Design and Analysis of Hardness Improvement on Excavator Bucket Teeth

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ABSTRACT

The Excavator bucket tooth has to bear heavy loads of materials like soil, rock and subjected to abrasion wear due to the abrasive nature of soil particles. Its tooth got damaged due to abrasive wear and impact load. This paper deals with review of Excavators bucket tooth analysis to find out its actual failure. Excavators used in mining industry have bucket teeth usually made up of hard alloys. In order to improve the anti-wear properties of these alloys coatings are provided. The purpose of the present work is to make the deformation analysis of the bucket teeth. It was observed that maximum stress occurred at the fixed joint of teeth and tongue, while the maximum wear takes place at the tip of tooth. The abrasive nature of soil is one of the reasons of tip wear. An excavator is a typical hydraulic heavy - duty human - operated machine used in general versatile construction operations, such as digging, ground leveling, carrying loads, dumping loads and straight traction. After doing such operation, there is possibility of breaking of pin in tooth adapter assembly as well as bending of tooth point. The objective of this paper is to design an excavator bucket by using SOLID WORKS software. Model is exported through IGES file format for meshing in analysis software Boundary conditions and the forces are applied at the tip of teeth of excavator bucket. Static analysis is done in ANSYS 13.0 analysis software. In this paper the stresses developed at the tip of excavator bucket teeth are calculated. Percentage error between stress Analytical result and stress ANSYS result are calculated.

