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Design and analysis of jaw plate with various tooth profiles using FEM

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Abstract

Jaw crushers are heavy and slow speed machines which are major size reduction equipment used in mining industry. The life of Jaw crushers is mainly affected by the strength of the Jaw Crusherplates. The Jaw Crusher plate is mainlysubjected tocompressive forcesbetween the fed material and the jaws. Theseforcesare predominantly serious in the fixed plate and hence the plates of the fixed jaw should be properly designed. The main objective of the thesis is to strive for a design and analysis of a new tooth profile of the Jaw Crusher platesuch as Whit worth tooth jaw plate, Worm tooth jaw plate, ACME tooth jaw plate for increasing the strength and performance of the jaw plate.In addition to this Tooth and plate assembled type jaw plate model is also designed which allows to change the tooth of the jaw plate instead of total replacement of the plate. In present investigationthe Design of a plate is carried by using CATIA software and the finite element analysis (FEA) will be carried out by using ANSYS software. Based on the analysis of the jaw plat plate will require a more precise accounting of the stress and deformations in the crushing plates. The different comparisons of jaw plates behavior, calculated with the existed jaw plate.

Key Words: Jaw Crusher plate, Finite Element Analysis, New tooth profiles.

1. Introduction

Definition of Jaw Crusher:A jaw crusher uses compressive force for breaking of particle. This mechanical pressure is achieved by the two jaws of the crusher of which one is fixed while the other reciprocates. A jaw or toggle crusher consists of a set of vertical jaws; one jaw is kept stationary and is called a fixed jaw while the other jaw called a swing jaw, moves back and forth relative to it, by a cam or pitman mechanism.

Since the jaw crusher was pioneered by Eli Whitney Blake in the 2nd quarter of the 1800s, many have twisted the Patent and come up with other types of jaw crushers in hopes of crushing rocks and stones more effectively.

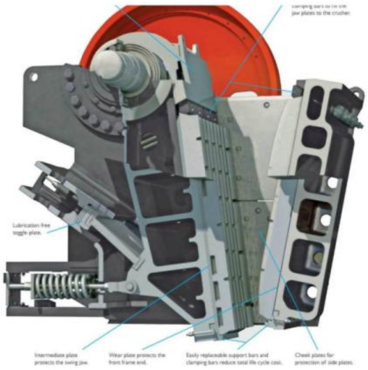

Fig 1.1 Jaw crusher

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Jaw crusher inventors having given birth to 2 groups:

i. **Blake Type Jaw Crusher**
   a) Single-Toggle Jaw Crusher
   b) Double-Toggle Jaw Crusher

ii. **Dodge Type Jaw Crusher**

1.1 Main Components of a Jaw Crusher:

Jaw Crusher Pitman: The pitman is the main moving part in a jaw crusher. It forms the moving side of the Jaw, while the stationary or fixed jaw forms the other. It achieves its movement through the eccentric machining of the flywheel shaft. This gives tremendous force to each stroke. Pitman is made ofhigh quality steel plates and carefully stress relived after welding.

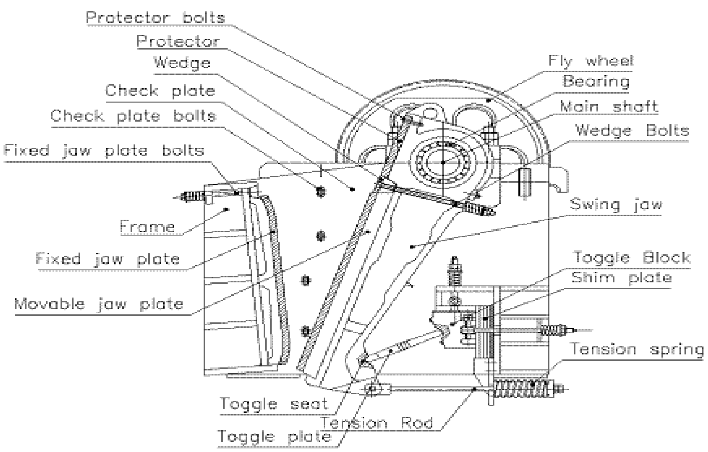

Fig 1.2 Sectional view showing Components of a Jaw Crusher

Jaw Crusher Fixed Jaw Face: The fixed jaw face is opposite the pitman face and is statically mounted. It is also covered with a manganese jaw die. Manganese plates which protect the frame from wear; these include the main jaw plates covering the frame opposite the moving jaw and the cheek plates which line the sides of the main frame within the crushing chamber.

