Re-Design of Single Toggle Jaw Crusher to Reduce Wear of Jaw Liners

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Abstract

Single toggle jaw crushers are mainly used as primary crushers in mining and allied industries. Though very productive and energy efficient, this type of crusher is faced with very high jaw liner wear rate. A typical jaw liner has been estimated to have a life span of only three months of continuous usage. The high wear rate has been attributed to the high level of sliding interaction that exists between the jaw liners and the crushed material. Researchers have tried to reduce the wear rate by mainly considering it as material property. The geometric properties of the crusher which equally increase wear of the jaw liners have not been given much attention. This research, therefore, seeks to modify the current design of the single toggle jaw crusher to enhance the wear resistibility of the jaw liners. The paper presents an improved design of Single Toggle Jaw Crusher with the aim of mechanically reducing the liner wear rate. The new design has a passive movable fixed jaw that is allowed to displace vertically to reduce sliding of the material on the surface of the jaw liners during the interaction of the crushed material and the liners. A conceptual design of the new crusher was modelled using Autodesk inventor. Finite element analysis was conducted on the crusher to determine the critical stress locations and displacements in the fixed jaw assembly. The results revealed that a maximum Von Mises stress of 18.398 MPa developed at the top inner corners of the main frame. The stress amount was within safe values as the material used has a yield strength of 207 MPa. A maximum displacement of 0.017 mm occurred at the top middle section of the sliding plate. Fabrication using locally available materials has been completed. A test run of the new crusher has been done successfully. Evaluation of the new design is ongoing.

Keywords: Liner, Jaw Crusher, Wear, Improvement, Modelling, Design.

1 Introduction

The jaw crusher is the most common comminution machine in the mining industry. However, due to the abrasiveness of the crushed materials, the jaw liners of these crushers wear rapidly. The life of a typical jaw liner has been estimated to be from three to five months.

Mining companies therefore incur high cost of production due to the huge amount of money they spend in replacing the jaw liners. It also leads to low production rate, as the crushers must be shut down occasionally to allow for jaw liner replacements. Wearing of the jaw liners has been ascribed to the localised sliding and contact pressure between the jaw liners and the crushed material. Several research projects have been carried out to increase the working life of the jaw liners. However, these researchers have not yielded the needed results, because wear was mainly considered as a material problem. Meanwhile, the design parameters of the single toggle jaw crusher affect the wear rate of the crusher liners (Bayer, 2002). In this research, the single toggle jaw crusher has been redesigned by incorporating a passive movable fixed jaw to decrease the sliding interaction between the crushed material and the jaw liners. Which in turn reduces the wear rate of the jaw liners.

1.1 Conventional Design and Features of Single Toggle Jaw Crusher

The single toggle jaw crusher has some special main features as illustrated in Figure 1. This type of jaw crusher provides compression forces to break rock particles. Under the action of the eccentric shaft and the toggle, very powerful compressive forces are generated. To break a particle, the crushing forces (compressive) must be high enough to exceed the fracture strength of the particle. When a particle is nipped between the liners of a jaw crusher, tensile stresses are induced in the particle. Thus, the compressive force applied by the jaw liners causes the rock particle to fail.

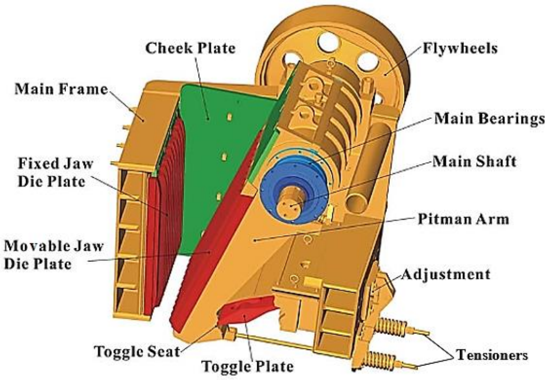

Figure 1 Features of Single Toggle Jaw Crusher (Source: Anon., 2015)

1.2 Wear in jaw crushers

A work published by Shyam (2014) reveals that, the two main factors affecting the rapid wear of jaw liners include: squeezing and sliding. Manganese steel, which is the dominating material in the manufacturing of jaw liners, has an outstanding work hardening ability (Ghasri-Khouzani and McDermid, 2019). The high compressive force generated through the squeezing action makes the manganese steel liners harder. The work hardening property increases the resilience of the liners against wear due to impact loading. It has been established by several researchers that sliding of the crushed material at the contact interface with the jaw liners is the main cause of the rapid jaw liner wear rate (Sham, 2014, Juuso *et al.*, 2017, Deepak, 2010, Lindqvist and Evertsson, 2003). This means that the work hardening ability of a manganese steel jaw liner cannot withstand sliding wear. Therefore, decreasing the sliding interaction between the jaw liners and the material can considerably increase the jaw liner life.

