MODELING OF SOLID WASTE SHREDDING CUTTER USING FINITE ELEMENT METHOD

A thesis submitted

In partial fulfillment of the requirement for the award of degree of Master of Science in mechanical and industrial engineering (mechanical design)

By

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This is to certify that the thesis prepared by BETHELHEM H/ MICHAEL AYALKE entitled by Modeling of Solid Waste Shredding Cutter Using Finite Element Method that Assembled in Ethiopia and submitted in partial fulfillment of the requirement for the degree of Masters of Sciences (Mechanical and Industrial Engineering) complied with the regulation of the university and is intended to meets the accepted standards with to originality and quality.

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Declaration

I, the undersigned, declare that this thesis is my original work and has not been presented for any degree in any university and all the sources of materials used for the thesis have been fully acknowledged.

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Abstract

The solid waste disposal method is most challenging in Addis Ababa city. The most known disposal site in Addis Ababa is "Rappi" or "Koshe" which is in south west part of the City, 13 km away from the city center. The disposal method is traditional. However, the solid waste material is needed to cut and use for the recycling and reduction of the solid waste material; where we need modeling of solid waste shredding cutter. This thesis deals with modeling of solid waste shredding cutter by using FEM. One particular existing Solid Waste Shredder Cutter was Design and production of Plastic Shredder Machine. Machine was selected for the studying model 1 that is existing cutter and the others are modified models by increasing the number of blade and cutter thickness. Analytical analysis of distribution of contact cutting effect along the cutting direction of cutter caused by applied force was solved by using separation method based on models 1, 2, 3 and model 4 shredder cutters. The material is used for finite element model of cutter drawing using the CATIA software. Finite element simulation for contact force and von misses stress were carried out using CATIA workbench for the case of the structural analysis of cutter was performed by applying applied force. The contact force and Von Misses stress are calculated analytically where CATIA workbench results are presented in contour plot and numerically for four models. As force applied on Model 1,2,3 and Model 4 increases, Von misses stress increases, and deformation of cutter at tip also increased however, the concentration stress and deformation is better in Model 2 than the others models. Finally, stainless steel is recommended and selected because the stainless steel has good corrosion resistance and effective than Tungsten carbide. And model 2 is the deformation result and Von Mises stresses are better effective than the other models.

Key words: shredder cutter, blade number solid waste, CATIA, Analytical analysis, finite element method, contacts force.

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Contents

LIST OF FIGURES

LIST OF TABLES

Nomenclature

Kg	kilo gram
N	newton
M	moisture content
W	weight
d	weight
σ_e	von misses stress analysis
$\sigma_1 \sigma_2$ *and* σ_3	principal stress
S_y	yield strength
n	factor of safety
n	rotational speed
R_o	outer cutter radius
V_c	cutting speed vector
U	feed speed
m	meter
mm	mile meter
min	minute
s	second
F_t	tangential cutting force
F_d	deflecting force
F_1, F2, F3, F4	force components
µ=	coefficient of friction between solid waste material and cutter.

List of Abbreviations and Acronyms

ASATM	American Society for Testing Materials
CATIA	Computer Aided- Three Dimensional Interactive Application.
FEM	Finite Element Method
HSS	Higher carbon Stainless Steel
ID	Inside Diameter
MSW	Municipal Solid Waste
OD	Outside Diameter
3R's	Reuse, Recycle and Reduce
WC	Tungsten carbide

CHAPTER 1

1 Introduction

1.1 Background of the study

Nowadays, “Solid waste” is the term used internationally to describe non-liquid waste materials arising from domestic, trade, commercial, and industrial, agriculture and mining activities as well as from the public services. Solid waste comprises different materials such as vegetable waste, papers, glass, plastics, wood, yard clippings, food waste, radioactive wastes and hazardous waste. Solid wastes are all the wastes arising from human and animal activities that are normally solids and semi-solids in containers those are discarded. [1]

The environmental pollution which arises from waste of resources has become one of the major challenges of urban development [2]. The principle of “Harmlessness, Reduction, and Resource” states that the trend for the disposal of municipal solid waste is an inevitable. A proper Solid Waste Management Policy should be developed based on the principles of sustainable development country. Because the policy is vital not only for environmental sanitation and personal hygiene, but also it makes that the solid waste shall be recycled properly in order to upscale economy of the country. In recent years, in connection with expansion of urban population and increasing of city scale, serious problems caused to the city life increase gradually as a result of increase in garbage.

Figure 1.1 Solid Waste Generations in Addis Ababa city [4]

Figure 1.2 Reppi or "Koshe" solid waste disposal site Addis Ababa Ethiopia [4]

Even though there is solid waste in Addis Ababa, there is no standard methods to reuse, recycle and reduce the solid waste, which are known as the (3R's) methods. The problems have been created as a result of lack of the (3R's) methods in Addis Ababa. Therefore, it is crucial issue to create awareness of the people about the use of the (3R's) methods for solid waste as well as the use of the Shredder Machine that directly related to the Shredder Cutter. The figure below indicates solid waste pre-processing the most and the least favored step options of the solid waste disposal methods.

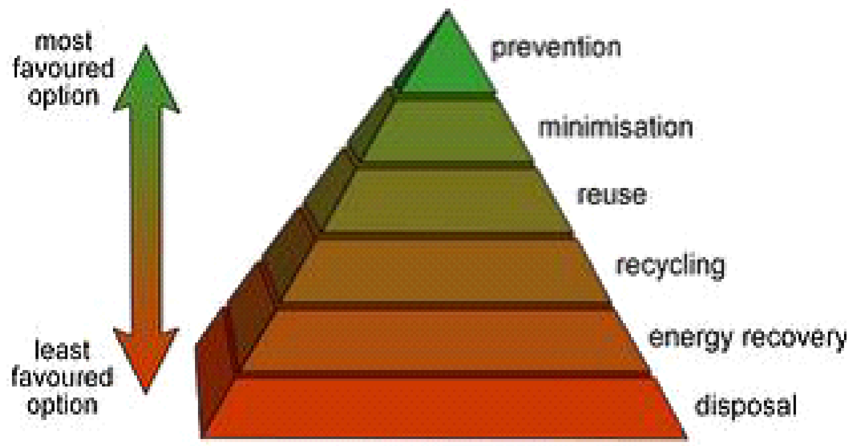


Figure 1.3 Waste Management Practices (source solid waste management) [1]

Rotary Tool or shredder cutter interacts with each other when crushing garbage. These interactions include friction, shear and extrusion. It is inevitable to encounter wood, food waste, papers, other harder trashes and soft rubbish. As a result, proper tool is needed to easily crush the solid waste into fine pieces. Therefore, effective solid waste cutting and crushing tools are required to solve the problems and to facilitate the recycling process of the solid waste. The cutting and crushing tools are the major key for optimizing the problems arises from the waste and to make the recycling process mechanism. The tools should be cost-effective, hard, and tough and wear resistance in order to decrease the depreciation percentage. [3]. Solid waste has its own property. Due to this, before commencing the cutting and crushing process of the solid waste it is very important to sort the solid waste materials time of trash materials according to their similarities and study the thorough chemical, physical and other properties of the solid waste materials. Then the proper cutting and crushing tools shall be applied to facilitating processing of the solid waste in order that the tools resisting corrosion rust and stress concentration for durability of the tools. The solid waste is a mixture of different materials such as moisture, compound of element. So, it has its own effect on cutting and crushing tool, cutting size and shape. This also needs proper cutting material selection regarding corrosion, rust, stress concentrate, tear and shear resistance, sharpening capacity and the other way need modified of technology by shape and size.

To this effect, assessment should be carried out in order to select the best materials to be used for fabrication of the cutting and crushing tool based on the chemical properties of the materials to be selected.

In this project, the study of the thesis focuses on better and technical cutting mechanism which is needed for quality requirements of the cutter and crusher tool modeling, modification and material selection. Stainless steel and tungsten carbide are selected because, the different waste material have their own physical and chemical property. So, thus two materials are good advising for the waste material cutting. Use two materials as an input to for finite elements analysis by comparing and contrasting the result in better material are selection. In addition, we have observed that the cutter modeling the effect on the size of grinding or crushing of the solid waste materials into fine pieces.

1.2 Statement of the Problem

According to the recent estimates—i.e. starting from 2005 until now, the population of the Addis Ababa City is estimated to be 3 million and this figure increases at the rate of 3.8% per year. Solid waste generation in the City of Addis Ababa is 0.4kg/c/day, collecting more than 200,000 tons each year and about 500tone/day. The source of the solid waste is generated from household, institutions such as commercial, factories, hotels and street sweeping. Of the physical composition of the total waste generated, 60% is organic, while 15% is recycled, and 25% others. [4]

Currently, cutter tool is available in different shape and size. The available cutter was simply cut the solid waste material but it does not have pulling the waste [17,18]. This problem identified when the shredding machine is at the operation time. It indicates all waste material were not equally fining or crushing. As a result, the solid waste cutter tool under consideration is the cutter which conveys the crushed waste and pulls the waste which is not crushed in order to be crushed and grind it into fine pieces. The cutter tool technology has modified model of the cutter from time to time in its shape and size.

Therefore, the thesis focuses on the modification the solid waste shredder in order to solve problems of the available cutter reducing the size of solid waste material and increasing the puling effect and cutting effect of the solid waste material. Therefore, the aim of this thesis is modeling of solid Waste Shredder Cutter.

1.3 Objective

This thesis has general and specific objectives which are:

1.3.1 General objective

To optimize and modeling of solid waste shredder cutter using finite element method analysis:

1.3.2 Specific objective

Specific objectives are:

- To select appropriate materials for specific solid waste shredder cutter:
- Determine weight of moisture content of the solid waste to demine the force applied on the cutter
- To estimate stress distribution on tip of cutter with different blade number:
- To estimate the deformation on tip of the cutter with different blade number:
- To modify the shredder cutter:

CHAPTER 2

2 LITERATURE REVIEW

2.1 Introduction

Solid waste material Cutter acts as a weapon in shredder machine, cutting blade is round-shaped blade with different cutting edges, given a hexagon-shaped hole or circular in the middle, mounted on the main shaft and main shaft move together. It used to cut, grind and fine pieces of the solid waste material. Tool material technology is advancing rapidly; enabling many difficulties to machine materials to be machined at higher fine or grind cutting solid waste materials with greater performance reliability. This thesis reviews the cutter tool material, what types of method to be used, force to be applied in the cutter and the result of the review discussion which are written in different journals and books.

The machine consists of motor, spur gear, bearings, structural frame, cutter and dual shaft. The machine frame is can be built using mild steel and High Carbon steel used for cutter tip preparation. cutters are mounted on two shafts, which rotate parallel driven by a spur gear. The power from the electrical motor is transmitted to cutter shaft through a gear drive or belt drive. Cut is made inside the chopping house that is hopper due to the effect of tensile, friction, and impact effect in cutting process.

Zhankuaz Z., et.al.[5] have been presented on mathematical model of tangential tensional stress in the edge of a circular saw blade tension by multi-spot pressure was established by theoretical analysis for the equality control of circular saw blade. The multi-spot pressure exerting tensioning processes was assumed to include three mathematical processes out of which was the one–spot pressure process; the process of elastic deformation of disk with a through-hole subjected to uniform radial compressive stress; and the stress superposition process. The objective of the study was to establish a mathematical model for tangential tensioning stress in the edge of circular saw blades tensioned by multi-spot pressure based on the theory of elastic machines and finite element method.

Priyanka P. and Roopesh T. [6]; have been presented during the machining process the circular saw undergoes various stresses because of the cutting forces generated, which affect the tool life. The project used Hyper Mesh Software method to reduce the stresses developed. This project involves the selection of an optimized saw out of three different saw blades (differ in design of type of slots cut) and calculating the stresses developed in the saw during cutting of four different specimens (differ in material). After comparing the results of stresses developed while cutting the four different specimens, maximum stress is calculated.

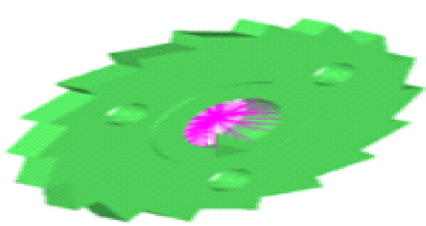


Figure 2.1: The circular saws blade [6]

Vusal Jivishov, Elchin Rzayevo) [7] have been presented finite element modeling of the machining process became possible and can be conducted with minimal costs. Finite element methods are tools used for predicting variables such as stresses, strains, temperatures and cutting forces during the machining process. The most significant input parameter for the simulation are the material flow stress data, also known as material model. This paper investigates the influence of material model on the modeling of cutting forces.

Zol Bahri Razali et.al [8]: - The study presented in this report is regarding on the conceptual design of the grater machine, which meant to shred food wastes into small and fine size particle. This study will focus on the waste management factor of the food waste produced in the home kitchen. The chosen material and blade design are to be evaluated for its characteristics and performance by using the FEM method. The analysis is taking all the constraints regarding the design as well as its advantages are to be considered in designing a new grating blade for the optimum end product making. This brings the meaning that the compact and small sizes design.

Where a. Collar diameter

b. Hook angle

c. Blade radius

d. Ramp angle

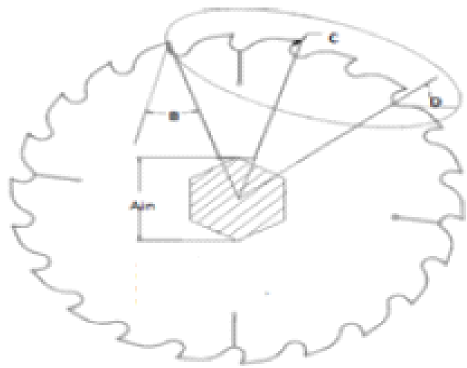


Figure 2.2 Typical nominal parameters of a typical circular cut-off cutting blade [8]

S. R. Tuprakay et .al [9] have been presented investigate the physical and chemical properties of solid waste produced by water tourism in Taling Chan Floating Market, Thailand. The results showed five types of waste; food, plastics, paper, leaves and foam. The largest component of all was food waste, which accounted for 53.95% [9] of total waste. Solid waste density was measured at 0.55 kg/m3 and the size of solid waste varied from 0.3–20 cm in width and 3–49 cm in length. The moisture content, combustion compound, ash, content of carbon, levels of hydrogen, Sulphur, nitrogen and oxygen accounted. Therefore, the solid waste from Taling Chan Floating Market was not suitable for combustive fuel due to its high moisture content. [9, 10]

Poggie, R. A., Wert, J. J. (1991). [11] and [12] According to; ASTM standard, the selection of stainless steels can be based on corrosion resistance, fabrication characteristics, availability, mechanical properties in specific temperature ranges, and product cost. However, corrosion resistance and mechanical properties are usually the most important factors in selecting a grade for a given application. Characteristics to be considered in selecting the proper type of stainless steel for a specific application include these: Factors in Selection of Stainless Steels

Corrosion resistance, Resistance to oxidation and sulfidation. Strength and ductility at ambient and service temperatures, Toughness, Resistance to abrasion, erosion, galling, and seizing Surface finish and/or reflectivity [11] and [12] Grade 420 stainless steel is a higher carbon version of 410; like most carbon and low alloy steels it can be hardened by heat treatment. It contains a minimum of 12 per cent chromium, just sufficient to give corrosion resistant properties. 420 have good ductility in the annealed condition but is capable of being hardened up to Rockwell Hardness 50HRC, the highest hardness of the 12 per cent chromium grades. Its best corrosion resistance is achieved when hardened and surface ground or polished. These properties are specified for bar product in ASTM grade 420 bar is the most commonly available.

Shi, J.; Liu, R.: (2004). [13] Factor selection of tungsten carbide tool Tungsten carbide (WC) powder, generally ranging in proportion between 70%-97% of the total weight, is mixed with a binder metal, usually cobalt or nickel, compacted in a die and then sintered in a furnace. These materials became popular during World War II, as they afforded a four- or fivefold increase in cutting speeds. Most carbide tools in use today are either straight WC or multi-carbides depending upon the work material to be machined. These tool materials are much harder, and chemically more stable, have better hot hardness, high stiffness, and lower friction, and operate at higher cutting speeds than HSS. They are more brittle and more expensive and use strategic metals W more extensively.

Albert J. Shih and Ryan C. McCall (2004). [15] Have been presented past decade, two popular blade materials used for waste cutting cutter have been the AISI 4340 and D2 tool steels. AISI 4340, heated-treated to about 40 Rc, was the blade material used in early waste shredding machines. The AISI D2 tool steel, denoted as D2 hereafter, can be air hardened to about 60 Rc and is more wear-resistant than AISI 4340. D2, although more expensive than AISI 4340, is one of the lowest cost tool steels and has become a popular choice of blade material for scrap waste shredding applications. The typical composition of D2 is 12% Cr, 1% Mo, 1% V, 1.5 % C, Fe accounting for the balance. D2 is a widely used tool steel and has been studied extensively. [14]

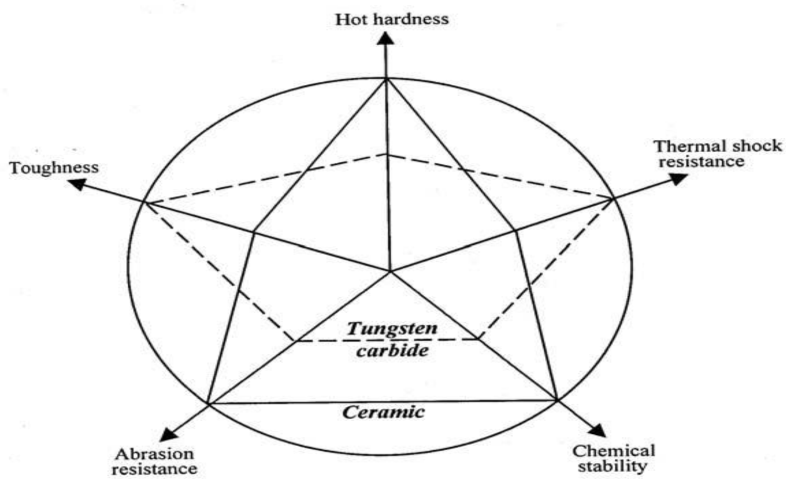


Figure 2.3 Important properties of tungsten carbide tools [16]

An analytical analysis expression that gives the desired unknown quantity at any location in the body, as consequence is valid for infinite number of location in the cutter. For comparison of von messes stress analysis between analytical and finite element method, the dimensions and specifications of cutter.