1. INTRODUCTION

An excavator is a piece of heavy equipment that is commonly used in construction work, mining work and work that requires lifting that can be too heavy for humans. An excavator is a vehicle that is engineered and consists of things that can be used such as a backhoe and also has a cab that tends to be mounted to the back pivot near the undercarriage. It also has tracks and wheels that it is running on. As the use of excavator in day to day life is increasing for many purposes but the applicable site is not inspected properly due urgency of work by the owner or the contractor due to which improper handling of it leads to damage of the ground engaging tool i.e. bucket teeth. The teeth of the excavator are main contacting part of it which comes first in contact with the soil while doing excavation at various sites. So in this case sometimes the tooth point of the bucket gets damage due to some improper handling by the operator, which leads to the damage of tip of teeth. Here I calculate the stresses at the tip of the teeth by analytically and Finite analysis approach and then compare their results. High values of hardness are also needed in those surfaces over which the extracted materials move and even harder materials to manufacture the mineral milling equipment. For the selection of appropriate material for bucket teeth, it becomes necessary to make an accurate analysis, also replacement of worn out teeth on weekly basis caused the increase in cost and hence an important economic factor in the mining industry. Hydraulic excavator plays a significant role in the modern engineering, it was bored complex and changing work stress and strain, its structural strength design directly affect the performance and reliability of the excavator. The virtual prototype technology can simulate all kinds of working conditions and achieve the ideal effect by optimizing parameters. In this paper, the 3D modelling of a hydraulic excavator was established using the Solid works and converted into ADAMS software environment, added the constraints, the drives and loaded epigenetic reasonably and generated the main working parts of the virtual prototype model. The limit work trajectory displacement graph was given, and we obtained the change characteristic curve of the hinge point of the force at work. The static strength was analyzed by the finite element model in ANSYS, the stress and strain nephogram of the working device show that the reasonableness and correctness of the design, it provides a convenient and efficient means for the excavators design and optimization [1]. In this paper, the actual working conditions in the excavator bucket load in the mining process and foreign load has random features of Pro/E and finite element analysis software ANSYS to establish the bucket entity model, based on rock mechanics, material nonlinear analysis theoretical Construction of the soil constitutive model simulation, and the bucket of the different movement of the force, respectively bucket two main conditions the stress and displacement contours and analysis of the ultimate stress values and bucket stress characteristics is to improve the bucket force and work performance, improve safety and efficiency of the bucket work to provide a basis [2]. This paper applies large-scale finite element software ANSYS and the module of LS-DYNA to establish the solid model of bucket teeth, and according to Smoothed Particle Hydrodynamics Method (SPH) establishes the soil constitutive model. Emulating the process that bucket teeth excavate soil of three different grade ruggedness coefficients obtains the stress and statistical value of bucket tooth point; Simulation results show that: the stress concentration of bucket teeth point is more serious. When the ruggedness coefficient is0.6< f <1.0, the corresponding maximum stress is 197 ~ 309MPa, which meets the strength requirement .The damage is caused by the fatigue failure [3]. The Excavator bucket tooth have to bear heavy loads of materials like soil, rock and subjected to abrasion wear due to the abrasive nature of soil particles. Its tooth got damaged due to abrasive wear and impact load. This paper deals with review of Excavators bucket tooth analysis to find out its actual failure [4]. Excavators are heavy duty earthmoving machines and normally used for excavation task. During the excavation operation unknown resistive forces offered by the terrain to the bucket teeth. Excessive amount of these forces adversely affected on the machine parts and may be failed during excavation operation. Design engineers have great challenge to provide the better robust design of excavator parts which can work against unpredicted forces and under worst working condition. Thus, it is very much necessary for the designers to provide not only a better design of parts having maximum reliability but also of minimum weight and cost, keeping design safe under all loading conditions. Finite Element Analysis (FEA) is the most powerful technique for strength calculations of the structures working under known load and boundary conditions. FEA approach can be applied for the structural weight optimization. This paper focuses on structural weight optimization of backhoe excavator attachment using FEA approach by trial and error method. Shape optimization also performed for weight optimization and results are compared with trial and error method which shows identical results. The FEA of the optimized model also performed and their results are verified by applying classical theory [5]. Excavator's machines are also called as heavy duty earthmoving equipment which is very important and normally used for excavation task. During the excavation operation unknown resistive forces offered by the terrain to the bucket. Excessive amount of these forces adversely affected on the machine parts and may be failed during excavation operation. Design engineers have great challenge to provide the better robust design of excavator bucket parts which can work against unpredicted forces and under worst working condition. It has been observed that the existing bucket material of backhoe excavator gives the satisfactory results. Also it has been found that deformation and stresses values are safe. In order to increase the life of backhoe excavator bucket other two materials i.e. HORDOX-400 and HORDOX-500 has been analyzed for the similar force and boundary conditions that of the existing bucket. It has been found that the value of deformation, stresses and life for HORDOX-400 is much better than other material. Also the cost of HORDOX-400 is affordable. So the HORDOX-400 can been used in place of EN-8 i.e. existing bucket material. Also Finite Element Analysis (FEA) is the most powerful technique for strength calculations of the structures working under known load and boundary conditions. Thus, in this paper, we will suggested the use Finite Element Analysis (FEA) as a tool for static analysis of backhoe excavator bucket for existing as well as optimized excavator bucket. And to find out the maximum stress point and deformation and the method to minimize it with increasing the life of backhoe excavator bucket [6].

2. METHODOLOGY

The following figure shows the methodology of this study.

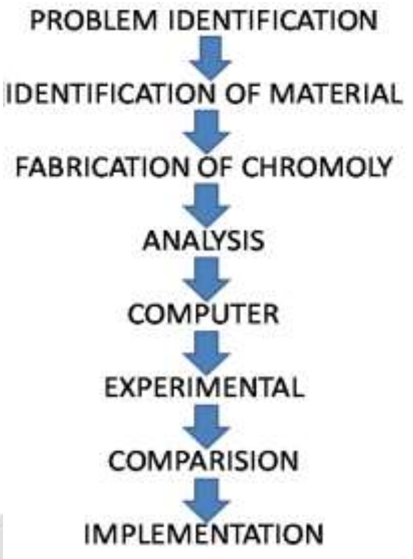

Figure 1 Methodology

3. MATERIALS AND METHODS

Metal casting process begins by creating a mold, which is the 'reverse' shape of the part we need. The mold is made from a refractory material, for example, sand. The metal is heated in an oven until it melts, and the molten metal is poured into the mould cavity. The liquid takes the shape of cavity, which is the shape of the part. It is cooled until it solidifies. Finally, the solidified metal part is removed from the mould. A large number of metal components in designs we use every day are made by casting. The reasons for this include:

(a) Casting can produce very complex geometry parts with internal cavities and hollow sections.
(b) It can be used to make small (few hundred grams) to very large size parts (thousands of kilograms)
(c) It is economical, with very little wastage: the extra metal in each casting is re-melted and re-used
(d) Cast metal is isotropic – it has the same physical/mechanical properties along any direction.