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

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Jaw Crusher Input Flywheel: Rotational energy is feed into the jaw crusher eccentric shaft by means of a sheave pulley which usually has multiple V-belt grooves. In addition to turning the pitman eccentric shaft it usually has substantial mass to help maintain rotational inertia as the jaw crushes material.

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

Jaw Crusher Eccentric Shaft Bearings: Bearings that support the main shaft normally they are spherical tapered rollerbearings on an overhead eccentric jaw crusher. Anti-Friction Bearings are heavy duty double row self-aligned roller-bearings mounted in the frame and pitman's are properly protected against the ingress of dust and any foreign matter by carefully machined labyrinth seals.

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

1.2 Jaw Crusher Working Principle:

Jaw Crusher is based on modern design "crushing without rubbing" The machine consists, two Jaws, one fixed and the other moving. The opening between them is smaller at the bottom and wider at the top. The pitman moving on an eccentric shaft on bearing, swing lever (Moving Jaw) swing on center pin. The Rock held in between two Jaws and crushed by mechanical pressure.

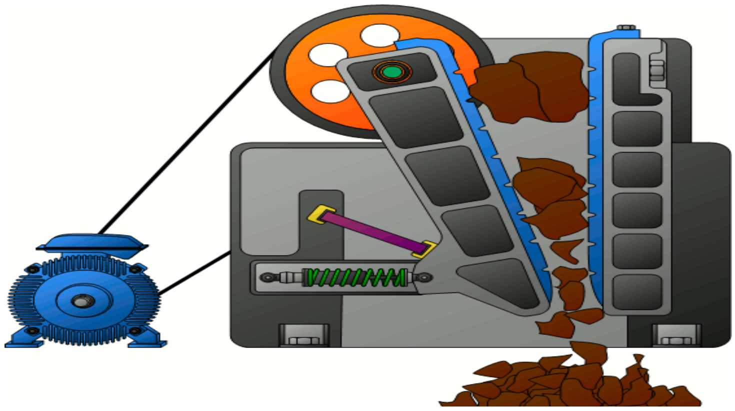

Fig.1.3 Working Principle of Jaw Crusher

2. Design Jaw Plates

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

- Height of jaw plate (H) $\approx 4.0 \times$ Gape
- Width of jaw plate (W) $> 1.3 \times$ Gape$< 3.0 \times$ Gape
- Throw (T) $= (0.0502)^{0.85}$

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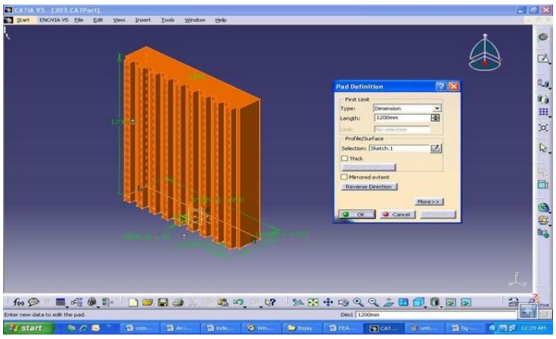
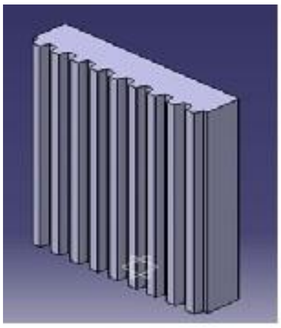
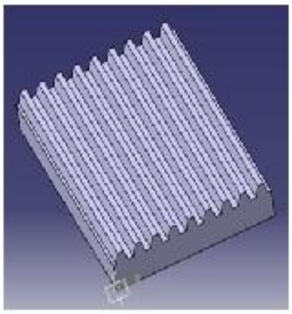