R. Tuprakay, et.al [19] have been presented the moisture content of waste depends on the initial waste composition, local climatic conditions, operating conditions, rate of decomposition and organic content. On exposure to water, the unit weight of any constituent absorbing water would increase (e.g. that of food waste, garden refuse, paper, yard waste) due to increased moisture content of the intra-particle voids. These increases in individual particle unit weight are added to the increase in bulk unit weight resulting from increased leachate in the void spaces between particles of waste to produce increases in the bulk unit weight of the waste mass. Therefore, older waste would be expected to have a higher bulk unit weight than fresh waste. Although there is limited field evidence to support this proposed mechanism, the data from investigations such as those described by provide some corroboration. The phasing of final cap construction also influences the evolution of moisture content changes. Addition of liquid wastes and re circulation of leachate will both have a fundamental influence on the magnitude and distribution of moisture contents, and hence on the magnitude and distribution of bulk unit weight.

Dr. Reinhart (2004) [20] to be conceder the chemical composition of solid waste material with and without waste. The general composition of solid waste can find from Appendix Table A is physical chemical compositions of solid waste vary depending on source and the types of solid waste. The nature of the deposited waste in a landfill will affect gas and leachate production and composition by virtue of relative properties of degradable and non-degradable composition, the moisture content and the specific nature of biodegradable element. The major physical characteristics measured in waste are density, size distribution of component and moisture content. Moisture content is defined as the ratio of weight water (wet water weight- dry water weight) to the total weight of the wet waste. Note dry wet is the weight of sample after drying at. Calculate the moisture percentage using the formula given below.

Moisture content (%)= $\frac{wet\ weight - dry\ weight}{wet\ weight} \times 100$ 2.1

$$M = \left(\frac{w-d}{w}\right)100$$

Where: - M= moisture content, %

W=initial weight of sample as delivered, Kg

d= weight of sample after drying at $105°C$, Kg

Ramadas Chennamsetti [21] have been presented using yield criteria the steps for a general structure are: Analyze structure to obtain stresses and principal stresses Obtain yields/ultimate via handbook (e.g., MIL HDBK 5, 17) or experimentation. Choose yield/failure criterion. Utilize calculated stresses in failure/yield criteria with associated material yields/ultimate. Theories of Failure.The Von Mises creation states the yield occurs when the principal stress satisfies the relation

$$\sigma_e = \frac{1}{2}[(\sigma_1 - \sigma_2)^2 + ((\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]^{1/2} = \frac{S_y}{n} \qquad 2.2$$

Where: σ_e is von misses stress analysis for structural effects

$\sigma_1 \sigma_2$ and $\sigma_3 =$ is the principal stress

S_y =is yield strength

$n =$ factor of safety

H. Ioras, T. Nicholls, et.al [22]. have been presented a major cutting characteristic of a shredder cutter is its cutting speed vector ($_{Vc}$) which is tangential to the cutting circle and perpendicular to the cutter radius, as shown in

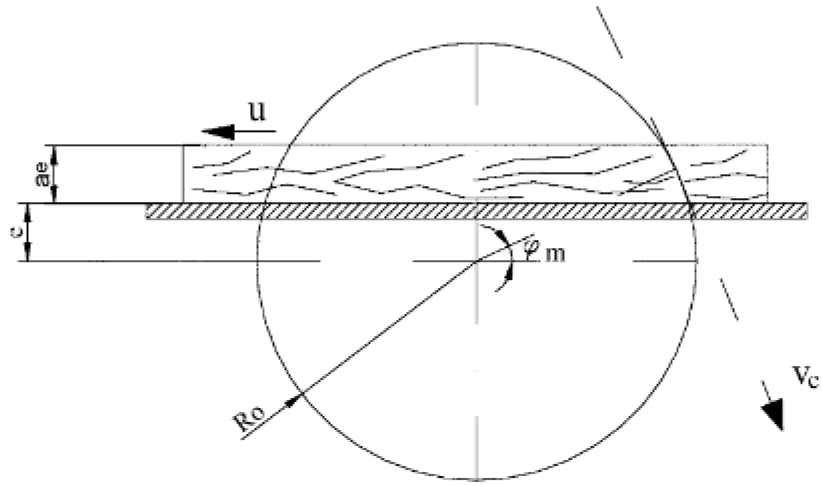


Figure 2.4 Peripheral velocity and cutting speed vector[22]

$V_c = \pi Dn/60$ [m/s] 2.3

Where

n = Rotational speed (1/min)

R_o = Outer cutter radius (m)

V_c =Cutting speed vector (m/s)

U=Feed speed (m/m)

φ_m = arc sin $e+a_e/2\ /R_o$

Such that the magnitude of the cutting vector V_c can be determined as follows:

Where D is the outer diameter of the cutter (m). The feed of material being cutter (u_n) for one revolution is given by:

$u_n = u/n$(m) 2.4

Where u feed rate [m/min], and therefore the cutting speed (V_c) is influenced by the density of the wood being sawn, and is normally in the range of 30 to 100 m/s. Furthermore, if the saw has z teeth then the feed per tooth (f_z) is given by:

$f_z = u_n /z = u/nz$ [m] 2.5

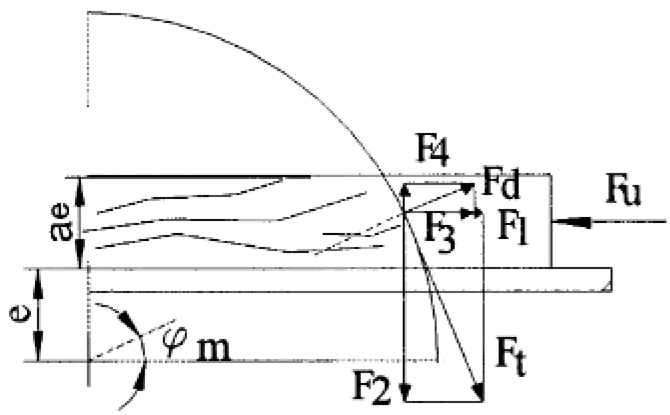


Figure 2.5 Force acting shredder cutters[22]

An earlier publication A fantasies 1968) identified two principle forces acting on circular cutter during use: the tangential cutting force (F_t) and the deflecting force (Fd). The tangential cutting force acts along the cutting speed vector (vc) while the deflecting force is perpendicular to this vector. These two forces oppose the force, which is applied to feed the material into the saw (Fu) see Fig. 2.6), and in this way they may be calculated Dogaru (1981)

F_t = tangential cutting force (N)

F_d = deflecting force (N)

F_1, F2, F3, F4= Force components (N)

μ= Coefficient of friction between solid waste material and cutter.

$F_u = F_1+F_3+ \mu (F_2+F_4)$ [N] 2.6

Where:

$F_1=F_t \sin \varphi_m$, $F2= F_t \cos \varphi_m$, $F3= F_d \cos \varphi_m$ and $F_4= F_d \sin \varphi_m=C_cF_t\sin \varphi_m$ 2.7

Where:Cc is the coefficient that is determined by the type of cutting and also by the wear of the cutting edge due to the working time Table 2.1). Rearranging Eq. [2.5] gives:

$F_u= F_t [\sin\varphi_m +\cos\varphi_m + \mu(C_c\, g \cos\varphi_m - C_c\, g \sin\varphi_m]$ 2.8

Table 2.1The cutting coefficient (Cc)

Cutting type	Working time (hours)			
	1	2	3	4
	Coefficient (C_c)			
Ripping	0.2	0.4	0.6	0.8
Cross cutting	0.4	0.6	0.8	1

Ajinkya S. Hande [23]. have been presented this is hand operated chaff cutter machine. Chaff cutters are meant for cutting all kinds of dry & green fodder into small pieces for cattle. These chaff cutters can chop the green or dry f Paddy, Grass, Groundnut etc. These machines are also useful for cutting, dry coconut leaves, Dairy Farms, and Jute Industries etc. where chopping is required. The advantages of the product are eco-friendly and maintenance is very easy.

Rodgers M. Hill [24] have been discusses about the three types of unique feature of cutter shredder designed this type of shear shredder makes it ideal for this one purpose. The second that same feature, rotor knives cutting against stationary knives on a center anvil, make it impractical for such materials as municipal solid waste, tires, "white goods", and other bulky waste. For those, the center anvil will result in a drastic reduction in capacity due to bridging of material on the anvil. Additionally, the nip angle, or line of attack of the cutters onto the material being shredded, is not sufficient to pull bulky items into the interface of the cutters.

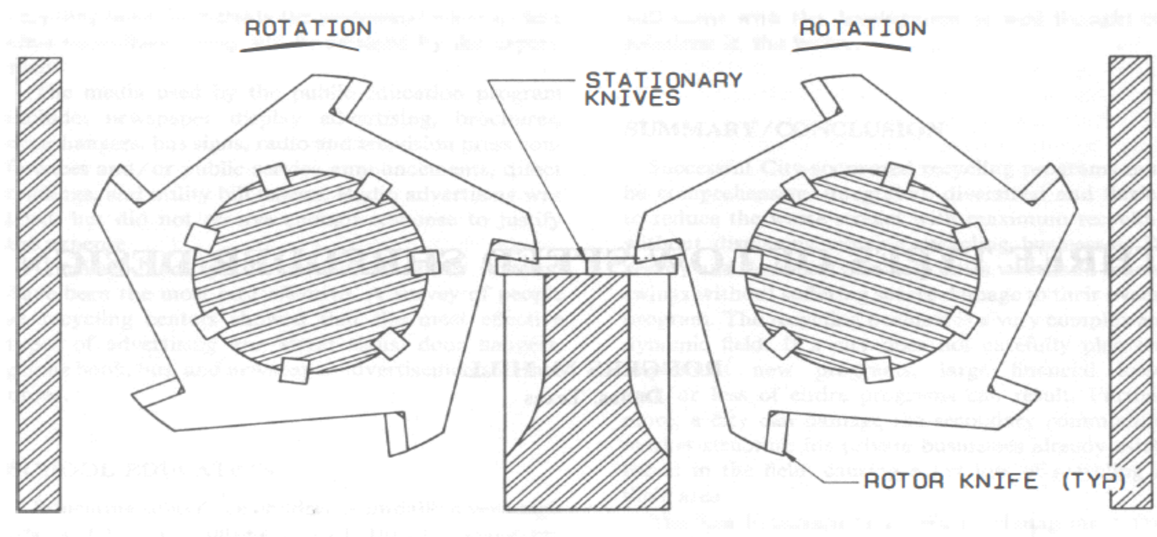


Figure 2.6 First shedder model cutters [24]

The first types of shedder cutter are two cutters are rotted easily the stationery knives and rotter knife type are worked together the above figure indicated this way of cutting system.

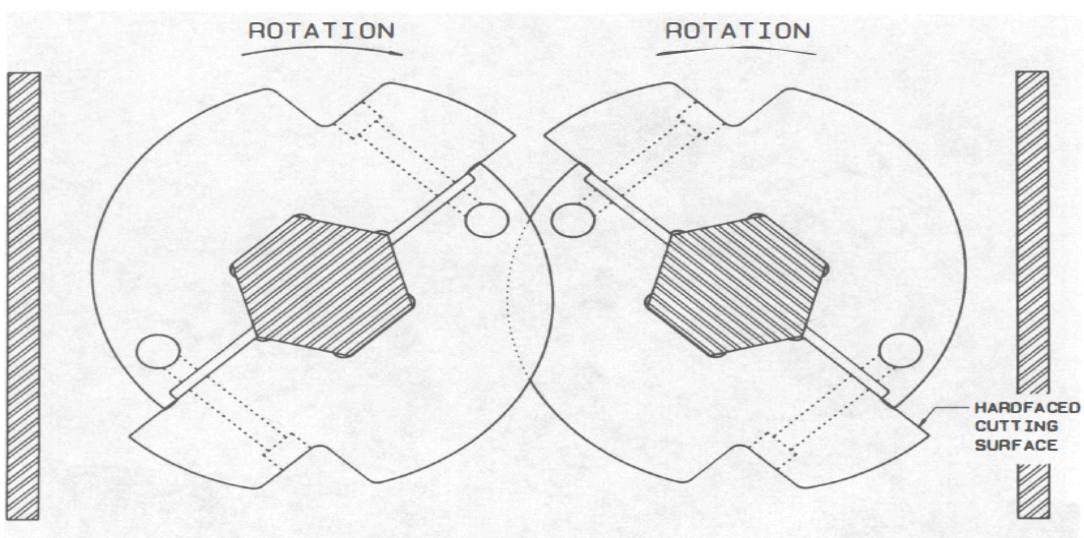


Figure 2.7 The second shedder type of cutter [24]

The third cutter design is below the figure this two features, has different shape and size are rotate and cut in different processing operations. Additionally, tires would still be free to bounce around on top of the rotating cutters; these feeders engage the tire carcass and feed it into the cutters at a feed rate less than the peripheral speed of the cutters. as the tires are fed into the cutting zone the cutters engage them with a true shearing action. it is not possible for the tires to be extruded through the intermeshed cutters.

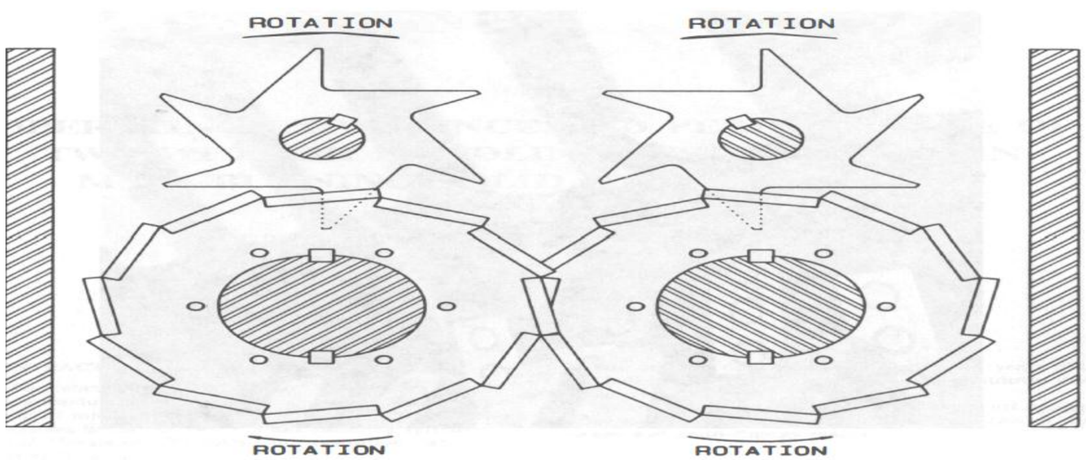


Figure 2.8 The third type shedder cutter [24]

Prof. S. Nithyananth et.al.(2014). [25] have been presented blade is positioned in between the crushing blade and powdering blade. Main purpose of this blade is to cut the waste material into small pieces. Here we used two chipping blades on the shaft at different angles. Length of the blade: 300mm Width of the blade: 60mm Sleeve radius: 35mm Shaft radius: 30mmPowdering blade This blade is used for powdering the agro-waste to get maximum fineness. This blade is placed is positioned at the lower most part of the machine. Length of the blades: 250mm Sleeve radius: 35mm Shaft radius: 30mm

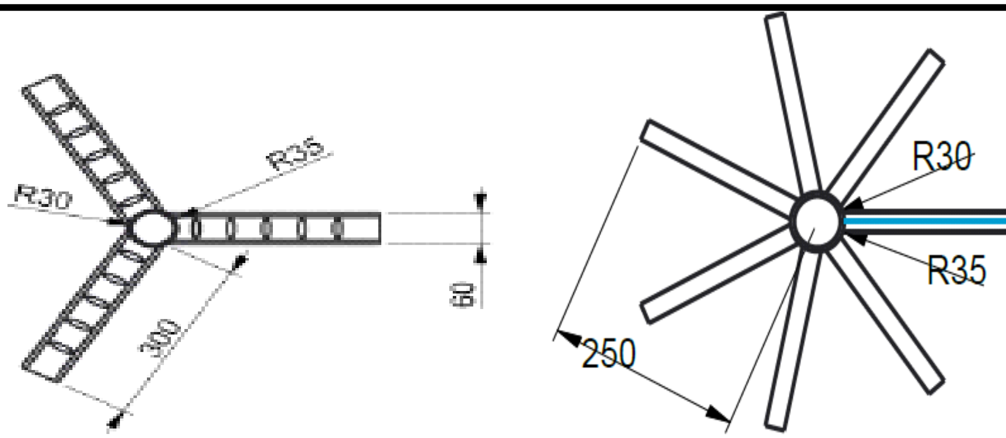


Figure 2.9 a) chipping blade b) powdering blade [25]

I.M.Sanjay Kumaret.al. [26] have been presented the cutter tip made from Tungsten carbide is a composite material manufactured by a process called powder metallurgy. The term "cemented" refers to the tungsten carbide particles being captured in the metallic binder material and "cemented" together, forming a metallurgical bond between the tungsten carbide particles and the binder (WC - Co), in the sintering process Cutter Specifications Outer diameter of cutter =150mm, Inner diameter of cutter= 32 mm, Number of teeth on cutter = 6 and Thickness of cutter = 25mm

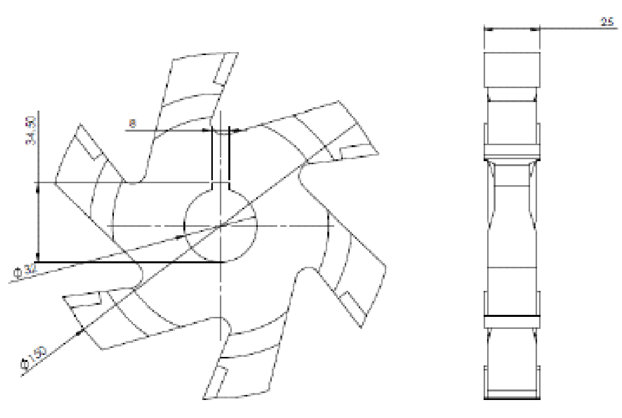


Figure 2.10 Agricultural waste cutters [26]

Naqib Daneshjo et.al [27] CATIA is widely used in all engineering sectors, particularly in the automotive and aerospace sector. CATIA, V5 VÁTI, Pro engineer, Solid Works and systems are dominant. CATIA is a comprehensive tool for the design in various industries such as mechanics, mechanical engineering, aerospace, automotive and consumer goods and so on. PLM (Product Lifecycle Management) is used to include all segments of the global aviation, aerospace and defense companies from civil and military aviation for satellites and launch satellites into space. In industries where there is no possibility to forward it as read, use and rely most companies implementing the aviation system to CATIA and other engineering solutions. Engineering Analysis: Applications are mainly intended for preliminary sizing accuracy of the proposed design engineers to quickly and provide available information on the stability of the structures directly in its creation. CATIA Workbench was chosen as the FEA software package because of its ability to accept a 3D computer aided design (CATIA) model. The program also allows for the accurate placement of contact force, in addition to the modeling of contact surfaces.

