational), and finally solve the resulting set of equations.

3) Post Processing: Further Processing and Viewing Of the Results:
In this stage one may wish to see:

- lists of nodal displacements,
- element forces and moments,
- deflection plots, and
- Stress contour diagrams or temperature maps.

E. Step-1 Pre-Processing:

1) First Prepare Assembly in Solidworks 2011 and Save as this assembly as .IGES for Exporting into Ansys Workbench Environment. Import .IGES Model in ANSYS Workbench Simulation Module.

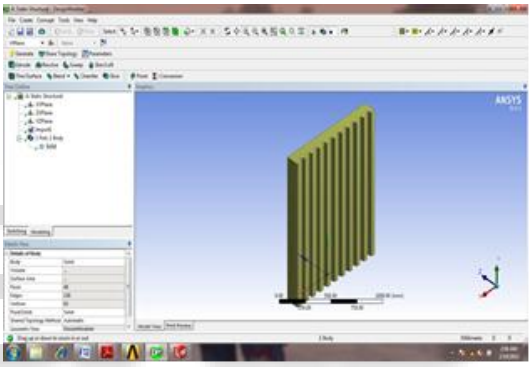


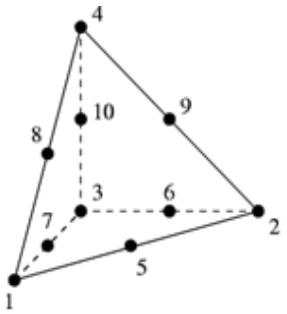
Fig. 5: Geometry of Swing Jaw Plate Using Static Analysis

2) Check the Geometry for Meshing.
3) Apply Material for Each Component.

Structure	**Material used**	**Young Modulus (GPa)**	**Yield Strength (MPa)**	**Poisions Ratio**	**Density (Kg/m^3)**
Swinging Jaw Plate	Martensitic Steel	210	550	0.266	7860

Table 1: Structural Steel Material Properties

4) Create Mesh:



Triangular surface mesh which is programme generated.
Fine Meshing is apply
No. of Nodes: - 58743
No. of Elements: - 11660

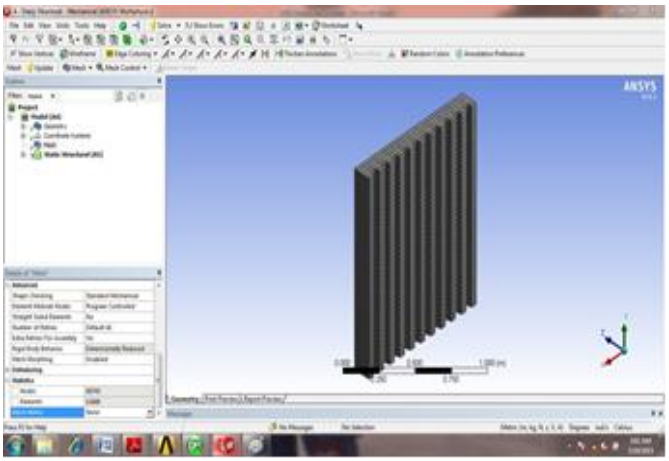


Fig. 6: Meshing of Swing Jaw Plate Using Static Analysis

5) Define Boundary Condition:

Apply Fixed Support at bottom edge and Remote Displacement at top end. In fixed support boundary condition, base edge having not movement along X,Y & Z and also rotation same axis. Remote Displacement means top edge rotate only Y-axis and another two axes are reamin constant.

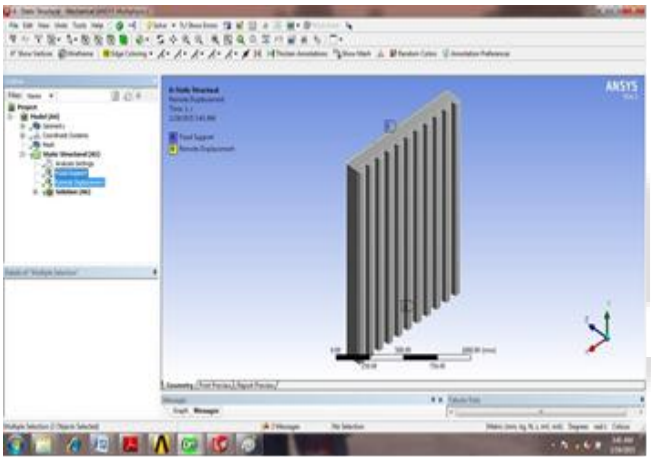


Fig. 7: Boundary Condition of Swing Jaw Plate Using Static Analysis

1) Apply Force:

Force magnitude on swing jaw plate.