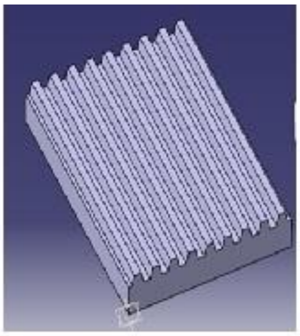
Fig 2.1 solid model of jaw plate



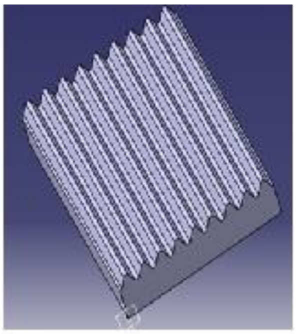
existed Jaw Plate



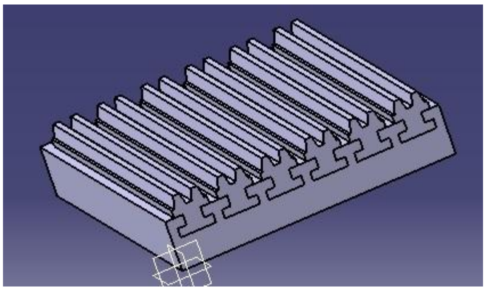
Worm jaw plate



ACME jaw plate



whit worth jaw plate



Tooth and plate assembled jaw plate

Fig 2.2Solid Model of new tooth designed Jaw Plates.

3. Applying Material Properties

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

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4. Apply Boundary Conditions:

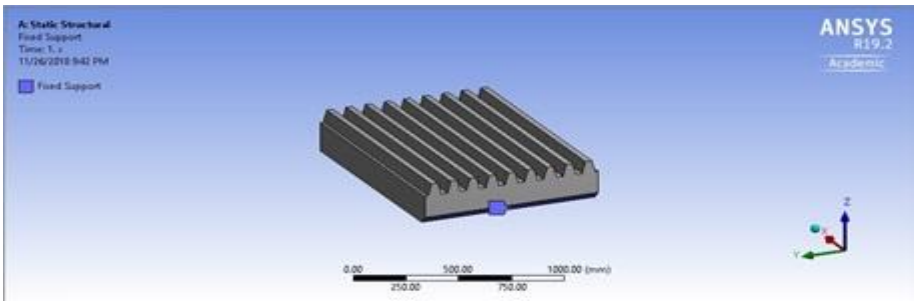

Fig 4.1without stiffener Jaw Plate Model Boundary Condition

4.1. Applying Loads:

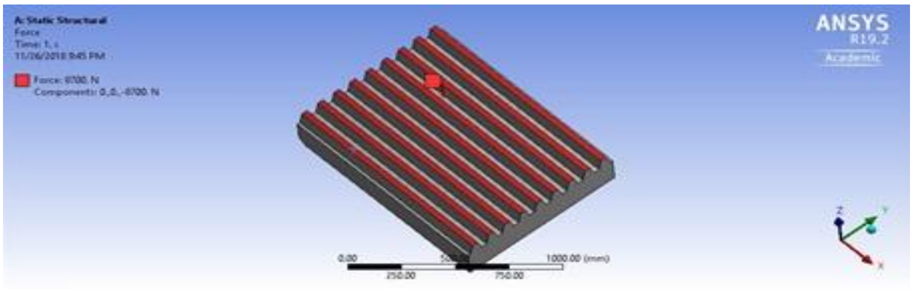

Fig 4.2 without stiffener Jaw Plate Model Applying Loads

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4.2. Linear Static Stress Analysis:

