Analyses Of Stress And Deformed Shape Of Hammer Mill Hammers (HMHs) By Using Autodesk Inventor

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ABSTRACT

Analyses on stress and deformed shape of Hammer Mill Hammers (HMHs) by using Autodesk Inventor software had been conducted. The simulation by using impact of 21.396 N and moment force of 1.326 Nmm resulted maximum result of Von Mises stress 153.5 Mpa and maximum displacement of 0.1695 mm with stress impact concentrated at one point (middle part) of the HMHs surface. If direction of impact load worked at the middle point and was distributed evenly at the periphery part of HMHs surface, the maximum Von Mises stress value was 204.4 Mpa and maximum displacement was 0.2819 mm. Seeing from obtained maximum Von Mises value, HMHs would not undergo failure because maximum of Von Mises value was lower than yield strength of used material; the manganese steel, with yield strength of 360 Mpa. Minimum values of safety factor or both directions of impact load were 1.761 and 2.345 respectively, and they excessed required values for a design (safety factor > 1).

Key Words: von mises; displacement; hammer mill hammers (HMHs); stress analysis; inventor

1. INTRODUCTION

Crushing is a process which is widely used in mineral processing plants, cement factories, aggregates plants and some other industrial plants. Demands for crushed stone aggregates have been increasing from day to day, because of increasing expansion of highway and other construction works and decreasing natural aggregate resources in the world (Umucu,et al 2013). A crusher is a machine designed to reduce large solid material objects into a smaller volume, or smaller pieces. Crushers may be used to reduce size or to change form of waste materials so that they can be more easily disposed or recycled, or to reduce size of solid mix of raw materials (as in rock ore) so that pieces of different compositions can be differentiated (Kumar, 2013). Crushers are typically the first stage of comminution processing for run of mine ore in mineral processing and

for the manufacture of aggregates and are also used in the preparation of aggregate, limestone and coal. Many different types of crushers have been developed over the years for a varied range of applications, material types and required products. Typically design, optimization and customization of crushers have been performed by using experimental approaches (Sinott, et al 2015). One type of crushers is a hammer mill. This operates by striking falling particles by near vertically oriented hammer surfaces attached rigidly or via hinges to a central horizontal impeller rotating at high speed (typically between 750 and 1800 rpm). Hammer mills rely on impact rather than pressure to crush material. Further reduction in product size occurs as circulating material within the crusher shatters against the breaker plate located at the periphery of the crusher. A discharge grate in the floor of the mill allows finer particles to flow through while larger particles are retained for further crushing. Due to the high velocity impacts with the hammers, more fine material is generated and resulting in a broader product size than that is given by jaw and gyratory crushers. This type of crusher is inexpensive to run but tends to suffer from wear due to the high speed of the hammers and the abrasiveness of feed material. It is usually used to crush soft material such as coal, but is also used for recycling materials. The impellors come in a range of forms. These can include fixed plates rotating around the shaft and hinged hammers that are free to swing around their satellite shafts (Sinott, et al 2015). Hammer mills are widely utilized in agricultural, wood, mining and chemical industry (Ebunilo, et al 2010).
In the hammer mills, HMHs design plays a significant role as the HMHs do most of the work. The factors taken into consideration while designing the HMHs are mass, general shape, the air paths created by hammer sweep, and heat treatment. The shape of the HMHs may be of T-, bar-, or, of ring shaped (plain and toothed) as shown in figure 1. The HMHs heads must be extremely hard and resistant to wear (Swain et al, 2011).

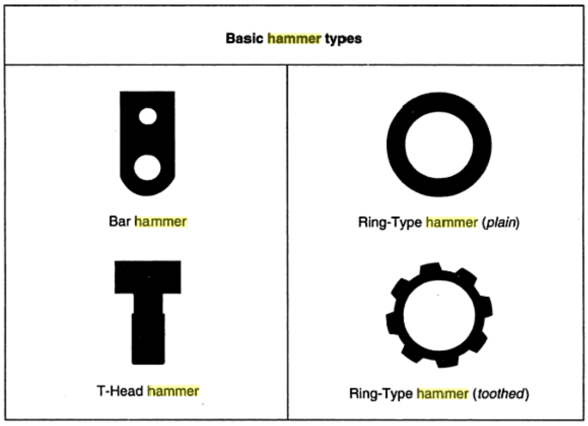

Figure 1. Basic Hammer Types

Hammer mill hammers (HMHs) are the main components to wear out because of high impact load. Resulted centrifugal force causes big tensile strength to HMHs, so that estimation to design HMHs is required to obtain optimal design. Many researches on HMHs have been conducted especially on how to make them, their microstructures and material compositions, but researchers on analysis of stress received by HMHs is seldom to do. The design is the initial step of any effort to produce a product. Initial design enable efforts to minimize failure possibilities of a particular product. This research emphasized on a design by analyzing stress concentrated on the middle point which was distributed evenly of the tip and surface of HMHs.