Garrett C. Fitzgerald [29] High speed hammer mills generally are available with higher capacity that of the low speed shredders designed specifically for MSW. The hammer mills range from less than 1 ton/hour all the way up to 300 tons/hour at maximum operation capacity. The hammer mills that are rated to 300 tons/hour typically are not operated at such a high rate in order to minimize excess wear and maintenance. Low speed shredders are limited in capacity by their rotor speed and tolerances. The maximum output is defined by the volumetric displacement between the cutting surface and the rpm of the shaft. These devices are available in sizes up to 100-200 tons/hour at maximum rating, but are more commonly designed for between 20 and 70 tons/hour. The lower capacity of shear shredders can presumably be increased by creating larger machines based on the same size reduction principal. The manufacturing of such machines is limited by the current low demand for such high throughput applications. In the event that pre-shredding MSW becomes common practice these machines will likely be scaled up in capacity to meet the customer's needs.

CHAPTER 3

3 MATERIALS AND METHODS

3.1 Materials

We have conducted project of the thesis using specifications of Models. Specifications of the model have been labeled as "Specification for model 1" which is the recently available model cutter. Design and production of plastic shredder machine [17]

Specification available cutter

1. Inner diameter circular 40 mm
2. Cutting blade = 4
3. Thickness =10 mm
4. Tip cutting edge normal flat sharp
5. Overall length 850mm, overall height 570mm and overall width 300mm
6. The material of cutter Stainless steel

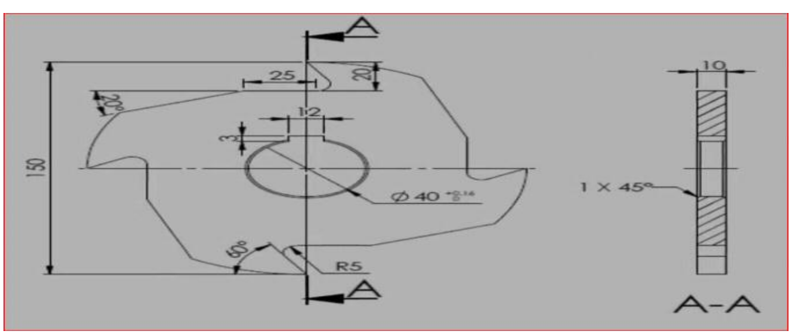


Figure 3.1 Design and production of plastic shredder machine cutter model 1 [17]

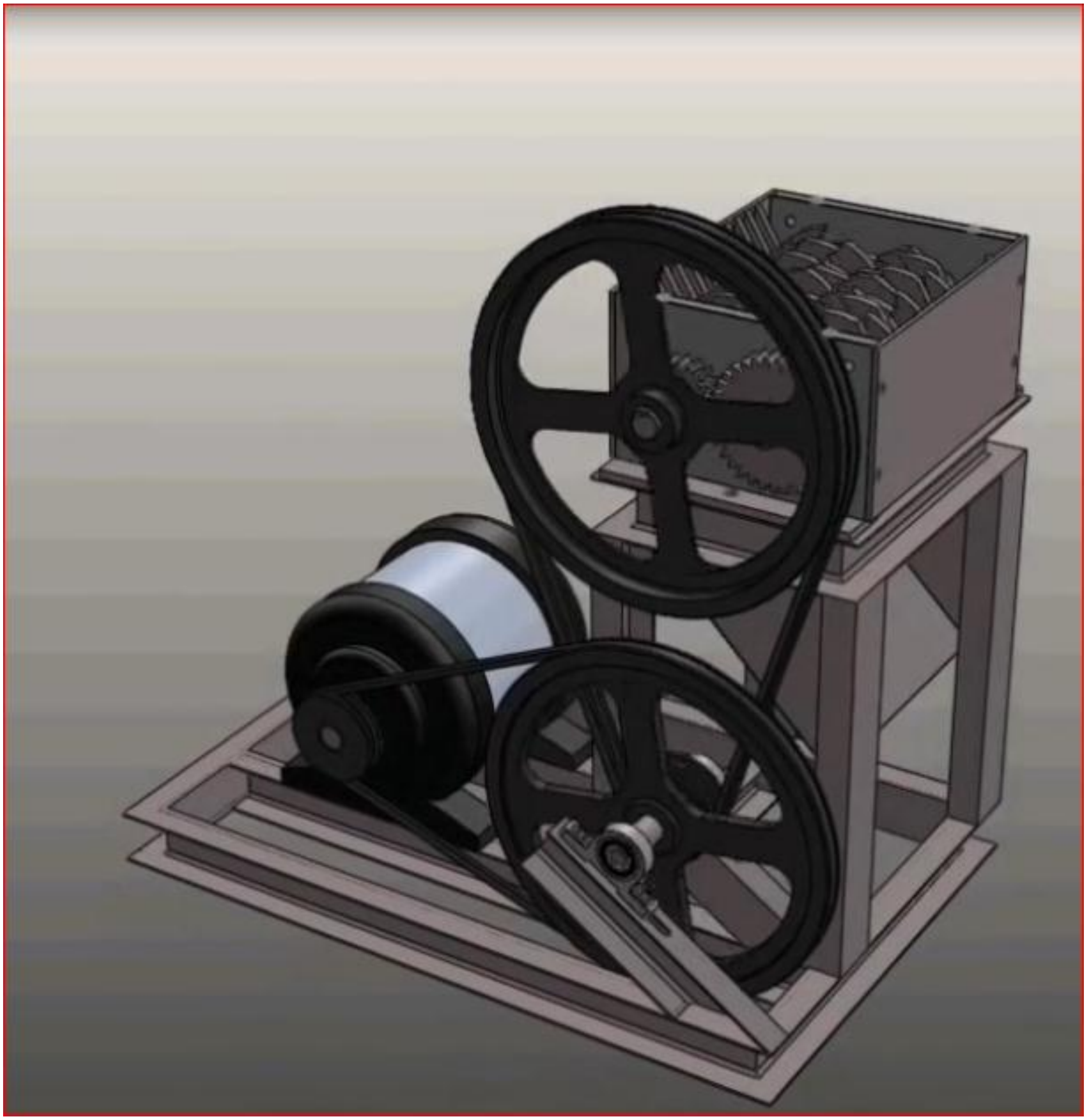


Figure 3.1 Design and production of plastic shredder machine [17]

3.2 Material Selection

In this thesis work the selection of material was performed based on material data book in the literature.the parameter of the material selected is from the different literal book information. the material property of cutter selected by different way that is: -

- Durability of the material
- Corrosion resistant of the material.
- Cost of the material
- Physical property of the material
- Mechanical property of the material

The parameters as indicated in table 3.1 and table 3.2. The specification and the properties of materials are also subjected in appendix A1.

Table 3.1 Stainless steel (HSS) material properties (from material data book) [28]

Material	Poisson's ratio	Density (kg/m^3)	Young's modulus (E) GPa	Yield strength (MPa)	Tensile strength (MPa)	Thermal expansion (µ/K)	Fracture toughens (Mpa)
Stainless Steel (Grade 420 ASTM)	0.31	7700	200	1365	1580	10.8	3.28

Table 3.1 represented the Stainless steel grade 420 ASTM materials property applied for model 1 and model 2 of cutter for the use of finite element analysis method. The all data we get from the data book as a detail.

Table 3.2Tungsten Carbide (WC) material properties (material data book) [28]

Material	Poisson's ratio	Density (kg/m3)	Young's modulus (E)GPa	Yield strength (MPa)	Tensile strength (MPa)	Thermal expansion (μ/K)	Fracture toughens (Mpa)
Tungsten Carbide (WC)	0.22	15.9	720	550	6833	5.5	3.8

The above tables 3.1 as indicate the Tungsten Carbide (WC) materials property applied for model 1 and model 2 of cutter for use of finite element analysis method. The all data we get from the data book as a detail.

3.3 Methods

Two methods have been used in this paper. The first one is Experimental Method and the second one is analytical method. Both methods are determining the resultant force applied in the cutter and von messes stress of the material.

3.3.1 Experimental test of Moisture Content of Different Solid Waste Materials

The experimental test of moisture content is being measured by oven; this oven machine works at a temperature of 105^{0}C constantly without variation in temperature even though there is increase time. The use of oven machine is in order to reduce the moisture content of the materials easily. Then to know how much is the weight of the wet and dry. Finally, it determines the maximum weight or the force applied on the cutter. It is directly related to waste materials cutting effect of the cutter. According to equation 2.1 it is possible to determine appropriate moisture content percentage of the solid waste and we get the result of weight of waste with moisture content. To measure the moisture content, first select the waste materials of food waste, wet paper, dry paper, plastic material, grass and wood and yard waste which we used for experimental purpose. Each waste material stays in the oven at maximum for duration of one day, except plastic waste material and we measured the other materials within an interval of one hour.

3.3.2 Experimental procedure steps

1. First Step: collect the solid waste from environmental conditions of the waste material, food waste, wet paper waste, dry paper waste, plastic waste, yard waste and garden fuse waste and material those we have taken.
2. Second Step: measure the solid waste material in gram by beam balance that the sampling waste are food waste 0.5Kg, dry paper waste 0.25Kg, wet paper 0.5Kg, plastic waste 0.25Kg, wood and grass 0.5Kg and yard waste 0.5Kg.
3. Third Step: adjust the oven at a constant temperature (equal initial and final temperature) of 105^0C which is measuring level.
4. Forth Step: put waste material into the oven and observe the effect using time function.

5. Fifth Step: measure the waste materials after 1 hr. for one day except plastic waste that is limiting time.

6. Finally, we get the result of dry-moisture content weight of the waste material at time interval of an hour.

Table 3.3 Use of sampling waste material per hours (hr.) and mass in Kg

Sample waste materials	Time (hr.) stay in oven	Mass (kg)	Weight (N)
Food waste	24 hr.	0.5	4.905
Wet paper	24 hr.	0.5	4.905
Dry paper	24 hr.	0.25	2.4525
Plastic	4 hr.	0.25	2.4525
Garden Fused Waste	24 hr.	0.5	4.905
Yard waste	24 hr.	0.5	4.905

Table 3.3 represents weight of moisture content of the waste (N) and initial mass of sample of waste material. Experimental condition uses the initial mass of the waste material from above table 3.3. The sample used for the experimental condition and from the above sampling initial weight of the moisture content of solid waste material is 2.4525 N for dry paper and plastic waste materials, while for all the samples Food waste, Wet paper, Garden Fused Waste and Yard Waste initial weight of the moisture content of solid waste material is 4.905 N; that is the result we get from the sample we used for the experiment. The

following tables represent moisture content result of the solid waste particles. According to equation (2.1), we can calculate the moisture percentage using the formula given below.

3.4 Assumptions for Applied Force Analysis

The major means of controlling the total weight determination for FEM analysis is used for this comparison assumption of the experimental result. A typical range of moisture content is 20 to 40%. This represents the extremes wastes in during an arid climate and in the wet season of a region with a high precipitation. However, values greater than 40% are not uncommon. [19] So, from the above explanation, in this thesis experimental analysis of weight of the moisture content result of the waste is taken between 20 to 40%, percentage.

3.5 Analytical Analysis and Conditions

An analytical analysis expression that gives the desired unknown quantity at any location in the body, as consequence is valid for infinite number of locations in the cutter. For comparison of Von Messes Stress Analysis between analytical and finite element method, details of the dimensions and specifications of cutter has been described above. Dimensions and specifications of the modified model cutter is taken from existing and which is used only for cutting purpose; as per [17]. This maximum force had been applied to all models of the cutter. We used stainless steel and tungsten carbide for all cutter models.

3.6 Analytical Analysis of Von Misses Stress for Structural Effect

The maximum distortion energy theory, also known as the von misses theory, was proposed by M.T.Huber in 1904 and further developed by R.von Misses (1913).In this theory failure by yielding occurs when at any point in the body, the distortion energy per unit volume in a state of combined stress becomes equal to that associated with yielding in a simple tension test is this gives calculate from equation 2.2 . this thesis concerned about von misess stress and the deflection of the cutter.so, this theory is need to this work.

The Von Misses creation states the yield occurs when the principal stress satisfies the relation

$$\sigma_e = \frac{1}{2}[(\sigma_1 - \sigma_2)^2 + ((\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2]^{1/2} = \frac{S_y}{n}$$

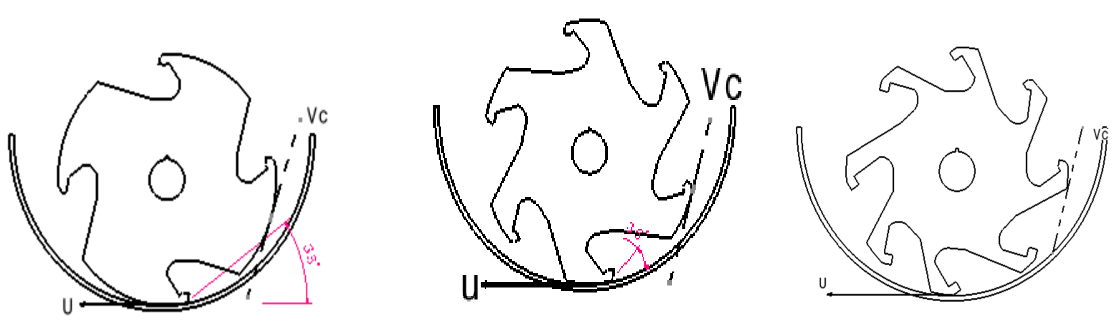
Where: σ_e is von misses stress analysis for structural effects

$\sigma_1 \sigma_2$ and $\sigma_3 =$ is the principal stress

$S_y =$is yield strength

$n =$ Factor of safety

According to the literate review [20] a major cutting characteristic of a shredder cutter is its cutting speed vector ($_{Vc}$) which is tangential to the cutting circle and perpendicular to the cutter radius, as shown in the figure below.



a) Model 2 b) model 3 c) model 4

b) Figure 3.2 Peripheral velocity and cutting speed vector

Such that the magnitude of the cutting vector V_c can be determined as follows:

$V_c = \pi Dn/60$ [m/s]

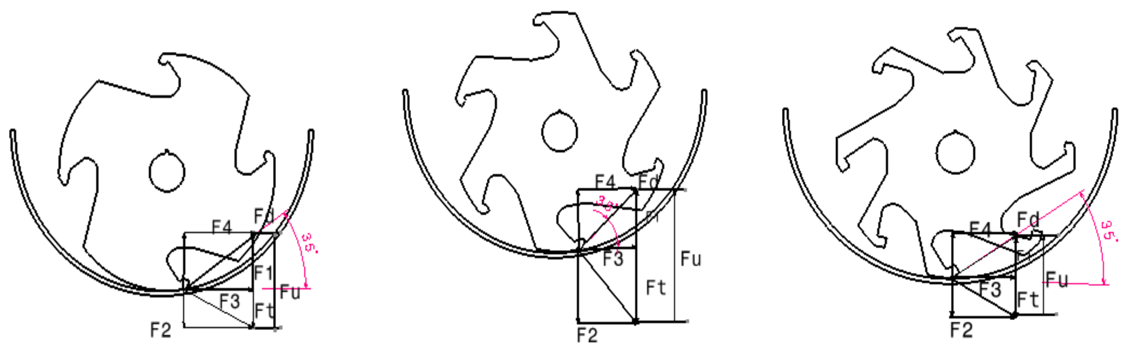
Where D is the outer diameter of the cutter (m)

The feed of material being cutter (u_n) for one revolution is given by:

$u_n = u/n$(m)

Where u Feed rate [m/min], and therefore the cutting speed (V_c) is influenced by the density. Furthermore, if the saw has z teeth then the feed per tooth (f_z) is given by: $f_z = u_n /z = u/nz$ [m]

In this paper more concerned about at the cutting and pulling effect area of the cutter. That is the tip of cutter at the orientation 35^0. This is modified area that is effective pulling and cutting effect of the waste material at 10mm x 10mm x 25mm and the filet radius 5mm x 45^0 on the tip. The total force applied on the cutter was get from the calculation of the waste weight that 905N. The force or weight calculation is detail discus chapter four. This force distributes in the cutter. That is detail shown force distribution on the cutter show below the figure 3.4.



c) Model 2 b) model 3 c) model 4

Figure 3.3 Force acting shredder cutter

Thus the above picture is illustrated the force applied on the cutter tip. All the total force distributes on the cutter indicated. For all models are the force applied tangents to the cutter. Maybe the shredder machines have screener or not so, the cutter oriented at angel of 35^0

$F_u = F_1 + F_3 + \mu\,(F_2 + F_4)$ [N]

Where:

$F_1 = F_t \sin\varphi_m = 360.255N$

$F_2 = F_t \cos\varphi_m = 514.493N$

$F_3 = F_d \cos\varphi_m = 102.898N$

$F_4 = F_d \sin\varphi_m = C_c F_t \sin\varphi_m = 72.05N$

Where:Cc is the coefficient that is determined by the type of cutting and also by the wear of the cutting edge due to the working time from Table 2.1.