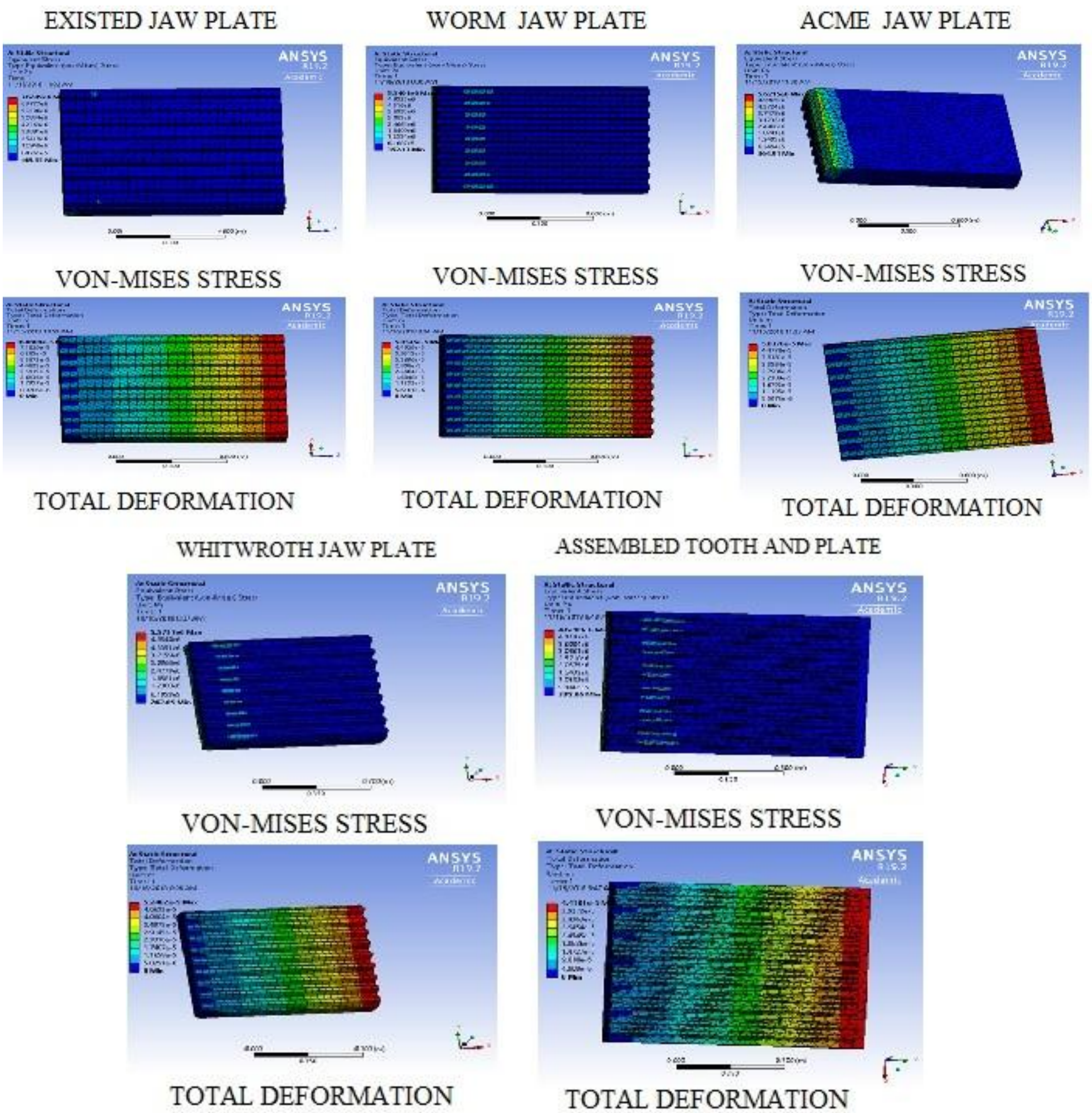

Fig 4.3 Static Stress Analysis results

5. Jaw Plates Static Stress Analysis Results:

In the current investigation stress and deformation for different jaw plates is done. The maximum stress distribution in the jaw plate was found to be tooth of the plate.