3.1 DESIGN

The below figure shows the 2 dimensional viwe of the proposed bucket teeth.

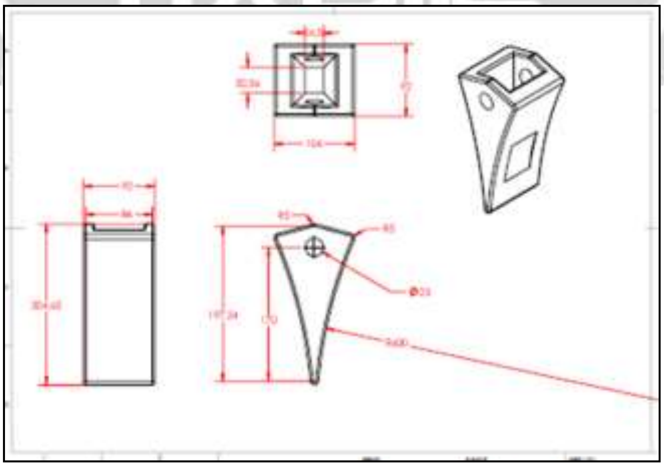

Figure 2 Two dimensional view of the excavator bucket teeth

3.2 FABRICATION

3.2.1 Cutting the sprue and the riser

To form the sprue - a passage through which you'll pour the metal - measure the depth of the cope, and mark this distance with tape on the side of a section of thin-walled 3/4-inch pipe. Push the pipe straight down into the sand in the cope, in a spot where it will not hit the pattern. Twist the pipe back and forth to cut an opening through the sand, stopping when the tape mark meets the surface of the sand. Use a slick to carve a funnel shape in the sand around the pipe, beveling the edges of the sprue opening. Then slip the pipe out, with the sand core inside, leaving a passageway through which you'll pour the molten metal. On the other side of the pattern, form the riser opening - the passage into which excess metal will rise - by using a slightly larger diameter pipe to cut through the sand in the cope.

3.2.2 Venting the mold

Use a 1/16-inch welding rod or a stiff wire (a bicycle spoke is ideal) to poke channels through the sand in the cope, so that hot gases can escape. Push the rod into the sand, stopping about 1/2 inch from the pattern. Make about a dozen vents over the pattern area. Lift the cope from the drag and set it on edge, off to one side, where it will not be disturbed.

3.2.3 Removing the pattern

Before lifting the pattern from the drag, firm the pattern edge of a water-based sand mold by moistening it with a molder's bulb or a small brush dipped in water. This will help to keep the sand from collapsing when the pattern is removed. Screw draw pins into the holes in the back of the pattern and lightly tap the pattern to loosen it from the sand. Then gently pull on the draw pins, lifting the pattern straight up and out of the casting cavity.

3.2.4 Cutting the gates

Using a piece of sheet metal bent into a 1/2-inch-wide U shape, cut a channel, or gate, running from the casting cavity to the riser position. Lift out a bit of sand at a time, forming a gate slightly smaller than the diameter of the riser and slightly shallower than the depth of the casting cavity. Scoop out a similar gate from the casting cavity to the sprue position. For large molds, cut several gates to the sprue and the riser from various parts of the casting cavity. Blow out or tamp down any loose bits of sand in the gates.

3.2.5 Refining the mold

Rebuild crumbled sections of the casting cavity by adding bits of moist sand, smoothing it into place with molding tools. Tamp down or blow away all loose sand to prevent it from mixing with the molten metal when the metal is poured. Replace the cope over the drag and set the flask, still on the bottom board, in the sandbox near the furnace. If you are not going to pour the casting immediately, cover the mold to keep dirt from falling into the sprue and riser.