$F_u = F_t\,[\sin\varphi_m + \cos\varphi_m + \mu(C_c\,g\cos\varphi_m - C_c\,g\sin\varphi_m\,] = 905N$

The total force that is 905N come the calculation of the moisture content of the solid waste. We get from the experimental result. Consider of sample size of solid waste material. If you need the detail result you get in the chapter four.

CHAPTER 4

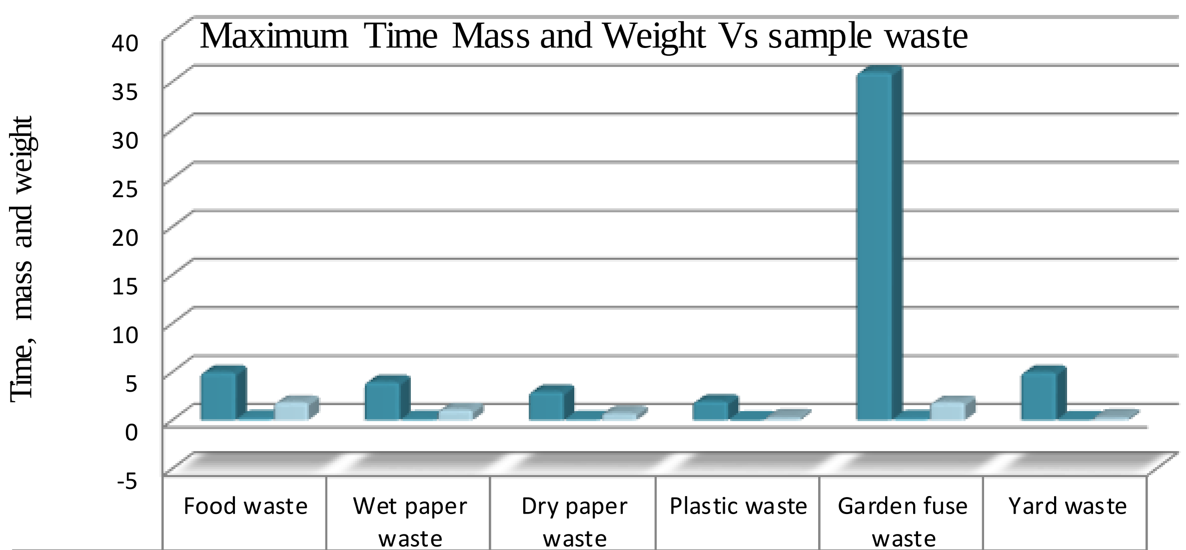
4 Result and Discussion

4.1 Experimental Result

In this chapter experimental method and computerized method analyses result have been included. When we see result of the experimental sample of the solid waste of food waste, wet and dry paper, plastic waste, garden fuse waste, and yard waste are experimental describes moisture content difference of the materials before and after we conducted the experiment. The initial weight of food waste is 4.905N and the final weight of food waste is 2.48710968N. The initial weight of the wet paper is 4.905N and the final weight of the wet paper is 1.0963656N. The initial mass weight of the dry paper waste the initial weight is 2.4525N and the final weight of plastic waste is 0.736731N. The initial weight of plastic waste is 2.4525N and the final mass and weight of plastic waste is 0.327654N. The initial weight of garden fuse is 4.905N and the initial weight of garden fuse is 1.872533N. The initial mass and weight of yard waste is 4.905N and the final weight of yard waste is 0.320787N. All of the above results are compared and contrasted on the basis of the previous work appendixes A2. From the above results we can draw conclusion that as the moisture content of the waste materials which means the force applied by the waste materials during crushing, cutting and grinding them into fine pieces. These all results were obtained from the sample size indicated in the above table. But if we assume that hopper of the crusher may hold (contain) 100 Kg at a time, the force to be applied on the cutter is 905N. This has been explained as follows.

Table 4.1 Use of sampling waste material per hours (hr.) initial and final mass in Kg and weight N

Sample waste materials	Time (hr.) stay in Oven	Initial Mass (Kg)	Initial Weight (N)	Final Mass (Kg)	Final Weight (N)
Food waste	24hr	0.5	4.905	0.253528	2.48710968
Wet paper	24hr	0.5	4.905	0.11176	1.0963656
Dry paper	24hr	0.25	2.4525	0.075	0.736731
Plastic waste	4hr	0.25	2.4525	0.0334	0.327654
Garden fuse	24hr	0.5	4.905	0,19088	1.872533
Yard waste	24hr	0.5	4.905	0.0327	0.320787



	Food waste	Wet paper waste	Dry paper waste	Plastic waste	Garden fuse waste	Yard waste
Time(hr.)	5	4	3	2	36	5
Mass(kg)	0.19191	0.11176	0.0751	-0.0334	0.19088	0.0327
Weight(N)	1.8826371	1.0963656	0.736731	0.327654	1.872533	0.320787

Figure 4.1 Sample waste mass vs weight moisture content

Figure 4.1 Graph represent of the maximum weight, mass and time all sample solid waste material with in a time interval this result to get from appendix table A3, A5, A7, A9, A11 and A13 this indicate how much weight or mass moisture content in the sample solid waste. The above bar graph shows results of all a sample size solid waste weight within observation of one-hour interval. It illustrates that the weight of the sample decreases as time increases which is as the duration of time the sample stays in the oven of constant temperature, weight of the sample decreases as time increases; because the moisture of the waste material escapes from the waste through evaporation. This results in reduction of moisture content of the waste. And selected the final mass and weight of the all a sample size solid waste as its moisture content is between 40% which means the ideal moisture content for effectiveness of the cutter performance. From the graph orange color represents maximum time of the all sample size solid waste material and yellow color indicates maximum mass of the all sample size solid waste material then the green color represented the maximum weight as time function increases within an interval of one hour.

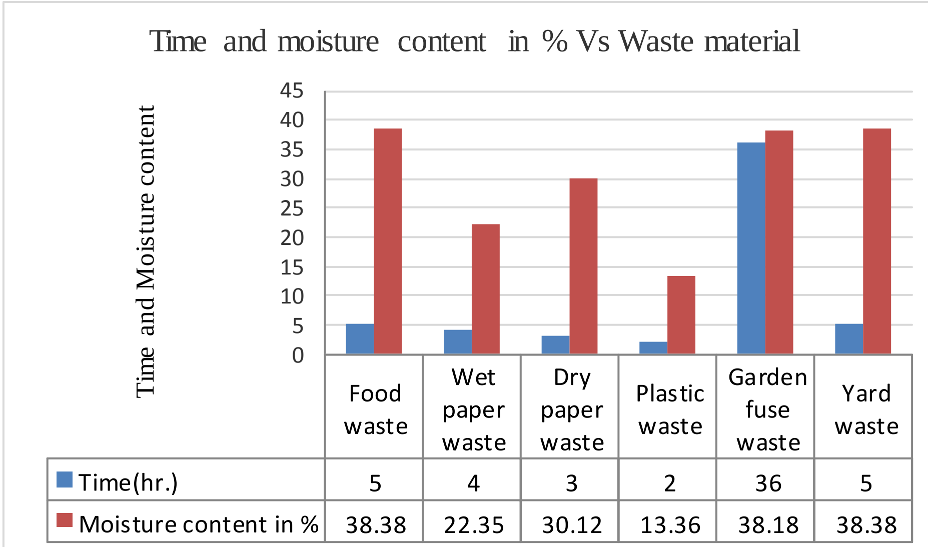


Figure 4.2 The maximum moisture content the sample waste

Figure 4.2 Graph represents the maximum moisture content of the all sample waste test result. Which are food waste, wet and dry paper waste, plastic waste, garden fuse waste and yard waste all are in percentage the experimental result get from appendix table A4, A6, A8, A10, A12and A14 this indicate how much moisture content in the sample solid waste. As we observe from the graph, at un hour the moisture content of the sample waste results. Which is less than 40% so, (the possible moisture content to for starting using the cutter to grind the food waste into fine pieces). This means it is possible to start the work but the most ideal moisture content for operation of the cutter is 20%. When cutting of solid waste material, by cutter the moisture content better indication easily cutting of material.

Table 4.2 summery of the total waste component weight

Component	Mass (Kg)	Weight (N)
Food waste	15	29.998
Wet and dry paper waste	5	14.034
Plastic waste	6	24.00
Yard waste	70	14.98
Garden fuse waste	4	821.59
Total	100	905

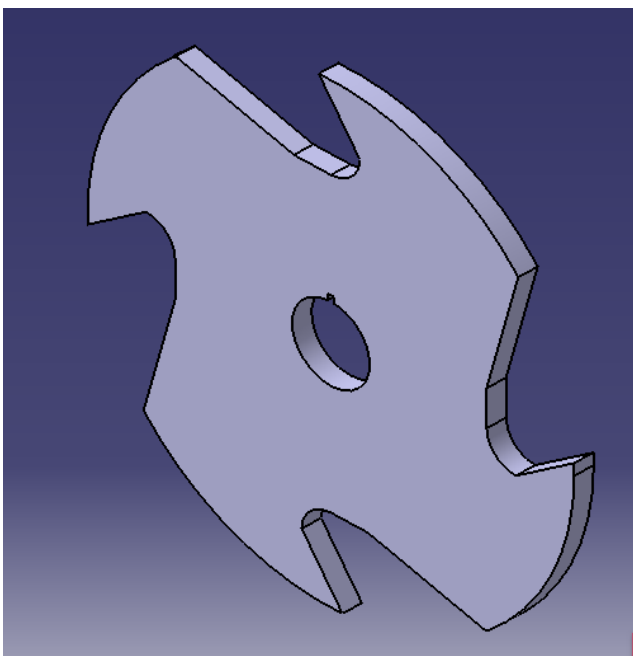
This table 4.2 explains that the major components of the waste materials are Food waste, Wet and dry paper waste, Plastic waste, Yard waste, Garden fuse waste and Garden Fuse Waste. Therefore, the above results were obtained from Literature Review in case of Addis Ababa, Ethiopia waste disposal data. From the data, we observe that when the total mass of the waste 100 Kg, the force to be applied on the cutter is 905 N on the bases that the hopper of the cutter can hold 100 Kg at a time.

4.2 Finite Element Methods

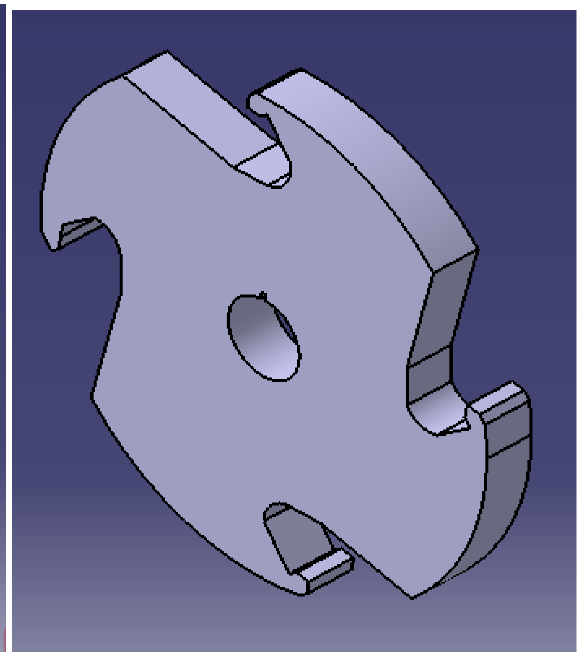
The finite element method is numerical analysis technique for obtaining approximate solutions to a wide variety of engineering problems. Because of its diversity and flexibility as an analysis tool, it is receiving much attention in almost every industry. In more and more engineering situation today, we find that it is necessary to obtain approximate solutions to obtain than exact to closed solution. The finite element method has become a powerful tool for the numerical solutions of a wide range of engineering problems.

4.3 Modeling solid waste shredder cutter

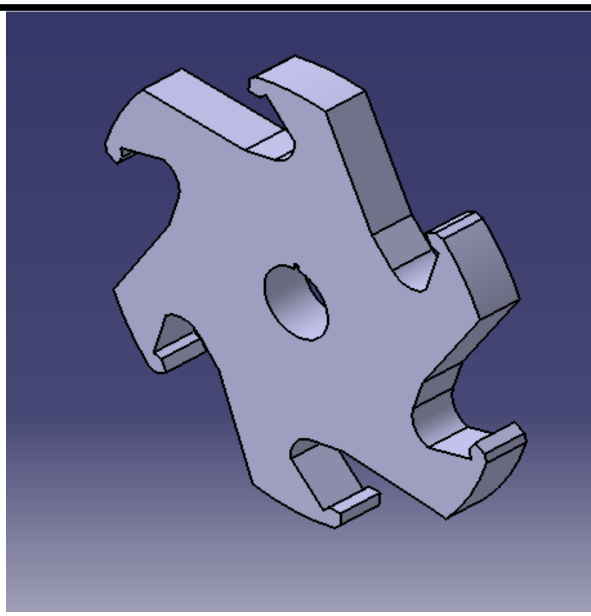
The model made by using the CATIA software. The model consists of exists cutter that is model 1 model 2 cutter blade 4, model 3 cutter blade 6 and the model 4 cutter blade 8. thus models cutters as shown below figure 4.1 a) model 1 cutter and b) model 2 cutters c) model 3cutters d) model 4 and detail drawing attached back of the page.

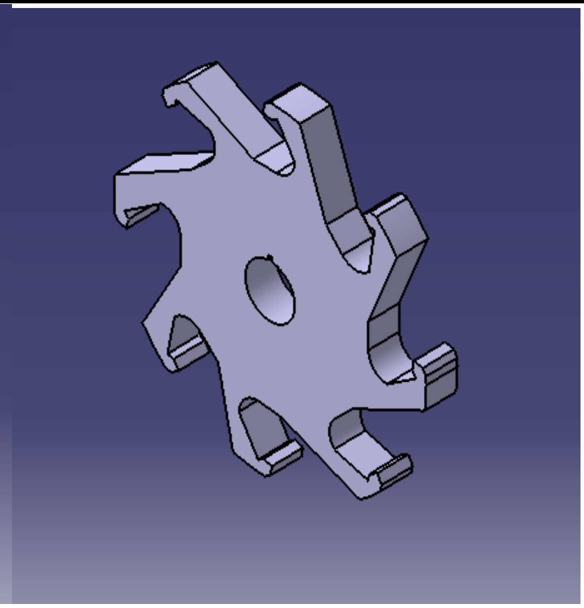


a) Model 1 existing cutter



b) Model 2 blade 4 cutter





c) Model 3 blade 6 cutter d) Model 4 blade 8 cutter

Figure 4.3 model a) existing cutter model b), c) and d) is modified cutter

4.4 Defining Material Properties of Study

The cutter is grade 420 stainless steel. It is a higher carbon version of 410 ASTM A276 and tungsten carbide (WC) ISO standard. These tool materials are much harder, and chemically more stable, have better hot hardness, high stiffness, and lower friction. Both material are good thermos physical characteristics have an isotropic elastic behavior, whose thermo-mechanical characteristics adopted in this simulation in the contact pressure and von misses stress analysis of the two parts are recapitulated in Table 3.2 and Table 3.3. The required material properties are added into the software by using the tribo material properties. Then the next step is to enter the Young's Modulus and Poisson's ratio and density of the cutter material that have been used for analytical calculation in the previous chapter. This can be done by selecting the Engineering Data from the analysis table of the CATIA Workbench and inserting the corresponding values.

Table 4.3 For model 1 and model 2 cutter WC material applied

Material	Tungsten Carbide
Young's modulus	7.2e+011N_m2
Poisson's ratio	0.22
Density	15.9kg_m3
Coefficient of thermal expansion	5.5e-006_Kdeg
Yield strength	5.5e+008N_m2

Table 4.4 For model 1 and model 2 cutter HSS material applied

Material	Stainless Steel
Young's modulus	2e+011N_m2
Poisson's ratio	0.31
Density	7700kg_m3
Coefficient of thermal expansion	1.08e-005_Kdeg
Yield strength	1.365e+009N_m2

4.5 Mesh Generation

The mesh with the default settings is not adequate to get the accurate results. In this analysis, cutter was finely meshed with "Sizing" option in menu. The element size was chosen to be 2mm and cutter contact surfaces were refinement. The figure appendix A 15 shows the meshed assembly according to the given mesh size value. For tungsten carbide and stainless steel material applied in to model 1, model 2, model 3 and mode 4 node and element value 296834, 290756,276201 and 280408 nodes and 182624, 174215,167457 and 171560 elements respectively. For both materials applied the same value of node and element value for all models. Appendixes A15 are shown the mesh generation of all cutters models.