Below are the lists of observation from current analysis.

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Serial No	Austenitic manganese steel material Jaw plate models	Von-mises stress values (Mpa)
1	Existed jaw plate	7.6249
2	Whit worth jaw plate	5.5737
3	Worm jaw plate	5.5491
4	ACME jaw plate	5.6215
5	Tooth and plate assembled jaw plate	4.6289

Table 5.1 showing jaw plate von-mises stress values (Mpa)

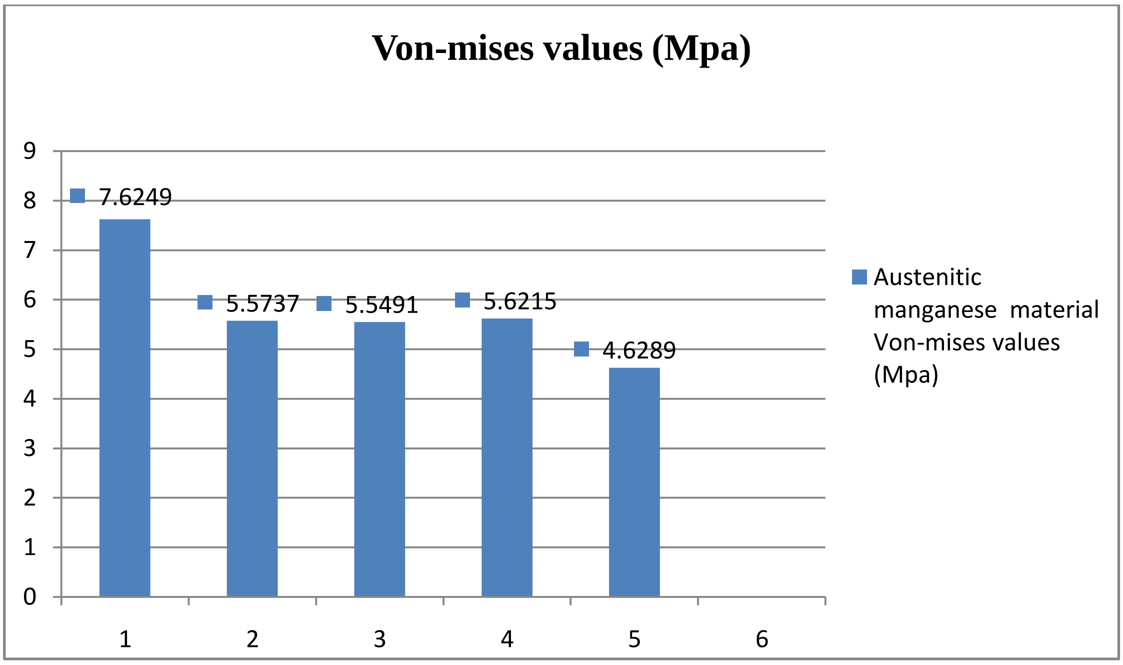

Fig 5.1showing jaw plate von-mises stress

The Fig 5.1 shows stress distribution pattern of the jaw plate. We can observe that in cases of equivalent (von-mises) stress values of the jaw plate of the Existed jaw plate, Whit worth jaw plate, Worm jaw plate, and ACME jaw plate model are shown. In these models Whit worth jaw plateis found to have least stress in comparison withpresent existed jaw plate and Tooth and plate assembled jaw plate is found to have least stress in all cases in comparison with remaining jaw plates including the present existed jaw plate.