3.2.6 Pouring of molten metal

With a helper, lift the crucible shank and hook its safety lock over the lip of the crucible by pushing the latch forward. Lift and tilt the crucible a few inches above the mold, pouring the molten metal quickly and steadily into the sprue, or molten metal passage, into the cast. Stop pouring when the metal nearly reaches the top of the riser. Immediately, while it is still molten, pour all the extra metal into the ingot mold. Leave the casting mold in place until the metal in the sprue and in the riser is hard. To test the newly cast metal for hardness, tap it with the tongs.

3.2.7 Removal of a metal casting

When the metal has hardened, carry the mold to the sand-storage area. Wearing gloves, separate the cope and the drag. Lift out the hot metal casting with tongs. Break apart the sand in the mold, and dump it back into the sand-storage container. Set the casting aside to cool, leaving in place the extrusions that the sprue, riser, and gates formed. When the casting is completely cool, cut off the gates with a hacksaw and file down the rough areas. Finish the surface as desired.

3.2.8 Position the pattern

Place the drag upside down on the molding board and center the pattern in the drag, flat side down. Leave enough room between the pattern and the drag for the openings of the riser and the sprue — the passageways through which the molten metal will flow. Dust parting compound evenly over the pattern.

3.2.9 Riddle sand over the pattern

Shovel molding sand into a riddle, and sift the sand over the pattern either by shaking the riddle or by pushing the sand through it with your hand. Cover the pattern with sand about 1 inch deep. Then set the riddle aside and use your fingers to tuck the sand around the pattern, working from the sides of the drag in toward the center.

3.2.10 Ram the sand

Shovel sand into the drag until it is almost full, and compress it with a bench rammer. Starting with the peen end of the rammer, push the sand against the sides of the drag, and then use the butt end to flatten the sand in the center. Pack the sand firmly, but not so rock-hard that hot gases cannot escape. Repeat until sand is slightly higher than the sides of the drag.

3.1.11 Level the sand in the drag

Pull a strike-off bar across the top of the sand, using the edges of the drag as a guide. Work the bar back and forth to make the surface of the sand perfectly flat. Then place the bottom board over the drag, sandwiching the first half of the mold between the bottom board and the molding board.

3.1.12 Roll the drag

To turn the drag right side up, grasp the edges of the molding board and the bottom board tightly on each side and flip the drag over. If the drag is especially large or heavy, pull it toward you and roll it over to the opposite side, using the edge of the workbench for leverage. Remove the molding board from the top of the drag, exposing the mold's parting plane and the underside of the pattern.

3.1.13 Perfect the Parting Plane

Blow away stray bits of sand with a bellows, and use a trowel or a slick to smooth rough spots or fill in loose areas, especially around the pattern edge. Sprinkle the entire surface lightly with parting compound. For guidance in placing the sprue and the riser, measure the distance from the pattern edges to the sides of the drag. Place the cope on top of the drag, fitting the pins of the drag through the holes of the cope (inset). Sprinkle parting compound over the pattern back, then repeat steps 2, 3, and 4 to fill the cope.