4.6 Boundary Conditions and Applied Loads to Structural Analysis

Here, the displacement in the x and y direction of the outer round faces of the cutter are arrested, so given the value as zero. At the same time, z direction displacement given as free, for allowing the movement of cutter only in the z direction. Then displacement in the x and y direction of the outer and inner round faces of the cutter made free. At the same time, z direction displacement is arrested, so given the value as 905N, for allowing the movement of cutter in the x and y direction. The variable force 905N is applied in the edge face of the cutter. It represents the result of applied forces at the direction of, and for model 1 and 2 respectively for material of WC and stainless steel material. Appendixes A16 are shown the boundary condition of all cutters models.

4.7 Finite element result

In this section, results of analytical method approach of at the edge of cutter, finite element approach for applied force and von misses stress model 1 and model 2 cutter in CATIA Workbench and analytical method is compared, analytical method the tow model shape and size different. Using both CATIA Workbench software and analytical method, along with the boundary conditions, a variable force [N] is applied then we got a value for these aforementioned parameters. The result of the analysis summarized as follow.

4.8 Von Misses Stress Analysis by Structural Effect

The maximum and minimum value of Von Misses stress finite element analysis result it done by CATIA workbench using FEM analysis applied material WC and stainless steel at the edge of cutting cutter the maximum applied force on the cutter is 905N. When applied Tungsten Carbide (WC) material for model 1, 2, and 4 as shown the result contour plot, von misses stress is the maximum value is indicating by red color, which has value of 3.92x e^7 N/m^2, 3.56 x e^7 N/m^2 ,4.48 x e^7 N/m^2 and 1.06 x e^8 N/m^2respectively and the minimum value is 0.0747 N/m^2, 0.0694 N/m^2 ,0.0644 N/m^2 and 0.0137 N/m^2 it indicates by blue color respectively. And also for stainless steel model 1 ,2 ,3 and 4 the result contour plot, von misses stress the maximum value is indicating by red color, which has value of 3.91x e^7 $N/m^2$and 3.53x e^7 N/m^2, 2.88 x $e^7$$N/m^2$ and 8.77 x e^7 N/m^2respectively and the minimum value of von messes stress 0.105 $N/m^{2,}$ 0.115 N/m^2, 0.019 N/m^2 and 0.00468 N/m^2 indicate by blue color respectively. Below the figure shown that the von misses stress is highly concentrated at around peripheral edge of cutter.

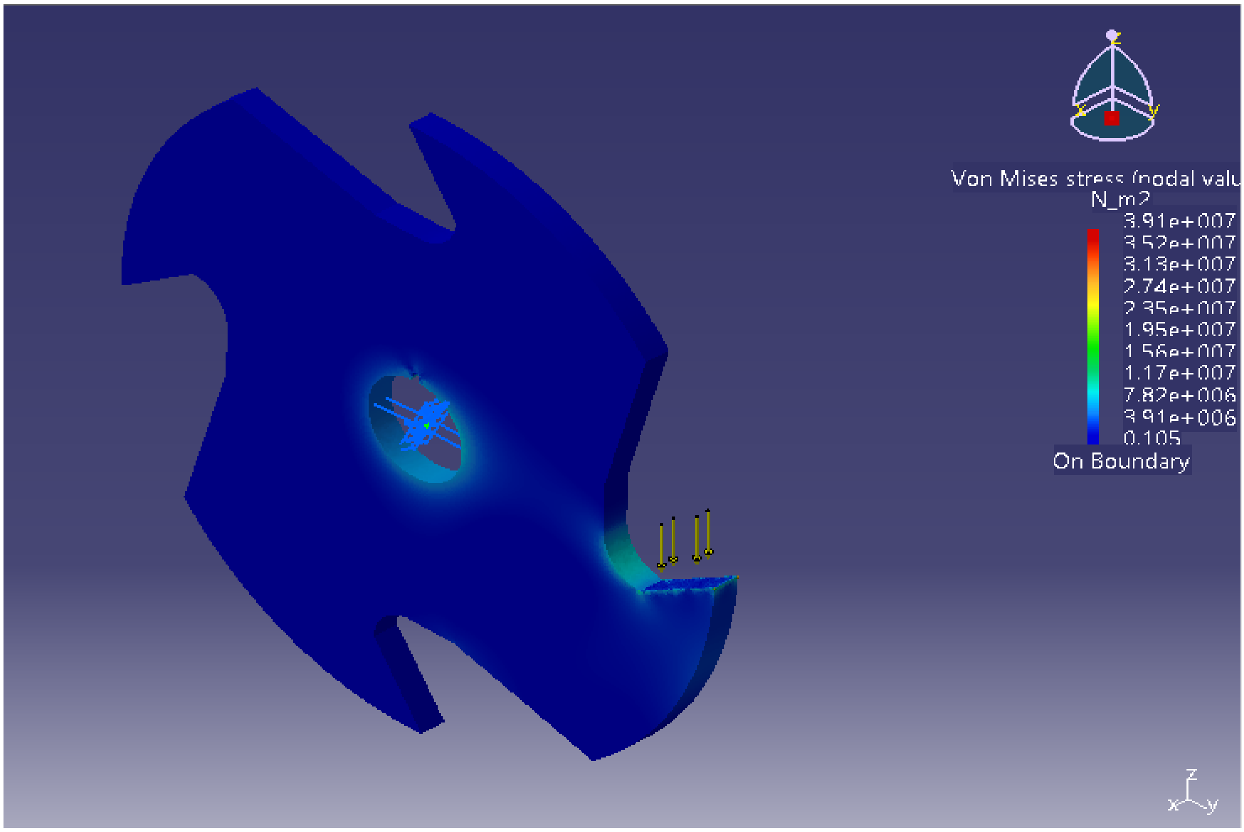
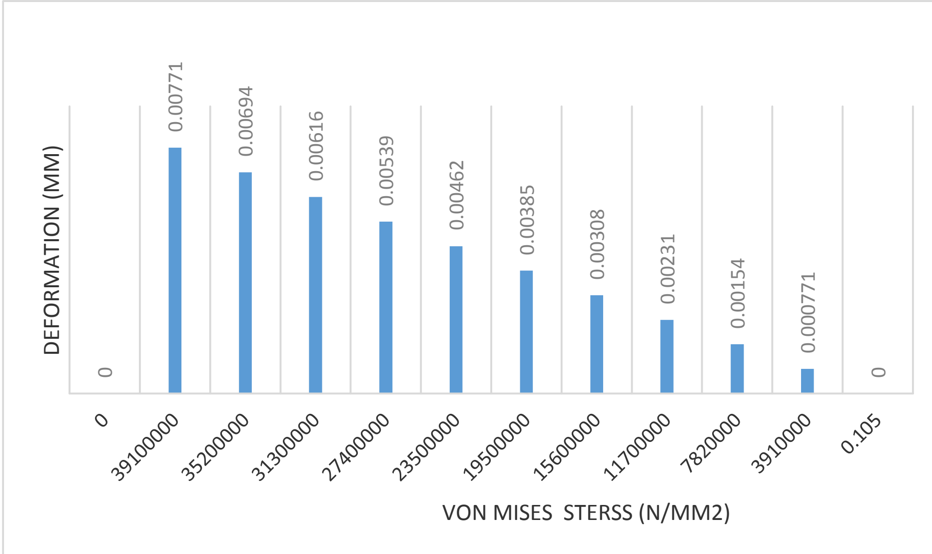


Figure 4.4 stainless steel applied on model 1 von mises stress result

The figure 4.4shows that magnified image of von misses' stress value for model 1 applied material stainless steel on the cutter. The maximum value 3.91x e^7 N/m^2 and the minimum value 0.105 N/m^2. When we see the figure the stress concentration at the edge of the cutter is higher than the other part of the cutter. That indicate the cutter edge area is more sharp and working region. This analysis result much lesser than yield strength of the material. So, the model 1of cutter is safe from faller of cutter when the cutter is cutting.



Figurer 4.5Von misses stress vs deformation model 1 for stainless steel

The result indicated in figure 4. 5 Von misses stress verses deformation value of for model 1. The material stainless steel applied at maximum deformation at a point is 0.00771mm which is the maximum von misses stress is 3.91 x $e^7 N/m^2$. Which indicate the material of yield stress value is save when compare to the maximum von misses stress result.

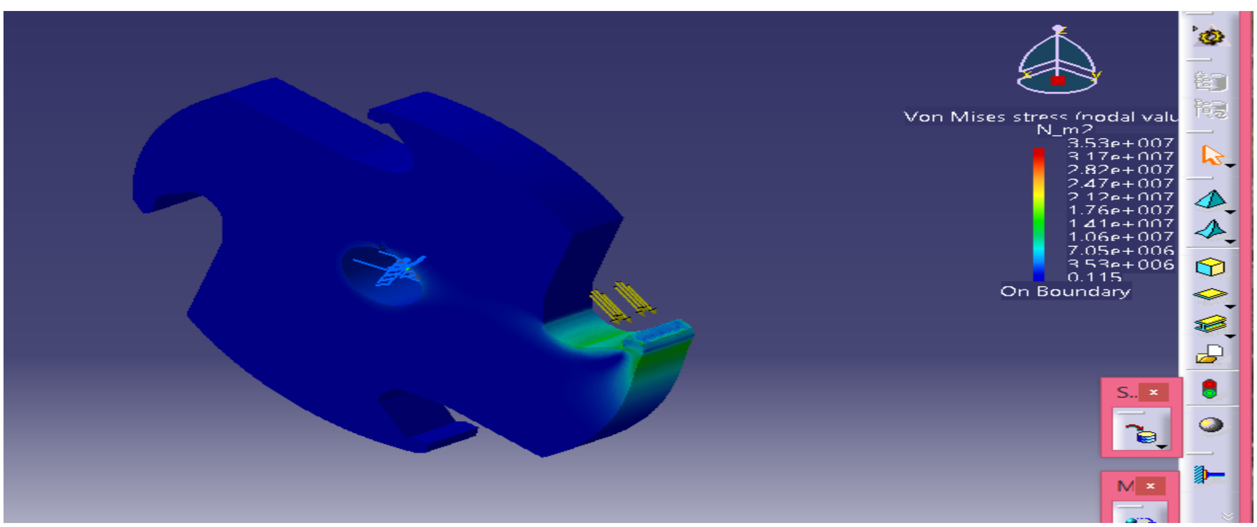
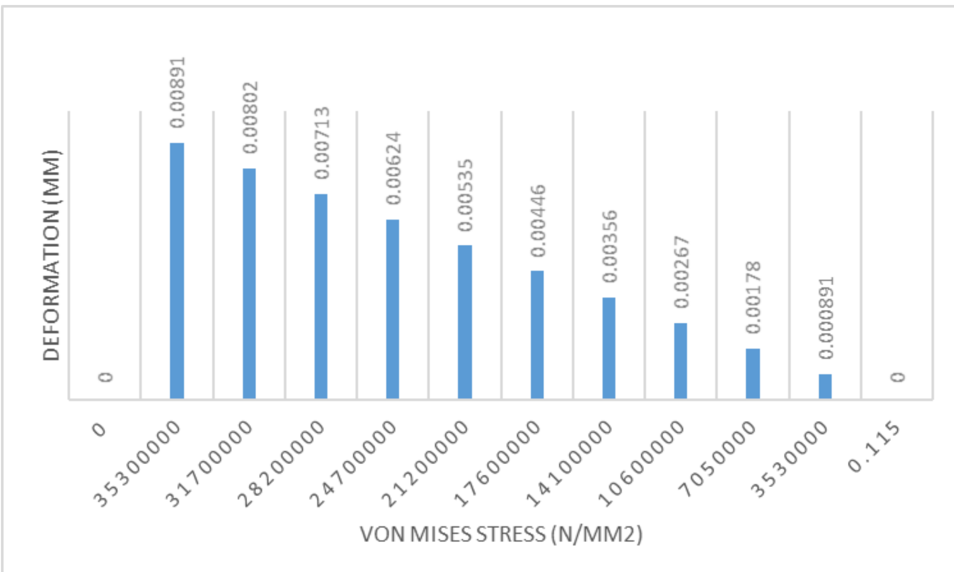


Figure 4.6 mode 2 von miss stress result for stainless steel

The figure 4.6 shows that magnified image of von misses' stress value for model 2 applied material stainless steel on the cutter. The maximum value 3.53 x e^7N/m^2 and the minimum value 0.115 N/m^2. When we see the figure the stress concentration at the edge of the cutter is higher than the other part of the cutter. That indicate the cutter edge area is more sharp and working region. The applied force at the edge of the cutter is higher than the other part of the cutter region. This analysis results the maximum von misses result is much lesser than yield strength of the material. So, the model 2 of cutter is safe when the cutter is cutting. The maximum point represented by color red which is the maximum point of the material faller point and the minimum point of the material point which represented by blue color.



Figurer 4.7 Von misses stress vs deformation model 2 for stainless steel

The figure 4.7 represented Von misses stress verses deformation value of for model 2. The applied material is stainless steel and the maximum translational displacement analysis result is 0.000891mm. As result, the maximum von misses stress is 3.53 x e^7N/m^2. Which indicate the material of yield stress value is save when we compared to the maximum von misses stress result.

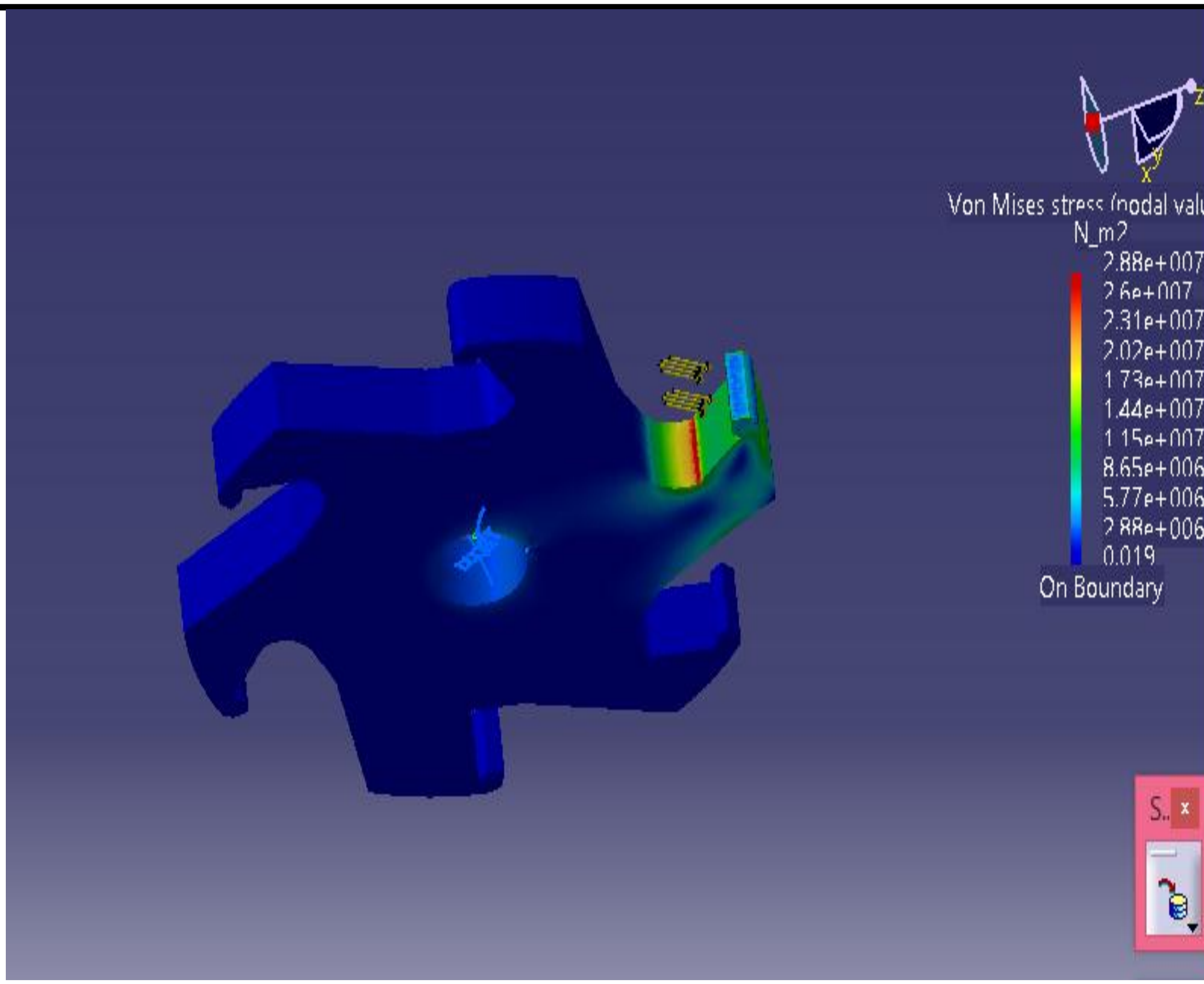


Figure 4.8 represented Von misses stress vs deformation of the model 3 stainless steel.

The figure 4.8 shows that magnified image of von misses' stress value for model 3 applied material stainless steel on the cutter. The maximum value 2.88 x e^7 N/m^2 and the minimum value 0.019 N/m^2.When we see the figure the stress concentration at the edge of the cutter is higher than the other part of the cutter. That indicate the cutter edge area is more sharp and working region. The applied force at the edge of the cutter is higher than the other part of the cutter region. This analysis results the maximum von misses result is much lesser than yield strength of the material. So, the model 3 of cutter is safe when the cutter is cutting. The maximum point represented by color red which is the maximum point of the material faller point and the minimum point of the material point which represented by blue color.