2. EXPERIMENT

Basically, designing method can be grouped into two groups; the designing with simple estimation and designing with computer aided model. These two methods are mutually completing in designing process of system or product processes. The designing process is started by determining HMHs dimension. The determination considers hammer machine construction to use. Hammer machine to use in this research was the one to mill dolomite and zeolite mineral, as it is shown in Figure 2a. The hammer machine to use was double shaft hammer mill type, with 12 HMHs and it worked at 2500 rpm. Machine capacity was 2000 kg/hour. Dimension of HMHs was 197 mm x 100 mm x 80 mm. HMHs materials to use were manganese iron steel. The reason of using the material was that this steel exhibited a unique combination of properties such as high strength, high toughness, resistance to wear, and especially the excellent strain hardening behavior (Wei,et al 2012).

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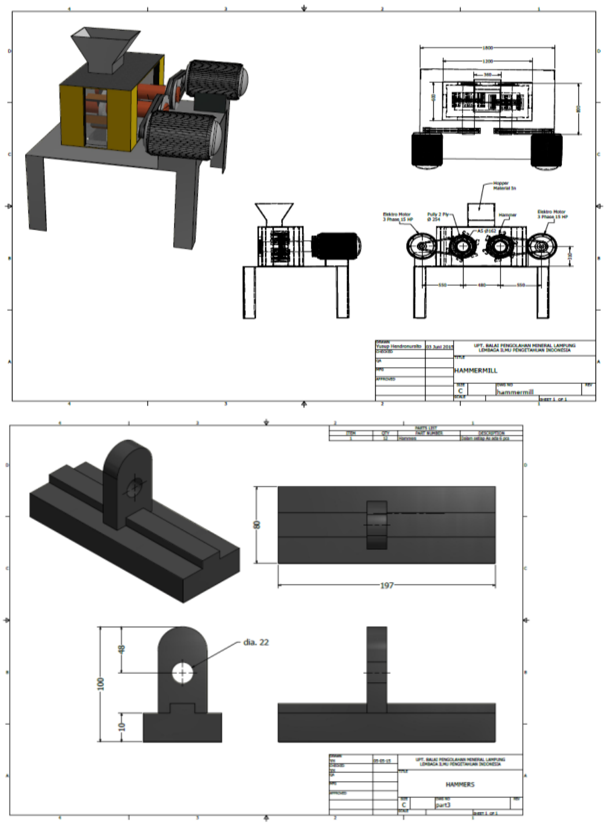

Figure 2. (a) Double Shaft Hammer Mill Machine. **(b)** Hammer Mill Hammers dimension

Estimation of stress impact received by HMHs was conducted by using equations with some assumptions; rotor mass was much greater than mass of single particles in the feed; before impact, linear velocity of the crushing bar was much more important than the particle velocity, hence kinetic energy of particles was negligible; it was also assumed that most particles enter into the collision with the rotor bars in the median region of their impact areas with the hammer. Consider of linear movement before and after impact the mass energy (Em) given by the following equation (Farag,et al 2015, Nikolov,2004).

$Em= 0.5\ R + 0.5\ H^2+\omega^2$ ------- (1)

Where:

- R= Rotor radius, mm;
- H= Height of the impact surface, mm;
- ω= Rotor velocity (rpm).

To insure the new design of the hammer was safe in this experiment conditions ,the allowance moment were calculated according to the following equations (Gupta et al, 2005).

Max. moment (Mmax) = p* Hhw/2-------------(2)

P= w (h+y)

Where:

- P= is the equivalent static force N.mm;
- w= impact force N;
- h=height of fall material mm;
- y= defalcation mm.