Shyam (2014) further observed that the wear in the inlet part of the crushing chamber was small, compared to the middle and exit sections. Again, it was established in the same research that since fewer particles are crushed in the edge parts of the jaw liners, the wear of the middle parts in the same crushing zone is intense compared to the edge parts. It was also noted that for a typical jaw crusher, the sliding distance between the crushed particles and the fixed jaw liner is more than that between the crushed particles and the moving jaw liner, so the wear of the fixed jaw liner is severe compared to that of the moving jaw liner.

It is, therefore, imperative to redesign the crusher to reduce the sliding interaction between the crushed particles and jaw liners, thereby reducing the wear rate of the jaw liners.

2 Materials and Methods

2.1 Material selection

The jaw crusher was designed and manufactured using locally assorted materials. The main frame of the crusher was manufactured using mild steel plate of 8 mm thickness. The support frame was made from mild steel angle iron. The eccentric shaft and the flywheels were made from cast iron. All the other parts were made from mild steel.

2.1.1 Characteristics of Some Mine Rocks

Most mine rocks have traits of mineral grains that are harder than steels used in crushing equipment (Mole, 2016). These grains can scratch off material from the surface of the crusher liners, thereby creating wear.

Table 1 Typical Test Results for Rocks In the mining Industry. (Source: Mole, 2016)

Material	Density (kg/m^3)	Impact Strength (N)	Abrasion Index
Dolomite	2.75	700	0.02
Limestone	2.69	720	0.001
Magnetite	4.6	750	-
Gneiss	2.72	910	0.48
Granite	2.68	940	0.46
Quartzite	2.65	970	0.79

Hematite	4.42	1040	-
Diabase	2.84	1060	0.28
Basalt	2.84	1160	0.25

Table 1 shows the characteristics of selected rocks from the mining industry. As seen in the fourth column of the table, the impact strengths of the rocks range from 700 N to 1160 N. The wear rate of a given liner is influenced by the hardness and the abrasion index of the crushed material (Mole, 2016). The impact strength is the amount force the rock can withstand when loaded suddenly.

2.2 Design Description and Mode of Operation

To reduce the sliding interaction between the particles and the liners, the jaw crusher was redesigned by incorporating a passive movable fixed jaw that is allowed to displace vertically under the influence of the swing jaw and the crushed material. The fixed jaw is allowed to slide in a guide on the main frame of the crusher with the help of a sliding plate. The jaw is spring loaded at the bottom which assists the sliding plate to return to its original position after being pushed downward by the action of the swing jaw and the crushed material.

In order to compare the wear rate of the jaw liner of the passive moveable jaw design with that of the conventional fixed jaw design, the fixed jaw was designed in such a way that it can be locked in place with the help of two lock bolts to mimic the conventional fixed jaw design. The conceptual design can be seen in Figure 2.

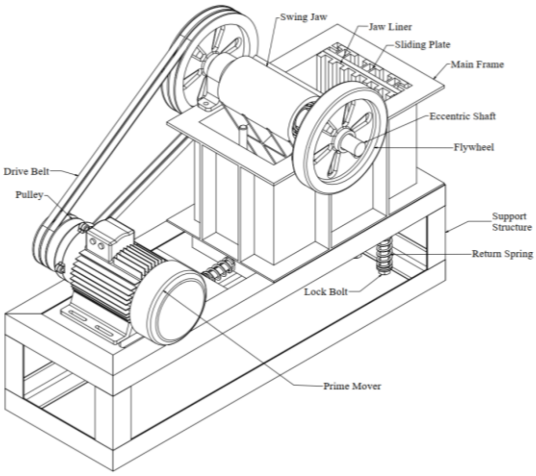

Figure 2 Conceptual Design

2.2.1 Finite Element Analysis of the Sliding Plate and Main Frame

Finite Element analysis (FEA) was conducted of the fixed jaw to determine the structural integrity of the jaw. The FEA was conducted using Autodesk Inventor Nastran. To reduce the computation power required for the simulation the model was simplified by sectioning off a portion of the main frame of the crusher.

Based on Table 1, Uniformly Distributed Load (UDL) of 20 kN was applied on the surface of the sliding plate, and fixed constraint was applied to the three sliding surfaces at the back (Figure 3). The same UDL was repeated for the second model (Figure 4), and a fixed constraint was applied to the sectioned surface of the main frame and the base of the main frame. This was done to determine the stress distribution and the critical stress locations on the fixed jaw of the crusher.

Figures 3 and 4 show the meshed models used in the simulation. For each model, the total iteration was set to five (5) in the software, and convergence of the solution was set to 5%. The software was then set to locally refine the mesh at the areas where stresses were high from the previous solution. Von Mises stresses and displacements were determined from the two models.