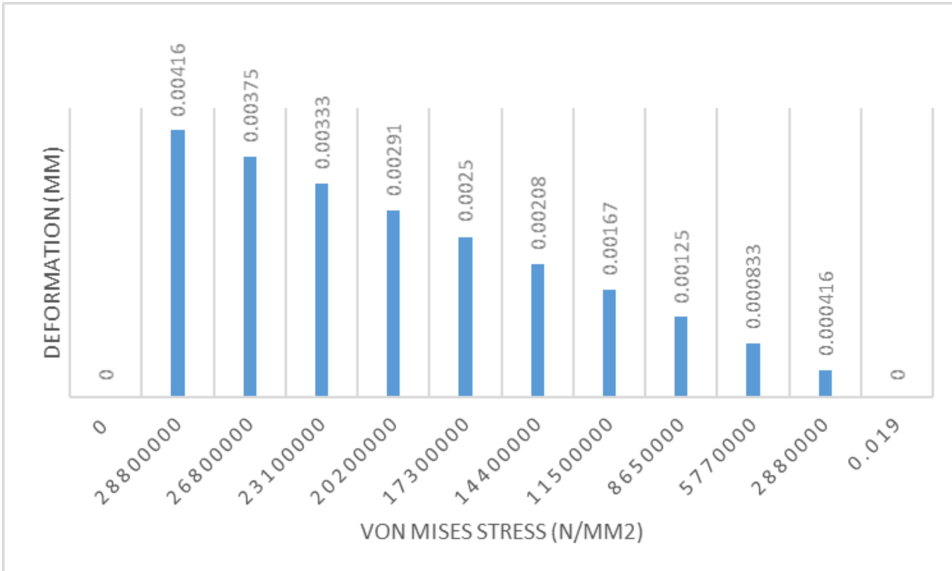


Figure 4.9 Von misses stress vs deformation for stainless steel material model 1

The figure 4.9 represented Von misses stress verses translational displacement value of for model 3. The applied material is stainless steel and the maximum translational displacement analysis result is 0.00416mm. As result, the maximum von misses stress is 2.88 x e^7N/m^2. Which indicate the material of yield stress value is save when we compared to the maximum von misses stress result.

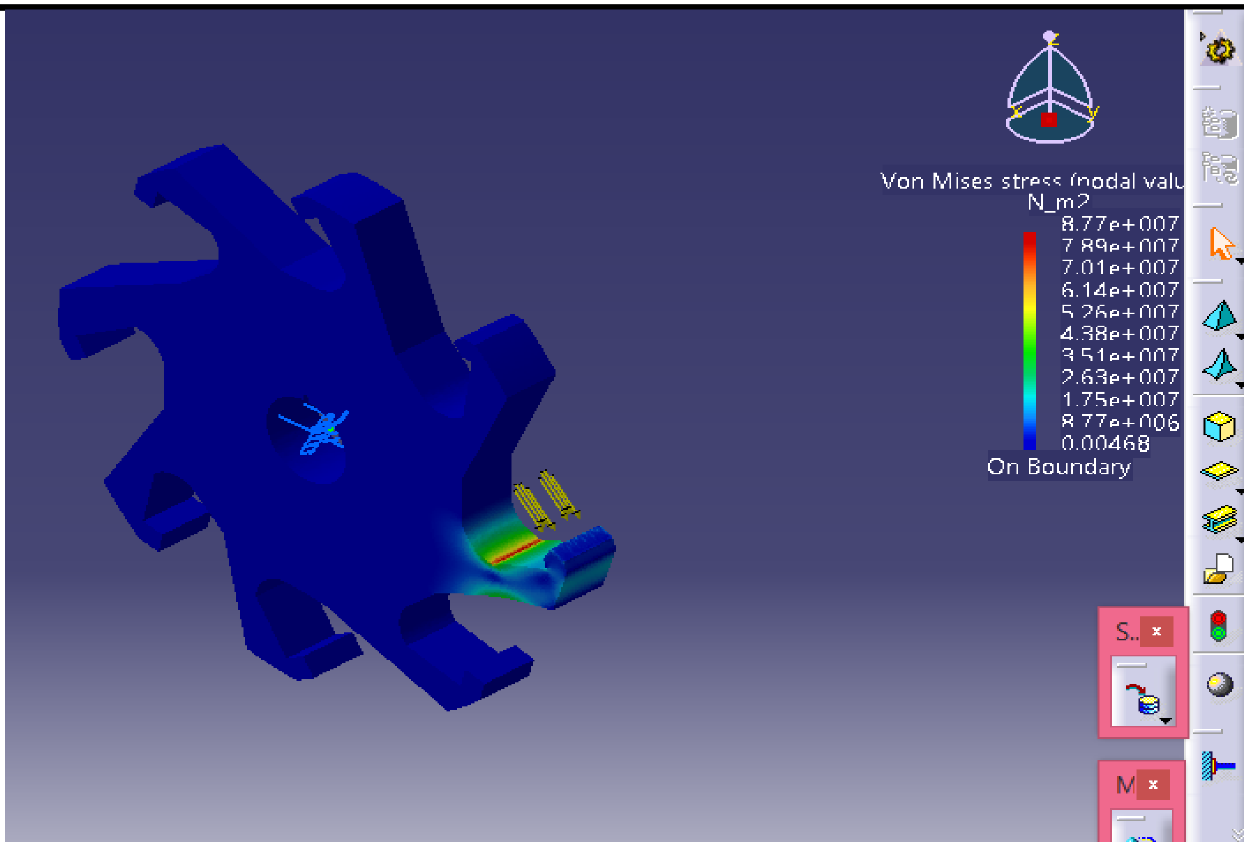


Figure 4.10 Applied Stainless steel model 4 von misses stress result

The figure 4.10 shows that magnified image of von misses' stress value for model 4 applied stainless steel material on the cutter. The maximum value 8.77 x e^7 N/m^2 and the minimum value 0.00468 N/m^2.When we see the figure the stress concentration at the edge of the cutter is higher than the other part of the cutter. That indicate the cutter edge area is more sharp and working region. The applied force at the edge of the cutter is higher than the other part of the cutter region. This analysis results the maximum von misses result is much lesser than yield strength of the material. So, the model 4 of cutter is safe when the cutter is cutting. The maximum point represented by color red which is the maximum point of the material faller point and the minimum point of the material point which represented by blue color.

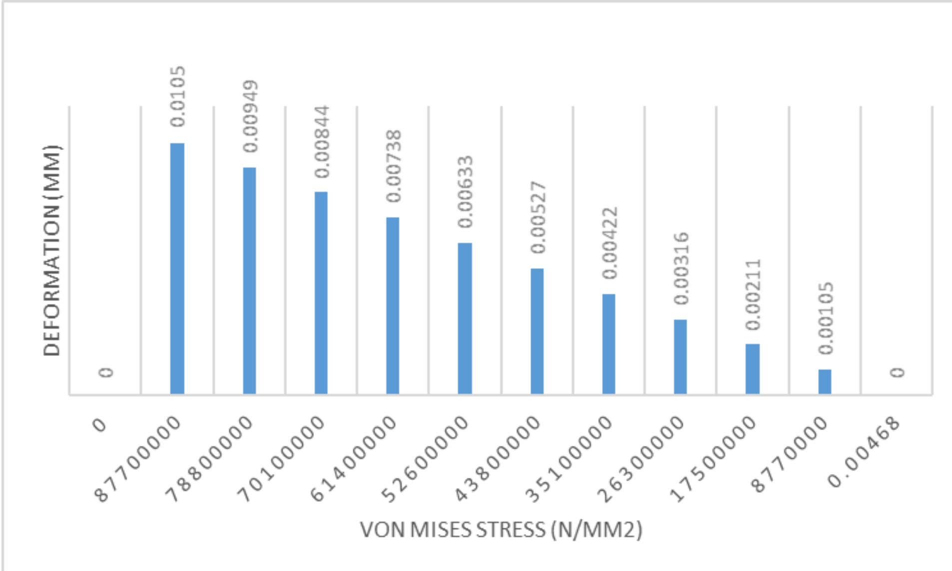


Figure 4.11 Deformation and von misses stress for stainless steel material model 4

The figure 4.11 represented Von misses stress verses deformation value of for model 4. The applied material is stainless steel and the maximum translational displacement analysis result is 0.0105mm. As result, the maximum von misses stress is 8.77x $e^7 N/m^2$. Which indicate the material of yield stress value is save when we compared to the maximum von misses stress result.

All the above result was discussed detail when the material stainless steel applied on the cutter. the above the figures represented the von mises result of the cutter for the all models. And the bar graph represented the deformation due to the stress applied on the cutter for all models. Then discuss the result applied material WC on the cutter as fowls.

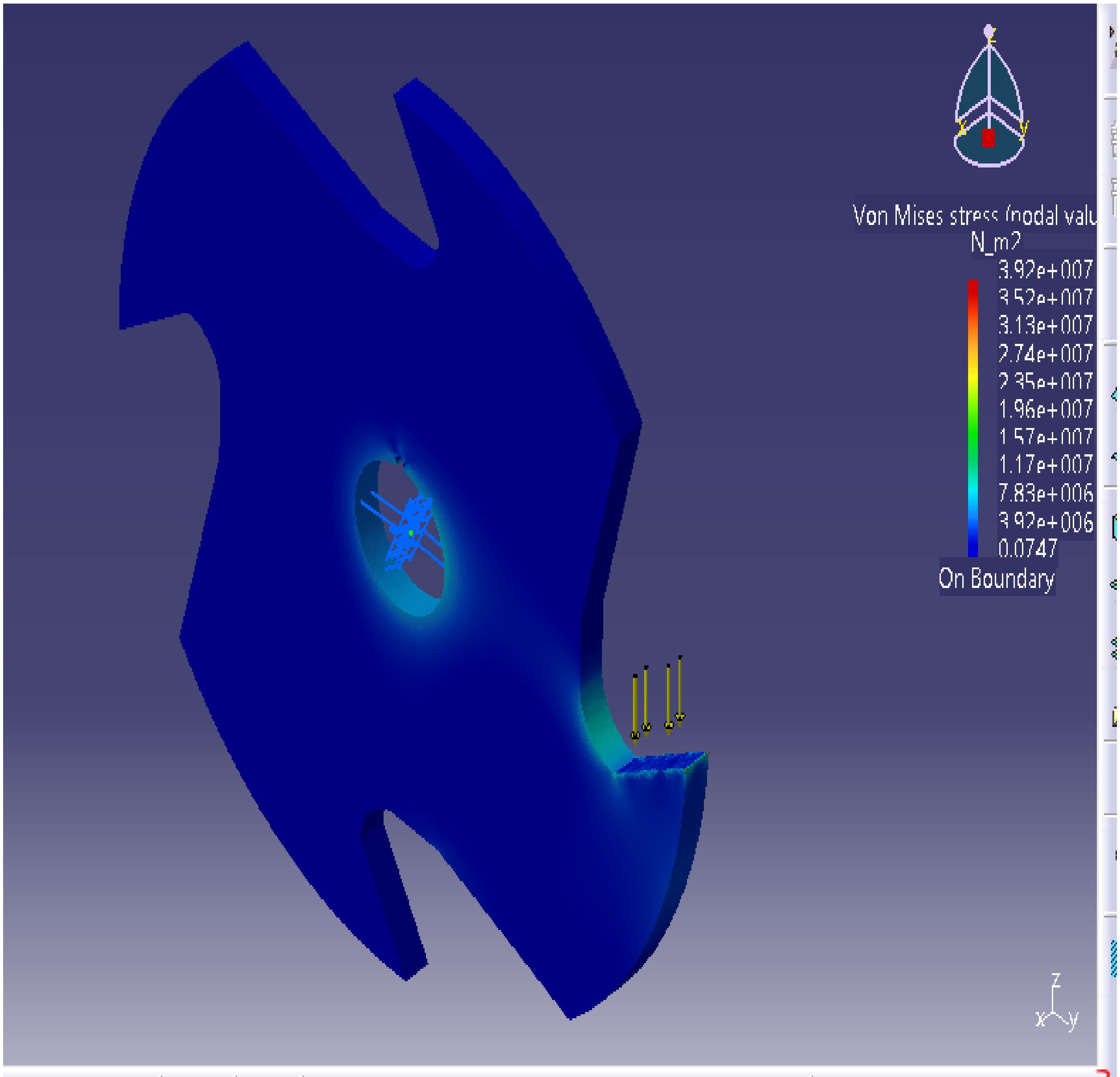
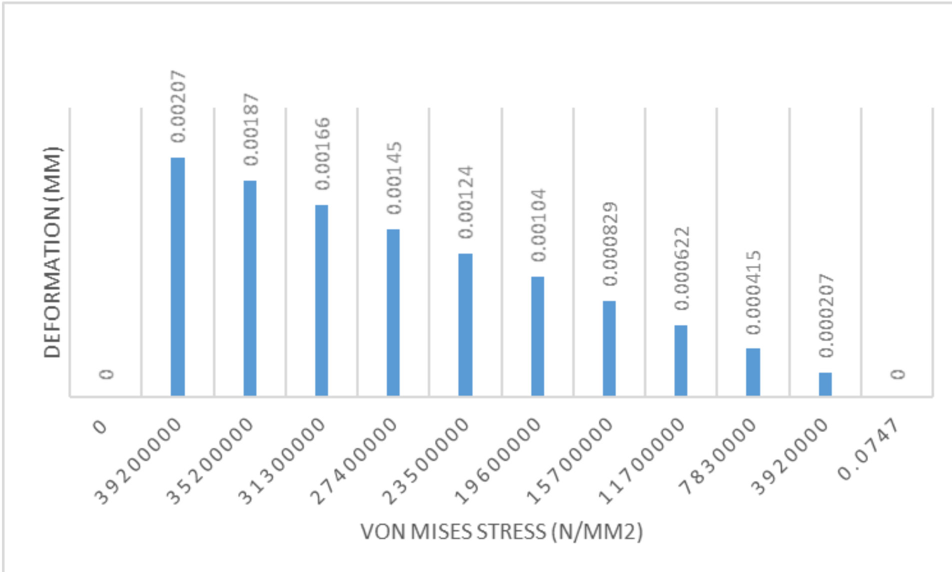


Figure 4.12 Applied material WC on model 1 von miss stress result

The figure 4.12 shows that magnified image of von misses' stress value for model 1 applied material WC on the cutter. The maximum value of von misses stress 3.92x e^7 N/m^2 and the minimum value 0.0747N/m^2. When we see the figure the stress concentration at the edge of the cutter is higher than the other part of the cutter. That indicate the cutter edge area is more sharp and working region. This analysis result much lesser than yield strength of the material. So, the model 1of cutter is safe from faller of cutter when the cutter is cutting.



Figurer 4.13 Von misses stress vs deformation model 1 for WC

The test result indicated in figure 4. 13 Von misses stress verses translational displacement value of for model 1. The material at maximum deformation point is 0.00207mm which is the maximum von misses stress is 3.92 x $e^7 N/m^2$. Which indicate the material of yield stress value is save when compare to the maximum von misses stress result.

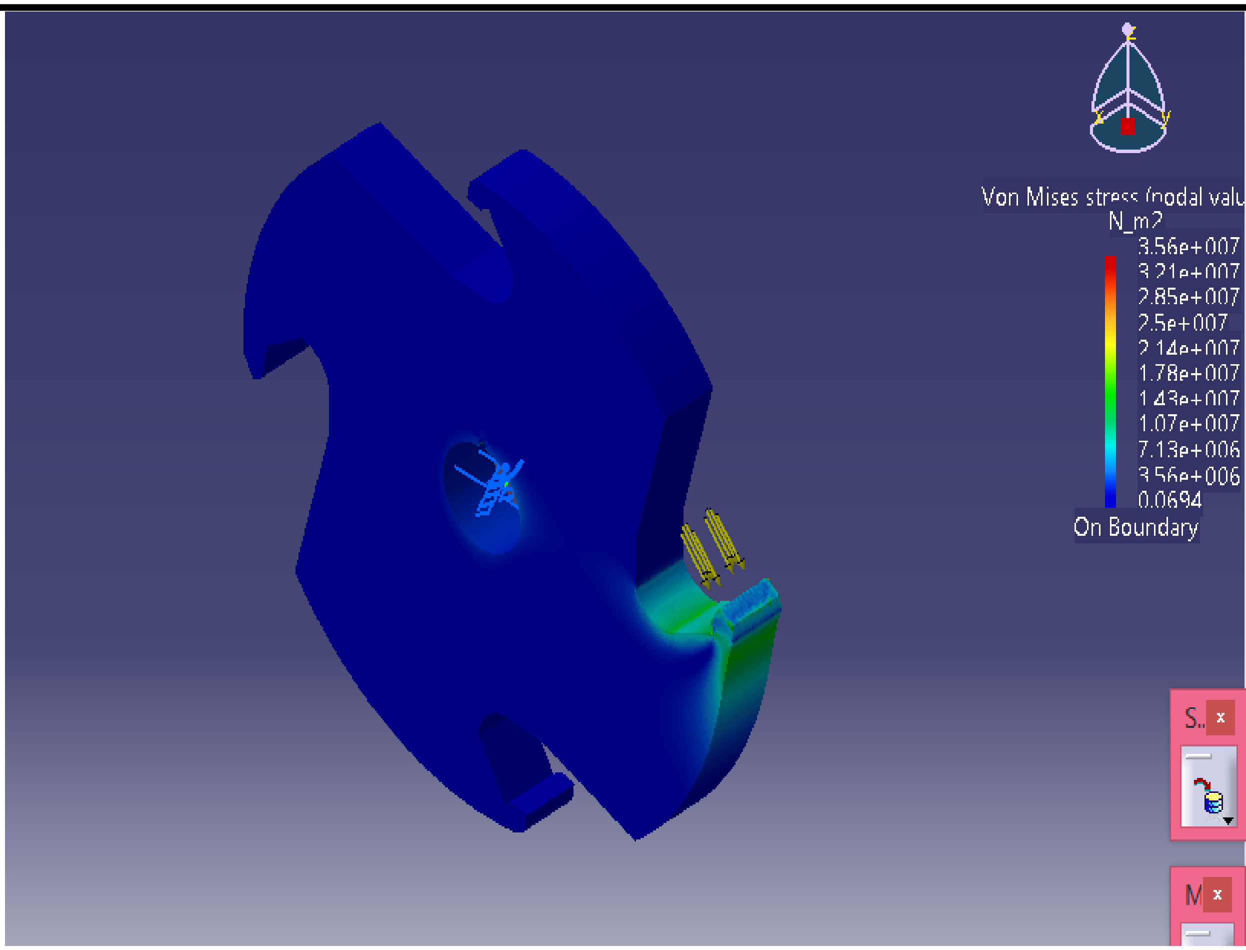
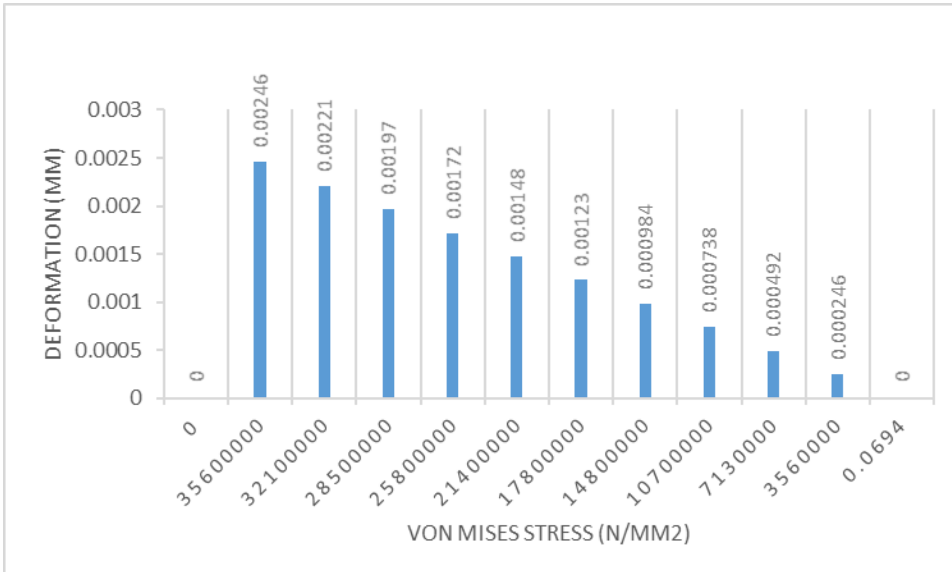