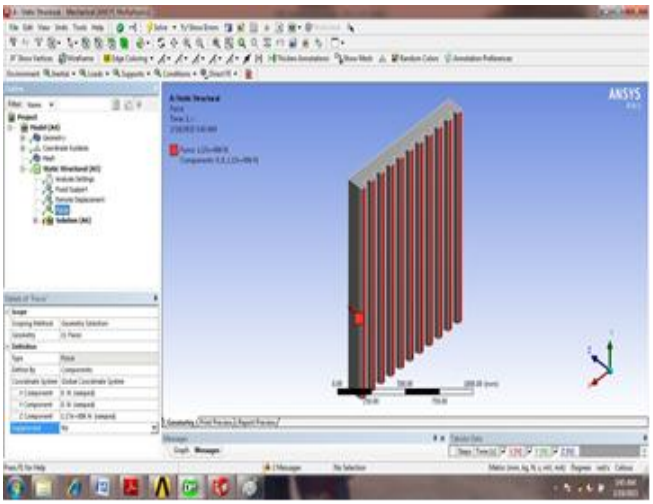


Fig. 8: Force Applying On Swing Jaw Plate

Results of Analysis

2) Equivalent Stress for Static Analysis:

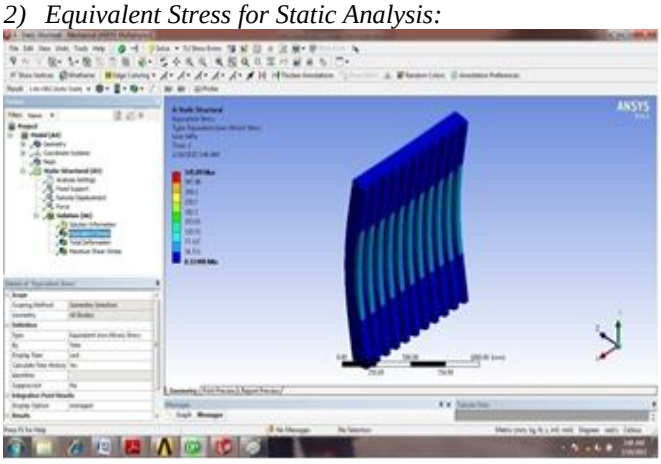


Fig. 9: Equivalent Stress analysis of Swing Jaw Plate

3) Maximum Shear Stress Form Static Analysis:

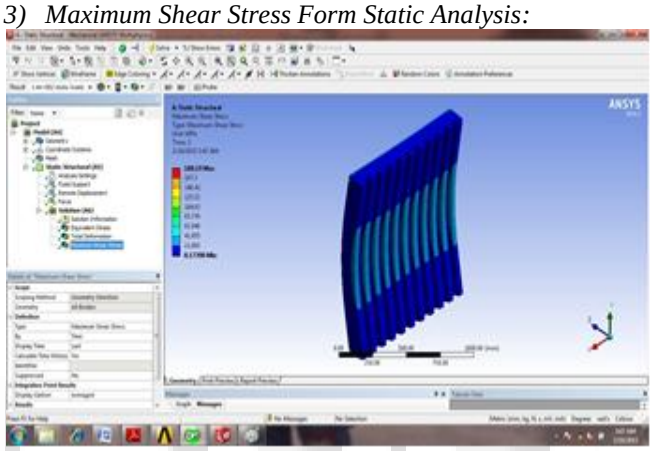


Fig.10: Maximum Shear Stress analysis of Swing Jaw Plate

4) Total Deformation:

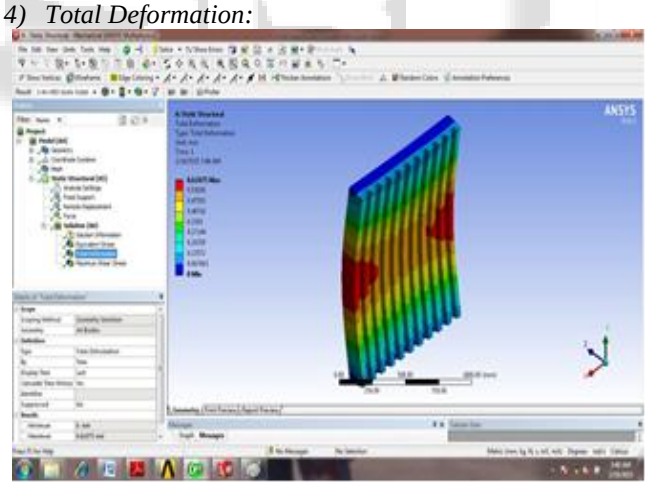


Fig. 11: Total Deformation of Swimg Jaw Plate

Material	Von mises stress (MPa)	Max. Shear Stress (MPa)	Total Deflection (mm)
Martensitic Steel	345.89	188.19	0.61075

Same procedure applying for taking different thickness of swing jaw plate for optimization overall size of plate with respect to standard boundary and loading condition. Compare result of ANSYS result with respect to their Von mises stress, Maximum shear stress and Total deflection.