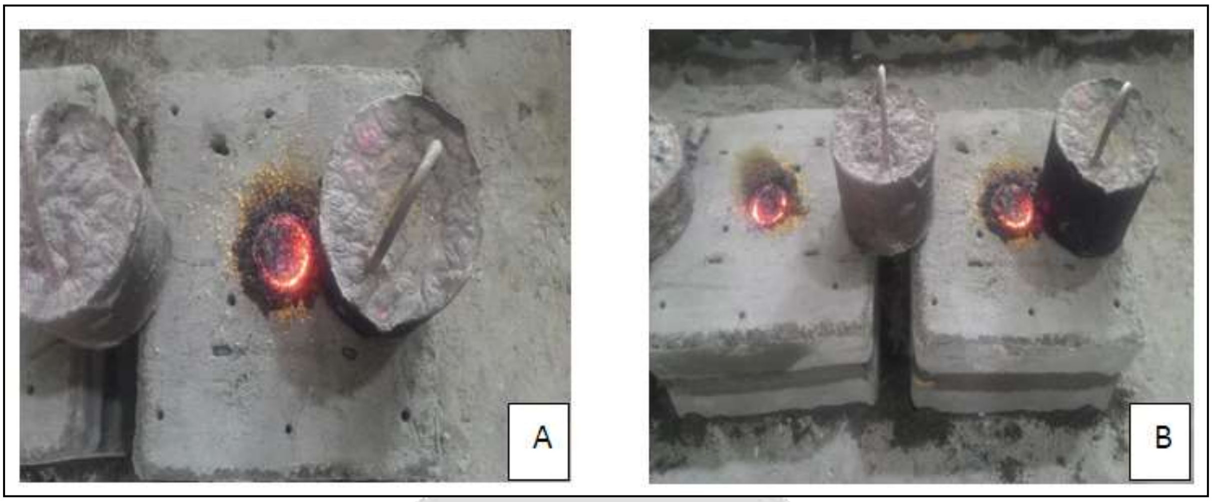

Figure 3 Fabrication process

4. RESULTS AND DISCUSSUONS

4.1 Analysis results

The below ANSYS images (Fig.5) shows the Von – Misses stress distribution and total deformation of excavator bucket teeth made up of Manganese Steel. It shows that the minimum and maximum Von – Misses stress distribution of 2.73×10^{-3} MPa and 0.2898 MPa respectively. It also depicts that the total deformation of an excavator bucket teeth made up of Manganese Steel. It shows that the minimum and maximum deformation of 0 &.0019 mm respectively.

The below ANSYS images (Fig.6) shows the Von – Misses stress distribution and total deformation of excavator bucket teeth made up of Chromalloy steel. It shows that the minimum and maximum Von – Misses stress distribution of 0.000207 MPa and 0.32699 MPa respectively. It also depicts that the total deformation of an excavator bucket teeth made up of Manganese Steel. It shows that the minimum and maximum deformation of 5.7152×10^{-5} mm and 0.00051437 mm respectively.

4.2 Heat treatment results

The following heat treatment tests were carried out on Manganese Steel and Chromalloy steel at PSG & Sons Charities Metallurgy and Foundry Division in Coimbatore. The following results were obtained from the above test which was carried out on Manganese Steel and Chromalloy steel. It shows that the excavator bucket teeth made up of Chromalloy Steel exhibits a maximum hardness value of 51 HRC respectively.