Figure 4.14 Applied WC on mode2 von miss stress result

The figure 4.14 shows that magnified image of von misses' stress value for model 2 applied material WC on the cutter. The maximum value 3.56 x $e^7 N/m^2$ and the minimum value 0.0694 N/m^2. When we see the figure the stress concentration at the edge of the cutter is higher than the other part of the cutter. That indicate the cutter edge area is more sharp and working region. The applied force at the edge of the cutter is higher than the other part of the cutter region. This analysis results the maximum von misses result is much lesser than yield strength of the material. So, the model 2 of cutter is safe when the cutter is cutting. The maximum point represented by color red which is the maximum point of the material faller point and the minimum point of the material point which represented by blue color.



Figurer 4.15 Von misses stress vs deformation model 2 for WC

The figure 4.15 represented Von misses stress verses translational displacement value of for model 1. The applied material is WC and the maximum deformation analysis result is 0.00246mm. As result, the maximum von misses stress is 3.56 x e^6N/m^2. Which indicate the material of yield stress value is save when we compared to the maximum von misses stress result.

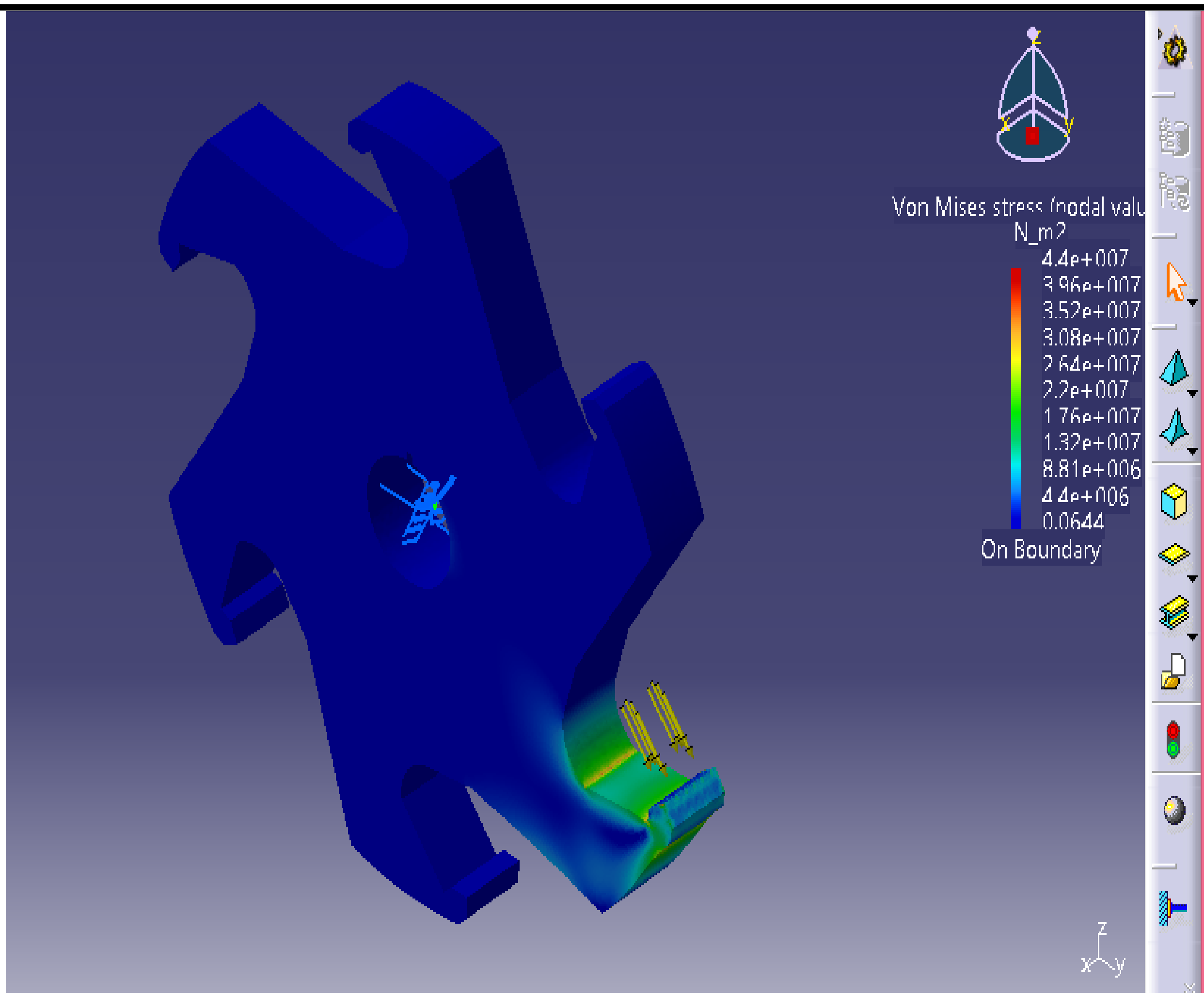


Figure 4.16 model 3 von miss stress result for WC

The figure 4.16 shows that magnified image of von misses' stress value for model 3 applied material WC on the cutter. The maximum value 4.48 x e^7 N/m^2 and the minimum value 0.0644 N/m^2.When we see the figure the stress concentration at the edge of the cutter is higher than the other part of the cutter. That indicate the cutter edge area is more sharp and working region. The applied force at the edge of the cutter is higher than the other part of the cutter region. This analysis results the maximum von misses result is much lesser than yield strength of the material. So, the model 3 of cutter is safe when the cutter is cutting. The maximum point represented by color red which is the maximum point of the material faller point and the minimum point of the material point which represented by blue color.

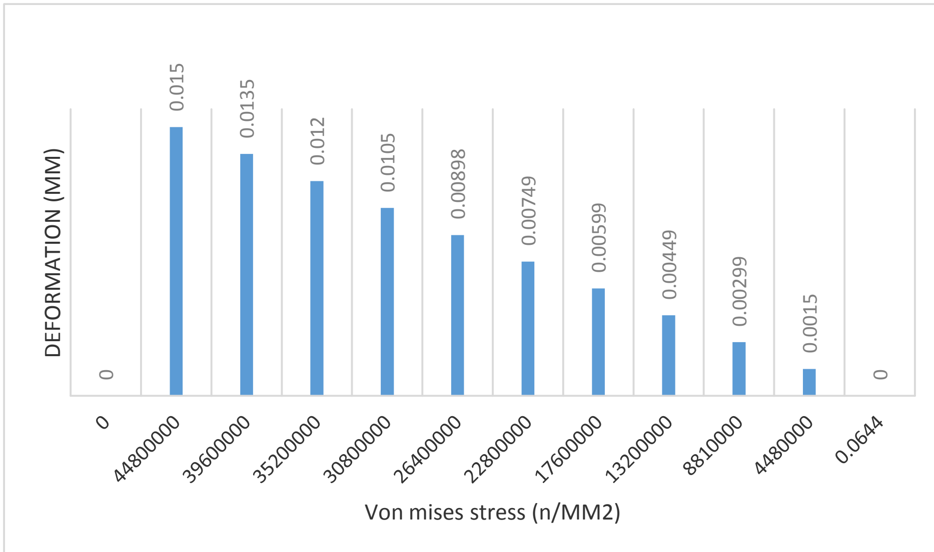


Figure 4.17 Von misses stress vs deformation for WC material model 2

The figure 4.17represented Von misses stress verses translational displacement value of for model 3. The applied material is WC and the maximum translational displacement analysis result is 0.015mm. As result, the maximum von misses stress is 4.48 x $e^7 N/m^2$. Which indicate the material of yield stress value is save when we compared to the maximum von misses stress result.

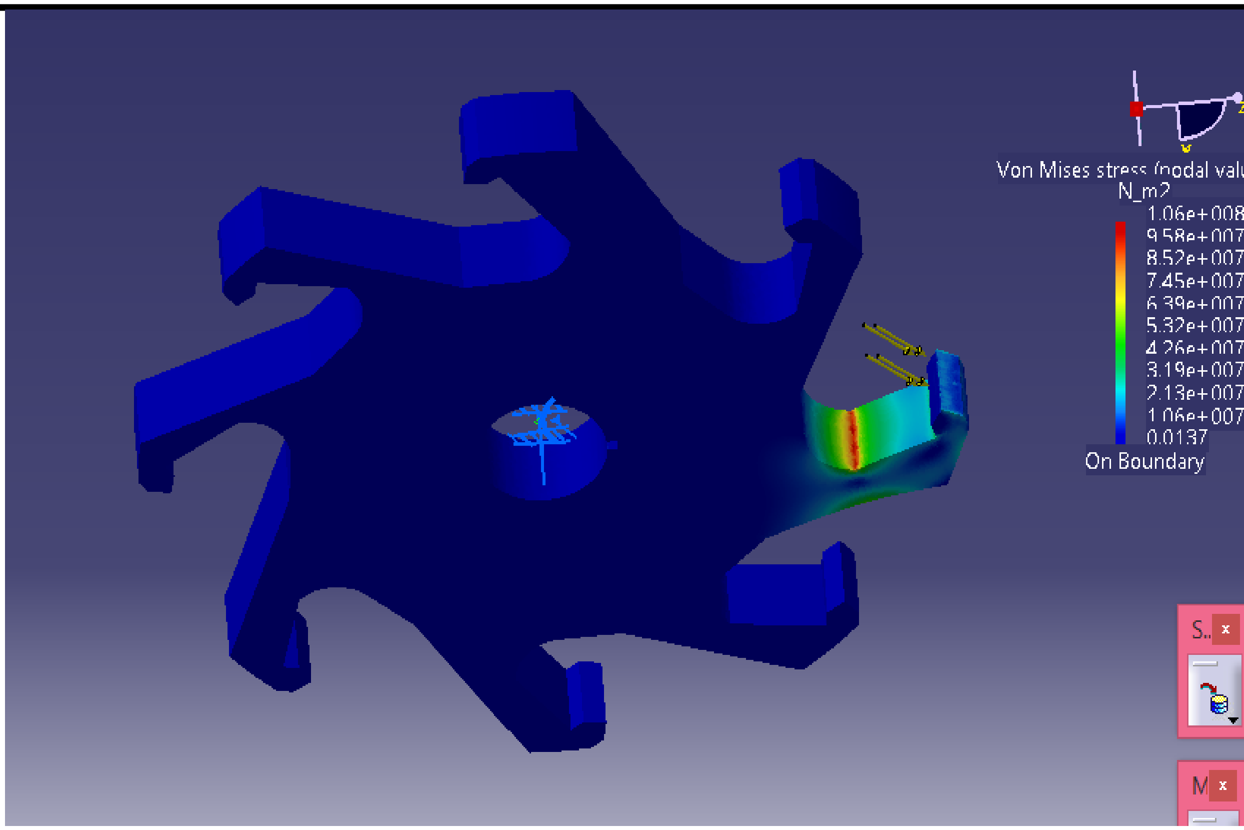


Figure 4.18Applied WC for model 4 von misses stress result

The figure 4.18 shows that magnified image of von misses' stress value for model 4 applied WC material on the cutter. The maximum value 1.06 x e^8 N/m^2 and the minimum value 0.0137 N/m^2.When we see the figure the stress concentration at the edge of the cutter is higher than the other part of the cutter. That indicate the cutter edge area is more sharp and working region. The applied force at the edge of the cutter is higher than the other part of the cutter region. This analysis results the maximum von misses result is much lesser than yield strength of the material. So, the model 4 of cutter is safe when the cutter is cutting. The maximum point represented by color red which is the maximum point of the material faller point and the minimum point of the material point which represented by blue color.

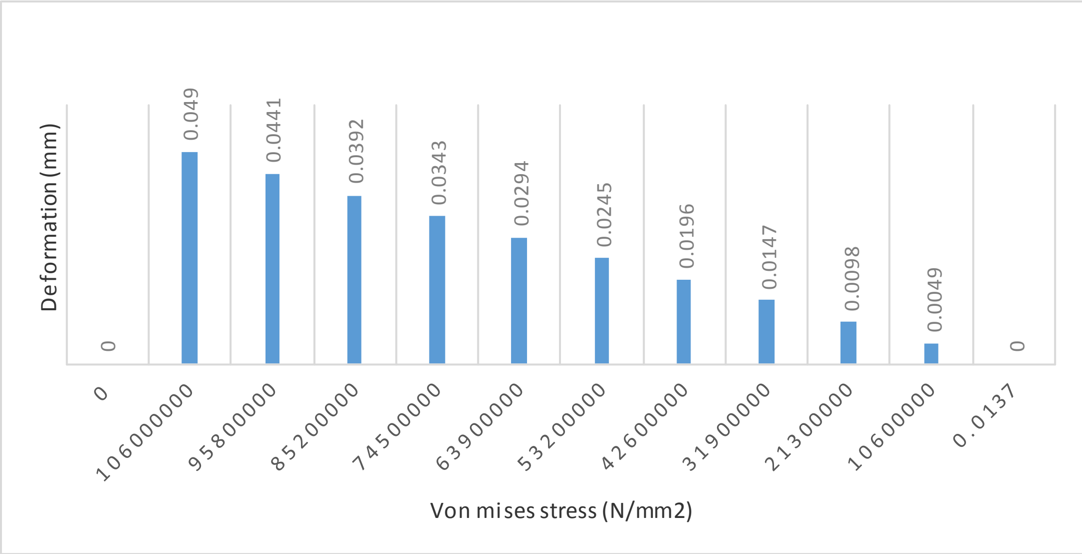


Figure 4.19 Applied WC deformation vs von misses stress for model 4

The figure 4. 19 represented Von misses stress verses deformation value of for model 4. The applied material is WC and the maximum deformation analysis result is 0.0049mm. As result, the maximum von misses stress is 1.06 x $e^8 N/m^2$. Which indicate the material of yield stress value is save when we compared to the maximum von misses stress result.

4.9 Summery result

Summarized the maximum deformation and Von mises stress result below the figure. When summarized the result all models for tungsten carbide material applied the result of von mises stress higher than stainless steel. But compere model to model, model 3 and model 4 are less stress concentration. Show below the figure the maximum deformation of all the models and the maximum result of von mises stress on the model. Cutting blade 8 maximum von mises stress for both material case. The minimum von mises stress on the models cutting blade 4 both material case.

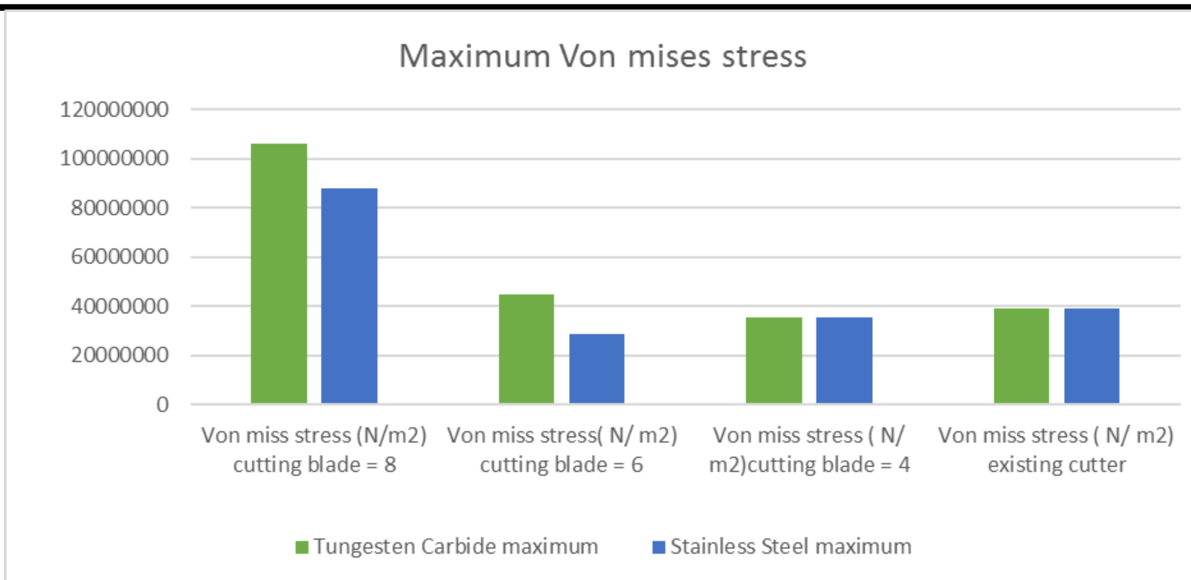


Figure 4.20 maximum Von mises stress for both material case

For all case stainless steel less deformation occurred than tungsten carbide material applied. When camper model to mode the deformation model 1 and 2 is less deformation result.