IV. RESULT

Jaw Plate Thickness (mm)	Max. Von mises stress (MPa)	Max. Shear Stress (MPa)	Total Deflection (mm)
224	189.05	101.06	0.15112
216	201.08	107.66	0.16767
203	224.08	120.29	0.20064
191	231.75	124.63	0.23977
178	264.22	142.53	0.29542
165	278.99	150.88	0.37067
152	327.70	177.83	0.47514
140	345.89	188.19	0.61075

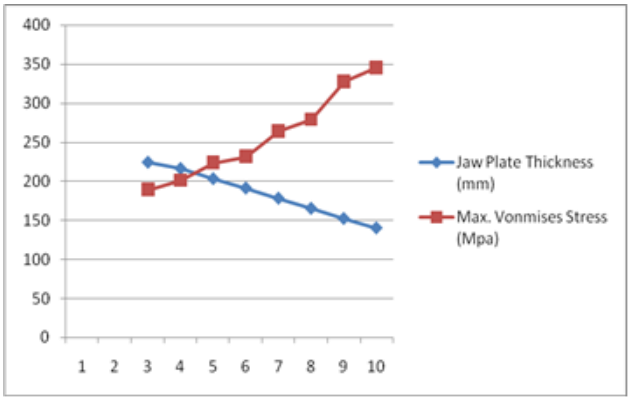


Fig. 12: Jaw Plate Thickness Vs. Maximum Vonmises Stress

From as shown Fig.12 reflect jaw plate thickness vs. maximum vonmises stress, value of vonmises stress value decrease when jaw plate thickness increase.

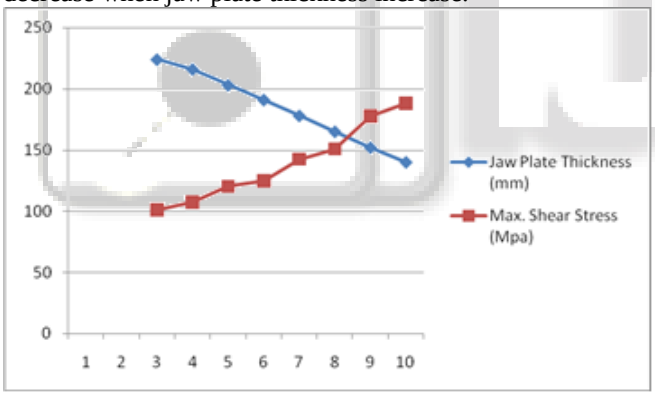


Fig. 13: Jaw Plate Thickness Vs. Maximum Shear Stress

From as shown Fig. 13 reflect jaw plate thickness vs. maximum shear stress, value of shear stress value decrease when jaw plate thickness increase.

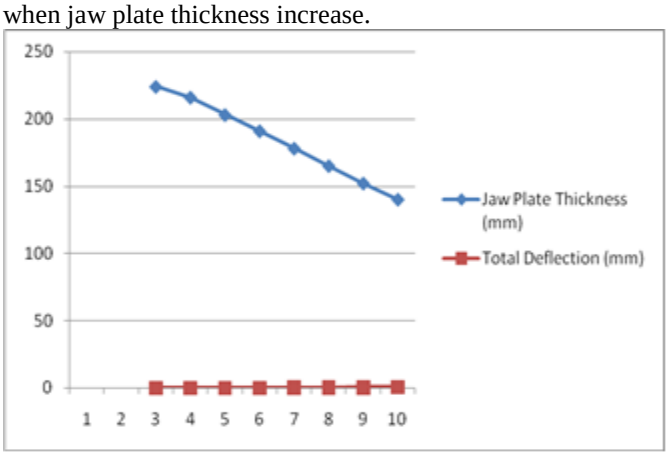


Fig. 14: Jaw Plate Thickness Vs. Total Deflection

From as shown Fig. 14 reflect jaw plate thickness vs. total deflection, value of total deflection decrease when jaw plate thickness increase.

V. CONCLUSION

In this study, Jaw Crusher is identified different mechanism used for crushing purpose and to improve performance of jaw crusher by using different types of Swing Jaw Plate.