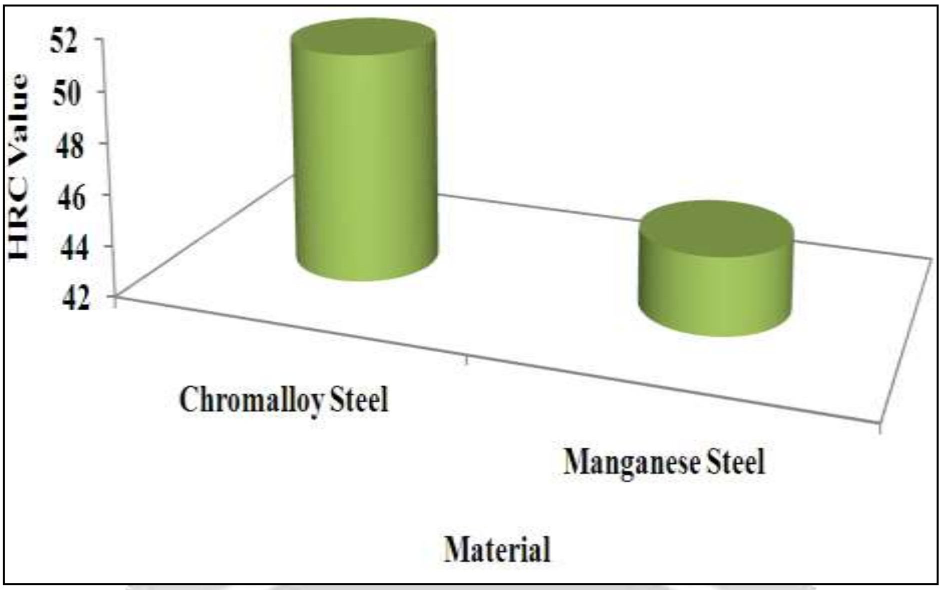

Figure 4 Effect of HRC values for different material

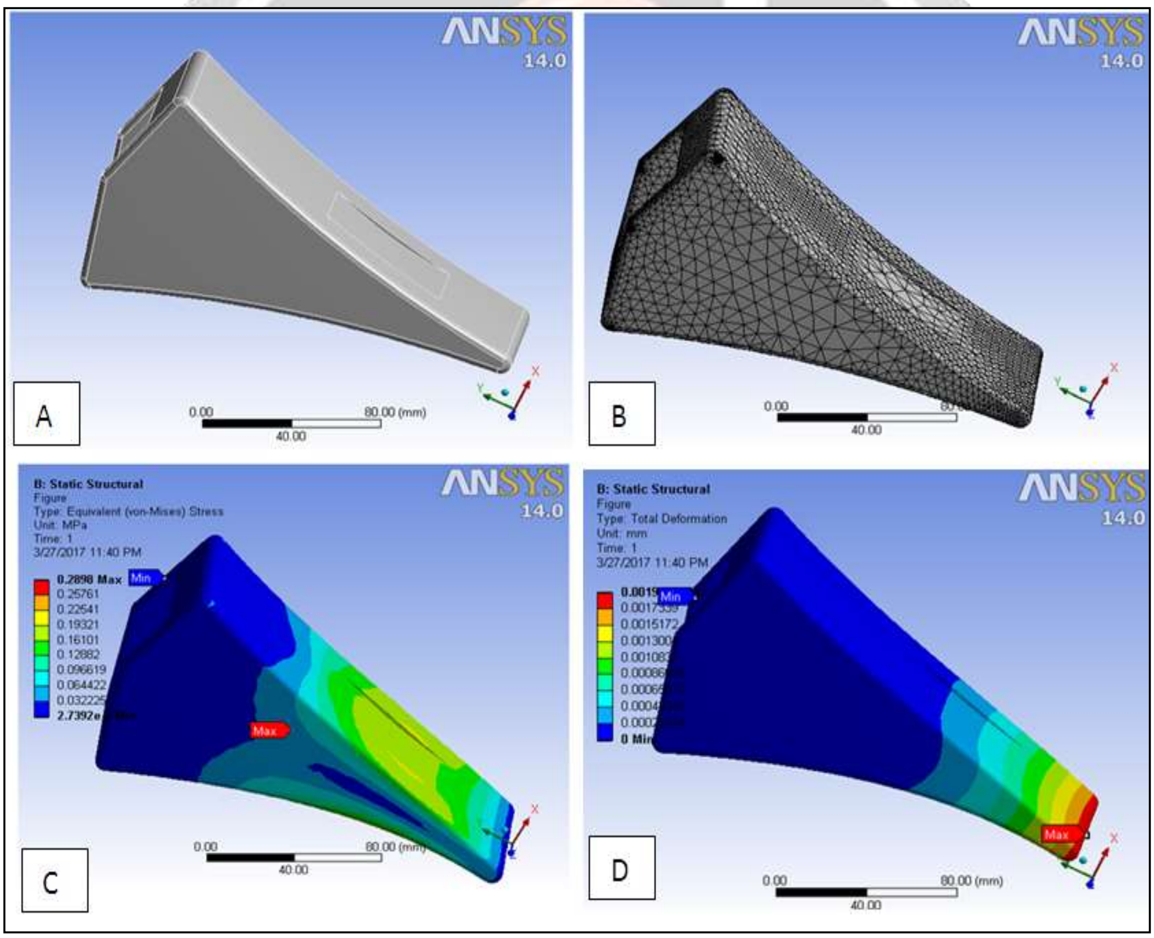

Figure 5 (A) 3D Model (B) Mesh model (C) Equivalent Von-Misses stress (D) Total deformation of Manganese Steel