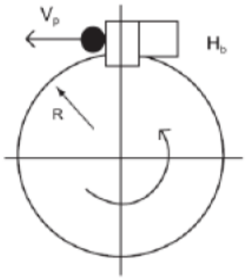

Figure 3. A Single particle just after with the rotor bar of a hammer crusher (Farag,et al 2015)

After working impact load and momentum force was known, simulation by using Autodesk Inventor Professional 2013 was conducted to help stress analysis process by inputting impact load and momentum force received by HMHs. Simulation was conducted by giving different direction of stress impacts to HMHs surface. Inventor 2013 was equipped with estimation of stress analysis. Its estimation module was supported with technology from ANSYS. The working sequences were as follows: making a model/part to analyze, selecting material for model/part, setting roughness/fineness of Mesh, giving load (it can be force, momentum, pressure, bearing load to cylinder surface, body load, constraint), running stress analysis, visualizing result and its animation, making report in HTML file (Agus 2009).

3. RESULTS AND DISCUSSION

Result of force estimation based on equation 1 and 2 obtained from impact load 21.396 N derived moment force 1.326 Nmm. Besides impact load and force moment, the following data input in Table 1 was conducted.

Table 1. Properties of Material

Name	Manganese Steel	
General	Mass Density	7,83341 g/cm^3
	Yield Strength	360 MPa
	Ultimate Tensile Strength	448,159 MPa
Stress	Young's Modulus	164,785 GPa
	Poisson's Ratio	0,266 ul

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Stress XX	-18,9449 MPa	42,4033 MPa	-87,2049 MPa	110,976 MPa
Stress XY	-15,362 MPa	14,8225 MPa	-22,5998 MPa	22,4548 MPa
Stress XZ	-11,4949 MPa	12,5252 MPa	-100,594 MPa	95,2679 MPa
Stress YY	-159,318 MPa	76,1296 MPa	-171,296 MPa	89,0073 MPa
Stress YZ	-32,7946 MPa	32,957 MPa	-30,7691 MPa	31,438 MPa
Stress ZZ	-41,7278 MPa	14,0736 MPa	-133,429 MPa	94,6068 MPa
X Displacement	-0,00433634 mm	0,0043143 mm	-0,131496 mm	0,0116444 mm
Y Displacement	-0,0371579 mm	0,0372028 mm	-0,0393582 mm	0,0393758 mm
Z Displacement	0 mm	0,168752 mm	-0,0604049 mm	0,250971 mm
Equivalent Strain	0 ul	0,000823716 ul	0 ul	0,00104904 ul
1st Principal Strain	0 ul	0,000437416 ul	0 ul	0,000979999 ul
3rd Principal Strain	-0,000957558 ul	0 ul	-0,00103487 ul	0 ul
Strain XX	-0,00010507 ul	0,000270461 ul	-0,000611649 ul	0,000804485 ul
Strain XY	-0,000118022 ul	0,000113878 ul	-0,000173628 ul	0,000172515 ul
Strain XZ	-0,0000883121 ul	0,0000962284 ul	-0,000772837 ul	0,00073192 ul
Strain YY	-0,000927827 ul	0,000437369 ul	-0,000984455 ul	0,000593369 ul
Strain YZ	-0,000251953 ul	0,000253201 ul	-0,000236391 ul	0,00024153 ul
Strain ZZ	-0,00023583 ul	0,00024671 ul	-0,000929946 ul	0,000659017 ul

Table 2 shows that maximum stress of von mises occurring at direction of impact load concentrated at one point is lesser than evenly distributed impact load at HMHs. Maximum value of von mises with impact load direction at one point is 153.507 Mpa. Maximum von mises stress at HMHs with evenly distributed impact load is 204.371 MPa. Distribution of von mises stress is shown in Figure 5.

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O.P.Ebunilo, I.A.Obanor, O.G.Ariavie.(2010). Design and Preliminary Testing of a Hammer Mill With End-Suction Lift Capability Suitable For Commercial Processing of Grains and Solid Minerals in Nigeria. *International Journal of Engineering Science and Technology,Vol.2(6),pp.1581-1593.*

Sinnott D.M, Cleary P.W (2015). Simulation of Particle Flows and Breakage in Crushers Using DEM: Part 2-Impact Crusher,*Minerals Engineering.*

Swain K.A, Patra H, Roy G.K. (2011). *Mechanical Operations*,Tata Mc.Graw Hill Education Private Limited,pp.67-68.

Xiaoyun L, Wei W, Fangqiu Z, Lanjun L, Xianfeng Z.(2012). Influence of Impact Energy on Work Hardening Ability of Austenitic Manganese Steel and Its Mechanism,*China Foundry,Vol.9.No.3,pp.248.*

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