From the results obtained in the analysis of different literature survey, the following can be concluded:

- The research survey was reflected different types of crusher machines such as bottle crusher machine, can or plastic bottle crusher machine, Cone crusher, Jaw crusher, Impact crusher, small-scale mobile jaw-crusher etc. The research had survey on their design and analysis of each component.
- Some research paper indicated about Finite Element Analysis of some critical components in CAD software such as Pro/Engineer, FLAC3D from this research reflected to checked behavior of different component in static condition.
- Result shows values of vonmises stress, shear stress and total deformation.

VI. ACKNOWLEDGMENT

It is indeed a great pleasure for me to express my sincere gratitude to those who have always helped me for this dissertation work.

I am extremely thankful to my thesis guide Asst. Prof. Vijay Pipalia, Asst. professor in Mechanical Engineering Department Noble Engineering College, Junagadh are valuable guidance, motivation, cooperation, constant support with encouraging attitude at all stages of my work. I am highly obliged to him for his constructive criticism and valuable suggestions, which helped me to present the scientific results in an efficient and effective manner in this thesis.

It gives me pleasure to express my deep sense of gratitude to Dr Vipul Vekaria, Principal ,NEC, Prof. Prof. Hiralkumar C. Badrakia, Head of the Mechanical Engineering Department and Prof.Vasim G. Machhar, P. G. Coordinator of M.E - Mechanical (CAD/CAM) to provide great opportunity to carry out this Dissertation work as a part of the curriculum.

I am also thankful to all the faculty members of Mechanical Engineering Department and my thanks are due to all of the friends who encouraged and supported me during thesis work.

REFERENCES

[1] Ramkrushna S. More, "A Design & Analysis of Swing Jaw Plates of Jaw Crusher", nternational Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463.Vol. 3 Issue 4, April-2014, pp: (400-408), Impact Factor: 1.252,

[2] Vishal N. Kshirsagar, Dr. S. K. Choudhary, Prof. A. P. Ninawe, "An Automatic CAN or Plastic Bottle Crusher Machine - A Review", IJSRD - International Journal for Scientific Research &

Development, Vol. 2, Issue 02, 2014,ISSN (online): 2321-0613.
[3] Vishal N. Kshirsagar, Dr. S.K Choudhary, Prof. A.P Ninawe , "Design Consideration in an Automatic Can/Plastic Bottle Crusher Machine", International Journal of Engineering Research and General Science Volume 2, Issue 4, June-July, 2014.
[4] Durgesh R. Verma and Pankaj R. Hatwar, "Design of A Horizontal Shaft Impact Crusher", International Journal of Application or Innovation in Engineering & Management (IJAIEM), Volume 3, Issue 1, January 2014.
[5] Ramakrishna S. More, Sunil J.Rajpal, "A Review on Study of Jaw Plates of Jaw Crusher", International Journal of Modern Engineering Research (IJMER), Vol.3, Issue.1, Jan-Feb. 2013 pp-518-522.
[6] Eugeniusz Rusiński , Przemysław Moczko, Damian Pietrusiak ,Grzegorz Przybyłek, "Experimental and Numerical Studies of Jaw Crusher Supporting Structure Fatigue Failure", Strojniški vestnik - Journal of Mechanical Engineering 59(2013)9, 556-563.
[7] Ashish Kumar Shrivastava, Avadesh K. Sharma, "Dynamic Analysis of Double Toggle Jaw Crusher Using Pro-Mechanica", International Journal of Engineering Research and Applications, Vol. 2, Issue 3, May-Jun 2012, pp.1132-1135.
[8] Shivam Choudaha, Sunil Kumar Tiwari, Sarang Pande, "Improving Productivity of Jaw Crusher through OTIF Delivery by Reducing Down Time", International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, Volume 2, Issue 10, October 2012).
[9] Refahi, J. Aghazadeh Mohandesi, and B. Rezai, "Comparison between bond crushing energy and fracture energy of rocks in a jaw crusher using numerical simulation", The Journal of The Southern African Institute of Mining and Metallurgy VOLUME 109 REFEREED PAPER DECEMBER 2009.
[10] Emrod Elisante, "Simplification of Jaw crusher for Artisanal Aggregates Miners", Journal of Engineering and Technology Research Vol.1 (6), pp. 102-108, September, 2009.
[11] Gupta Ashok, Yan D.S. "Mineral Processing Design and Operation-An introduction", Published by Elsevier, 2006, Pages 99-127.
[12] http://www.mistryjawcrusher.com/full-images/681579.jpg
[13] http://www.harisonjawcrusher.com/crusher-model.htm
[14] http://www.westpromachinery.com/jaw crusher/components/jaw plates
[15] Georget Jean-Pirrre, Lambrecht Roger "Jaw Crusher" United States Patent, Patent Number 4, 361, 289, Issued on November, 1988.