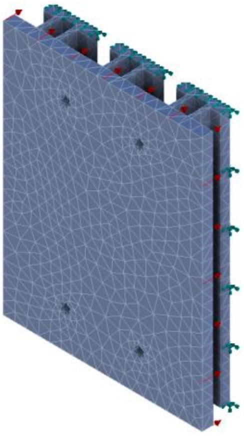

Figure 3 Meshed Model of the Sliding Plate

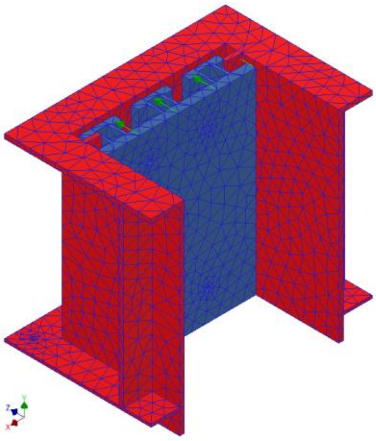

Figure 4 Meshed Model of the Sectioned Main Frame the Sliding Plate

3 Results and Discussions

3.1 Finite Element Analysis Results

Figures 5 and 6 show the stress and displacement distribution withing the sliding plate respectively. A maximum Von Mises stress of 3.859 MPa developed within the stiffeners of the sliding plate. The stress amount was within safe values as the material used has a yield strength of 207 MPa.

The maximum displacement of 1.534×10^{-3} mm at the edge region of the sliding plate was insignificant as the material remain undeformed.

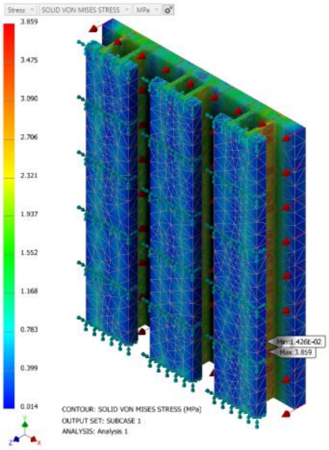

Figure 5 Stress Distribution in the Sliding Plate

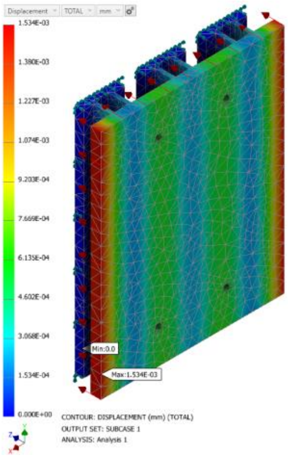

Figure 6 Displacement within the Sliding Plate

The simulation results from the assembly of the sliding plate and the main frame of the crusher are shown in Figures 7 and 8. The results revealed that the maximum Von Mises stress of 18.398 MPa developed at the top inner corners of the main frame. This was because the top end of the main frame was not constrained. It was however noted that this stress value is less that the yield strength of the material used to design the crusher therefore the material is safe.

A maximum displacement of 0.017 mm occurred at the top middle section of the sliding plate. The stiffeners on the main frame increased the resilience of the frame thereby reducing the deformation in that section of the crusher.

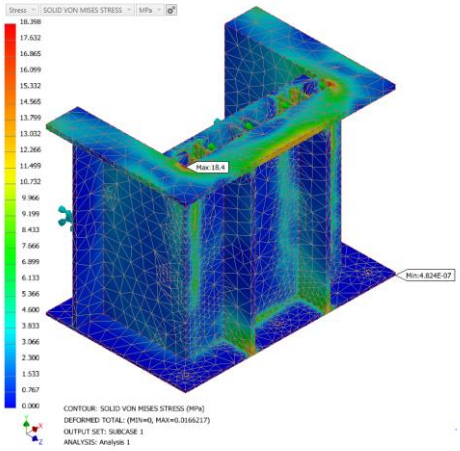

Figure 7 Distribution of Von Mises Stress in the Sliding Plate and Main Frame Assembly

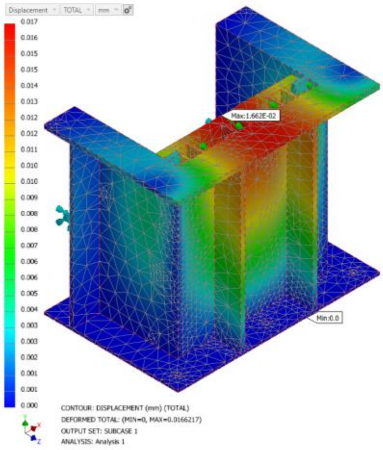

Figure 8 Displacement in the Sliding Plate and Main Frame Assembly

3.2 Manufacturing Outcome

The fabrication and assembling of the new crusher have been successfully carried out. Figure 9 shows the new crusher assembly. A successful test run result can be seen in Figures 10 and 11.

Figure 9 The Newly Manufactured Single Toggle Jaw Crusher

Figure 10 The New Jaw Crusher in Operation

Figure 11 Samples Crushed Rocks by the New Crusher

4 Conclusions and Further Works

Redesign and fabrication of the single toggle jaw crusher has been accomplished. A successful test run of the crusher has been carried out. The crusher can take in a maximum material size of 178 mm x 250 mm and the output can be adjusted to produce particle size distribution range from 20 mm to 54.5 mm. FEA was performed on fixed jaw section of the crusher to ascertain the resilience of the sliding plate and the main frame when under compressive loading.

Testing and evaluation of the wear performance of the new crusher is yet to be carried out. Comparative wear analysis of the crusher with a moveable fixed jaw and that of the conventional fixed jaw design will be done. The energy consumption and the Throughput of the crusher will also be determined.

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