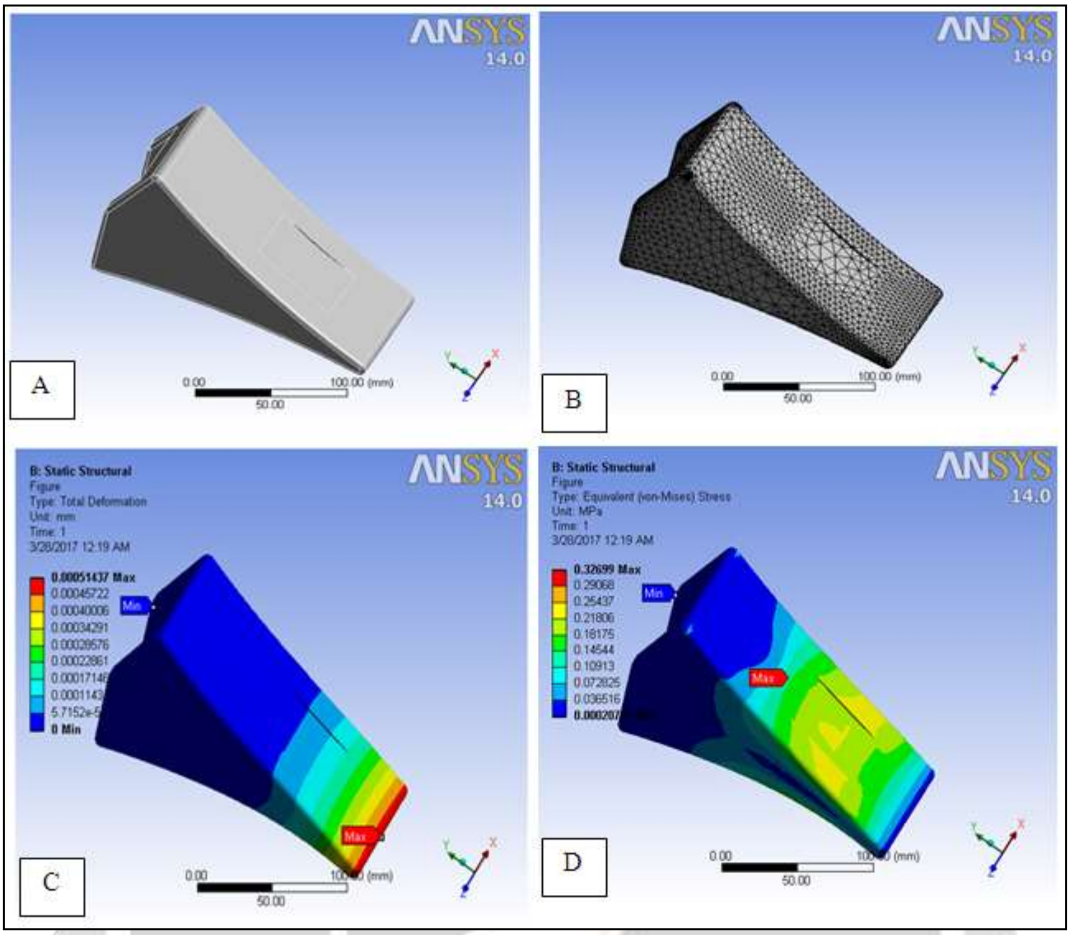

Figure 6 (A) 3D Model (B) Mesh model (C) Total deformation (D) Equivalent Von-Misses stress of Chromalloy steel

5. CONCLUSIONS

The following conclusions were made from the numerical analysis from ANSYS software and Heat treatment process.

- Excavator bucket teeth made up of Chromalloy steel exhibits a maximum Von – Misses stress distribution of 0.32699 MPa respectively.
- Excavator bucket teeth made up of Chromalloy steel exhibits a maximum deformation of 5.7152×10-5 mm respectively.
- Excavator bucket teeth made up of Chromalloy steel exhibits a maximum HRC value of 51 HRC respectively.

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