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Serial No	Austenitic manganese steel material Jaw plate models	Total Displacement (mm)
1	Existed jaw plate	0.080808
2	Whit worth jaw plate	0.052462
3	Worm jaw plate	0.050555
4	ACME jaw plate	0.050376
5	Tooth and plate assembled jaw plate	0.044181

Table 5.2 showing Jaw plate Total Displacement values

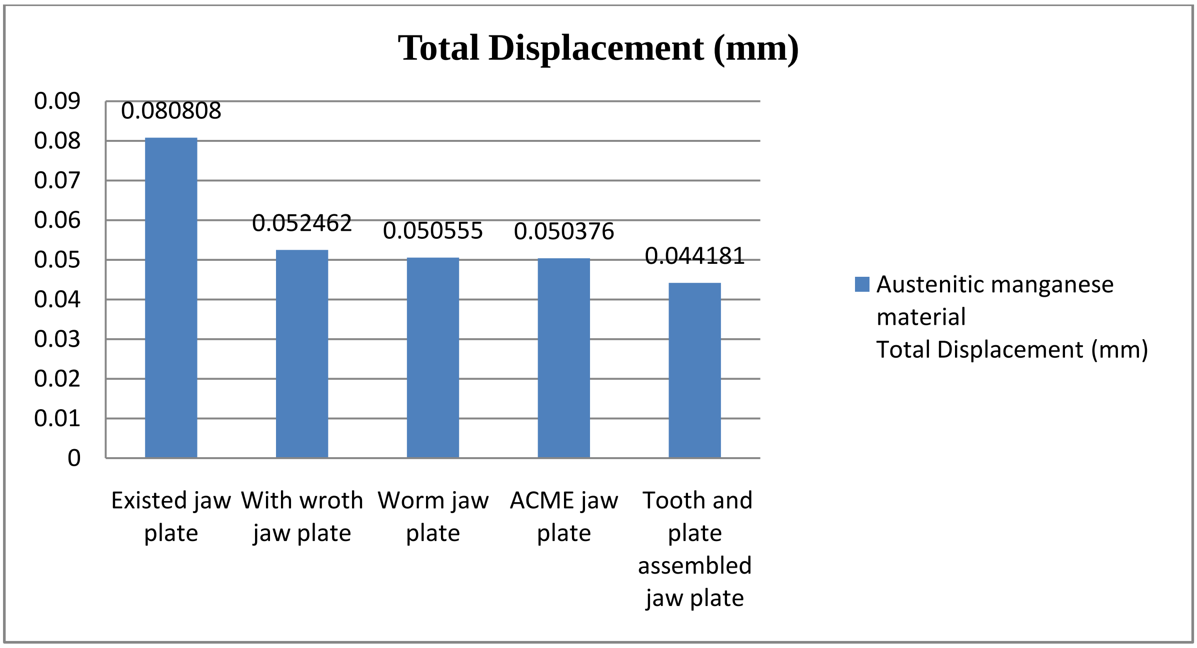

Fig 5.2 showing Jaw plate Total Displacement

The Fig 5.2 shows the deformation of the various jaw plates. We can observe that in cases of Total deformation values of the different jaw plates are Existed jaw plate, Whit worth jaw plate, Worm jaw plate ACME jaw plate and Tooth and plate assembled jaw plate are shown. In these jaw plate models Tooth and plate assembled jaw plate is found to have least deformation in all cases in comparison with remaining jaw plates including the present existed jaw plate. The jaw plate is made up of Austenitic manganese steel material. It can be seen that the tooth portion of the jaw plate, which is showing red deformed more than any other parts. The maximum deformation is found to be within the permissible limit.

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Conclusions

The following conclusions are drawn from the present work

Comparing the different results obtained from the analysis, It is concluded that Worm tooth jaw plateshows the better results than other models. All the values obtained from the analysis are less than their allowable values. Hence the jaw plate design is safe based on the strength criteria.

Commercially available jaw plates in working the squeezing process and the crushing force distribution process the jaw plates wear on a macroscopic level and failure of tooth of the jaw plate, therefore total jaw plate is replaced. But in this investigation we conclude that by using the tooth and plate assembled jaw plate model the failure tooth is only replaced instead of replacing total plate.

By observing analysis results, Austenitic manganese steel is best material for jaw plate design.

Future Scope for Study

The tooth and plate assembled jaw plate work in progress smaller vibrations are produced so vibration analysis can do.

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