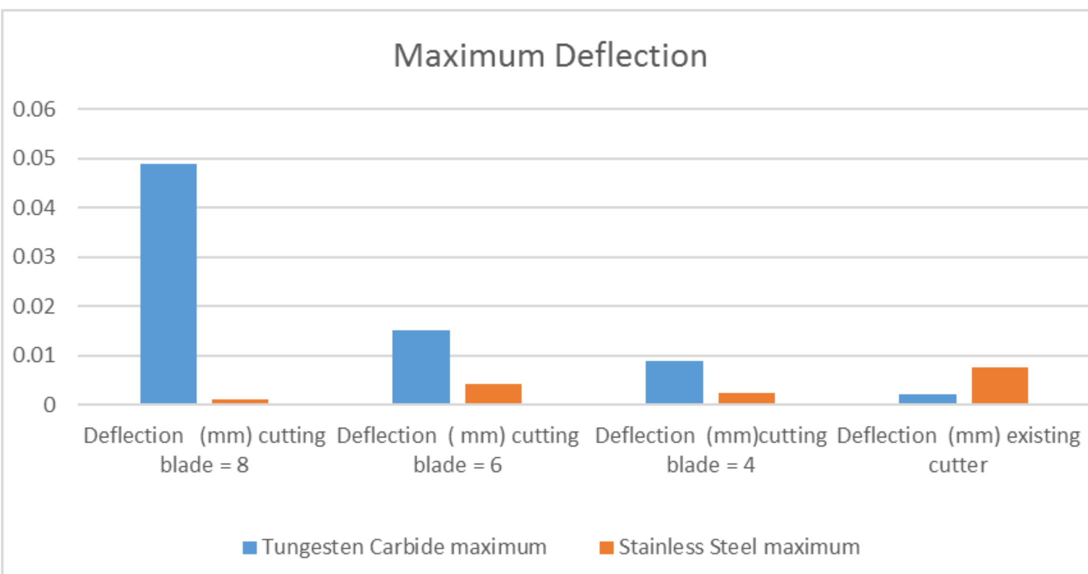


Figure 4.21 maximum deformation for both material case

CHAPTER 5

5 Conclusion and Recommendation

5.1 Conclusion

The results of this thesis, are obtained from the analytical analysis and finite element method modeling of solid waste shredding cutter using FEM. Comparison of CATIA workbench results with analytical method are done and similar results have been obtained with reasonable accuracy. So, this researcher has used both analytical and CATIA workbench to predict contact force of mechanical components of existing cutter model 1 to improve model 2, 3.and 4 solid waste shredding cutter. Generally, from this thesis work, the following conclusions can be drawn:

1. The cutter blade thickness increases the von mises stress is decreasing effect.
2. The maximum stress occurs around the edge of the cutter for all cases.
3. The material of tungsten carbide (WC) Von misses stress result higher than stainless steel models. And the model 2 result is better than for the others models, because of cutter structure, the models thickness difference, the result of deformation and von mises result.
4. There is a high Von misses stress components at the cutter edge and thickness of the cutter. Because the major cutting area the cutter.
5. It is observed that as the cutting effect increases, the Von-Misses stresses on the cutter increases which are the main reason of tool failure. And the depth of cut increases, also increasing deformation of the tool tip. It is main reason of tool failure.
6. Model 2 cutter has cutting and pulling effect at the tip of cutter 10mm x 10mm x 25 mm filet radius 5mm x 45^0. In this regard, more cutting and pulling effect increase at the tool

the rotation time, without blunt. The cutter at a tip of the cutting effective is 35^0-degree orientation when the cutter is in rotation time.

And finally, of the four the models, stress concentration result in model 2 is better than the other models. At the edge of the cutter, the modified cutter is used as the pulling and cutting effect of the waste material without difficulty with respect to the above angle. When you see in model 1, the cutter edge area is more flattened and thinner than other models and the former is used only for cutting of the plastic waste particle only without pulling effect. As the same time, model 2 cutter's edge is curved in the four side of the cutter and better thicker. This model 2 modification is effective for pulling and cutting effect of solid waste material. The model 2 software results von misses stress result—i.e. The deformation is better than the other models or existing one result.

5.2 Recommendation

1. The wear of cutter under repeated braking condition within temperature effect will be conducted
2. Investigations should be conducted considering the cost of tungsten carbide as it is higher than stainless steel material.
3. This may lead to failure of cutter due to crack and fracture parameters are functions of stress.
4. The crack analysis for cutter within contact pressure effect will be study at the edge of cutter.

Appendix

Table A-1. Types of Stainless Steel and its typical applications [8]

Type	Applications
420 (Martensitic)	Spatulas, Professional knives, Cooks, etc.
430 (Ferritic)	Moderately corrosive environment (e.g. dry foods, fruits, vegetables, drinks, etc.), Panel (i.e., components that require weld ability or little formability), table Surfaces or cladding equipment's.
304 (Austenitic)	Pipework, machinery parts (i.e. components requiring some formability or weld ability), Vats and bowls Greater corrosion resistance to 430.
316 (Austenitic)	More corrosive foods (e.g. meat/blood, foods with moderate salt contents) components, which requires frequently clean, not under excessive stress and without stationary solids.
14539 (Austenitic)	Corrosive foods (e.g. hot brine with solids that act as crevice forms, stagnant and slow moving salty foods).
14662 (Duplex)	Corrosive foods (e.g. hot brine in solids, stagnant and slow carrying salty foods). Higher strength when compared with austenitic. High stress corrosion cracking resistance within salt merchandise at elevated temperatures.
6%Mo.Types	Corrosive foods (e.g. hot brine in solids that act equally crevice formers,

(Austenitic)	tangent in addition to slow taking salty foods). Good stress corrosion cracking resistance within salt merchandise at elevated temperatures. Used in steam heating and hot performs circuits, hot water boilers, etc.

TableA-2 General Composition of Solid Waste (20)

Component	Wet Weight	Dry Weight	Composition					
	lb.	lb.	C	H	O	N	S	Ash
Food Waste	9.0	2.7	1.30	0.17	1.02	0.07	0.01	0.14
Paper	34.0	32.0	13.90	1.92	14.06	0.10	0.06	1.92
Cardboard	6.0	5.7	2.51	0.34	2.54	0.02	0.01	0.29
Plastic	7.0	6.9	4.16	0.50	1.58	0.00	0.00	0.69
Textiles	2.0	1.8	0.99	0.12	0.56	0.08	0.00	0.05
Rubber	0.5	0.5	0.39	0.05	0.00	0.01	0.00	0.05
Leather	0.5	0.4	0.24	0.03	0.05	0.04	0.00	0.04
Yard Wastes	18.5	6.5	3.10	0.39	2.46	0.22	0.02	0.29
Wood	2.0	1.6	0.79	0.10	0.68	0.00	0.00	0.02
TOTAL	79.5	58.1	27.37	3.61	22.95	0.54	0.11	3.48

Table A-3 Time and sample initial mass and weight of food waste material

Time(hr.)	Mass(kg)	Weight(N)
1	0.438382	4.3005274
2	0.376764	3.89605484
3	0.315146	3.09158226
4	0.253528	2.48710968
5	0.19191	1.8826371
6	0.130292	1.27816452

Table A-4 Food waste material Moisture content per hours

Sample solid waste material	Time(hr.)	Moisture content in %
Food waste	1	87.68
	2	79.43
	3	63.03
	4	50.71
	5	38.38
	6	26.06

Table A-5 Time and sample initial mass and weight of wet paper waste material

Time(hr.)	Mass(kg)	Weight(N)
1	0.40294	3.9528414
2	0.30588	3.0006828
3	0.28882	2.8333242
4	0.11176	1.0963656
5	0.0147	0.144207
6	-0.08236	-0.8079516

Table A-6 Wet paper waste material Moisture content per hours

Sample solid waste material	Time(hr.)	Moisture content in %
Wet paper waste	1	80.59
	2	61.30
	3	57.76
	4	22.35
	5	2.94
	6	-16.47

Table A-7 Time and sample initial mass and weight of dry paper waste material

Time(hr)	Mass(kg)	Weight(N)
1	0.1917	1.880577
2	0.1334	1.308654
3	0.0751	0.736731
4	0.0168	0.164808
5	-0.0415	-0.407115
6	-0.0998	-0.979038

Table A-8 Dry paper waste material Moisture content per hours

Sample solid waste material	Time(hr.)	Moisture content in %
Dry paper waste	1	76.68
	2	53.36
	3	30.12
	4	6.72
	5	-16.6
	6	-39.92

Table A-9 Time and sample initial mass and weight of plastic waste material

Time(hr.)	Mass(kg)	Weight(N)
1	0.1083	1.062423
2	-0.0334	0.327654
3	-0.1751	-1.717731
4	-0.3168	-3.107808
5	-0.4585	-4.447885
6	-0.6002	-5.887962

Table A-10 Plastic waste material Moisture content per hours

Sample solid waste material	Time(hr.)	Moisture content in %
Plastic waste	1	43.32
	2	13.36
	3	-70.03
	4	-126.72
	5	-181.36
	6	-240.08

Table A-11 Time and sample initial mass and weight of garden fuse waste material

Time(hr.)	Mass(kg)	Weight(N)
1	0.491413	4.8207612
4	0.46565	4.5680265
8	0.43133	4.2313179
12	0.39696	3.894178
16	0.362613	3.557237
20	0.328267	3.220299
24	0.29382	2.883355
28	0.259573	2.546413

32	0.225227	2.209479
36	0.19088	1.872533

Table A-12 Garden fuse waste material Moisture content per hours

Sample solid waste material	Time(hr.)	Moisture content in %
Garden fuse waste	1	98.28
	4	93.13
	8	86.27
	12	79.40
	16	72.54
	24	58.78
	28	51.91
	32	45.05
	36	38.18

Table A-13 Time and sample initial mass and weight of yard waste material

Time(hr.)	Mass(kg)	Weight(N)
1	0.40654	3.9881574
2	0.31308	3.0713148
3	0.21962	2.1544722
4	0.12616	1.2376296
5	0.0327	0.320787

6	-0.06076	-0.5960556

Table A-14Yard waste material Moisture content per hours

Sample solid waste material	Time(hr.)	Moisture content in %
Yard waste	1	81.31
	2	62.62
	3	43.92
	4	25.22
	5	38.38
	6	-12.152

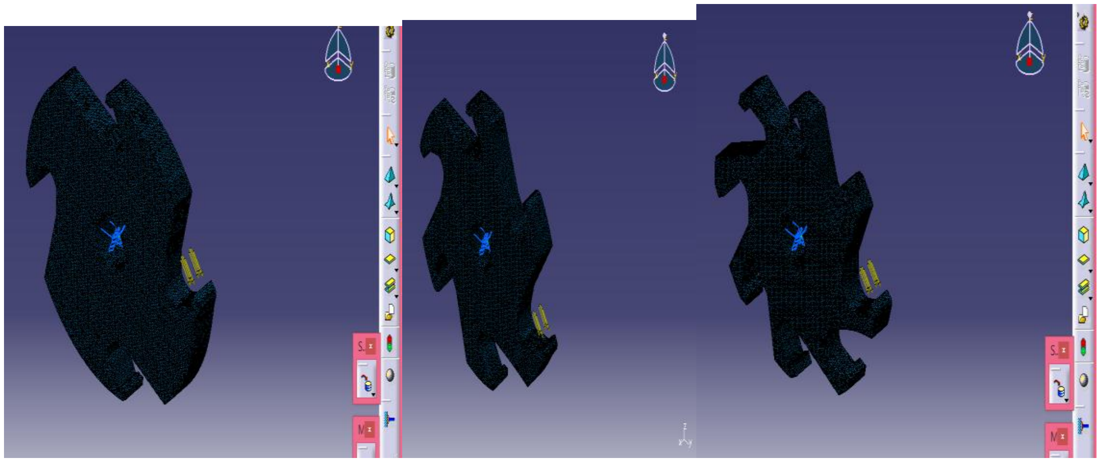


Figure A-15 mesh for model 2,3,4 cutters

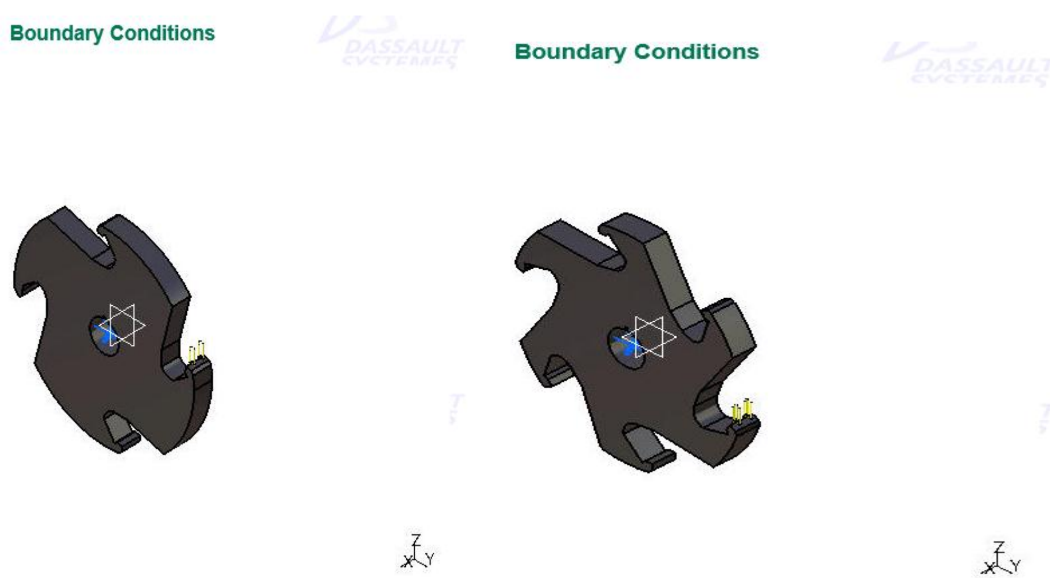
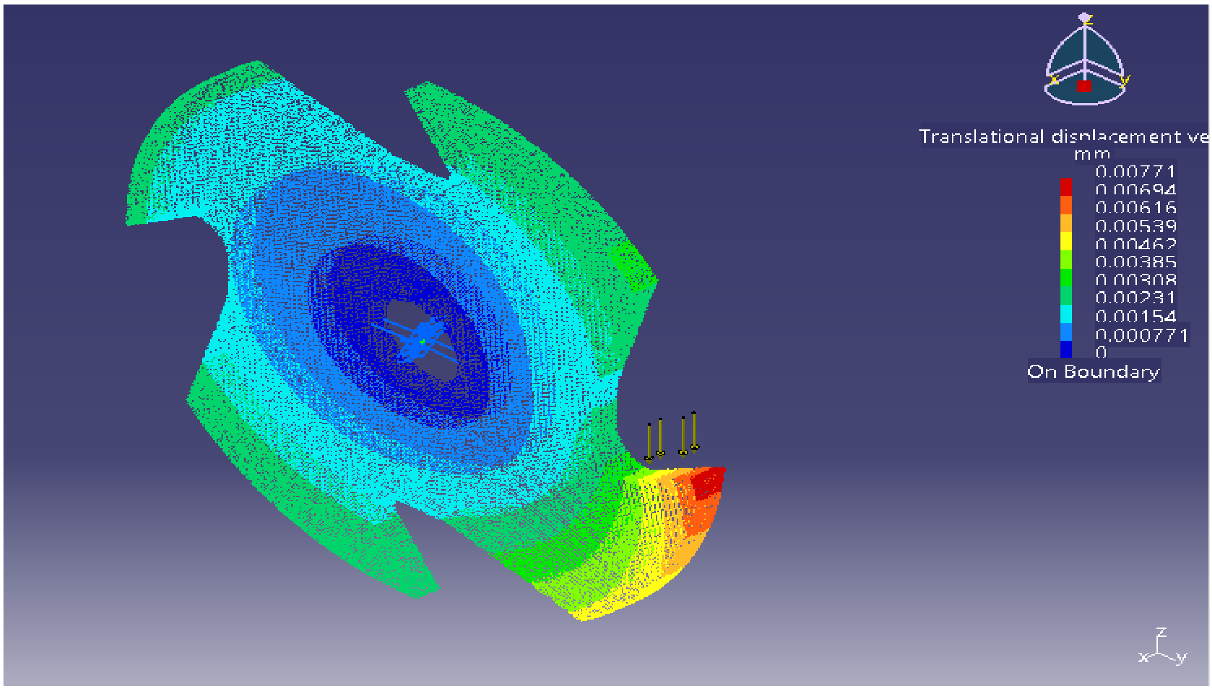
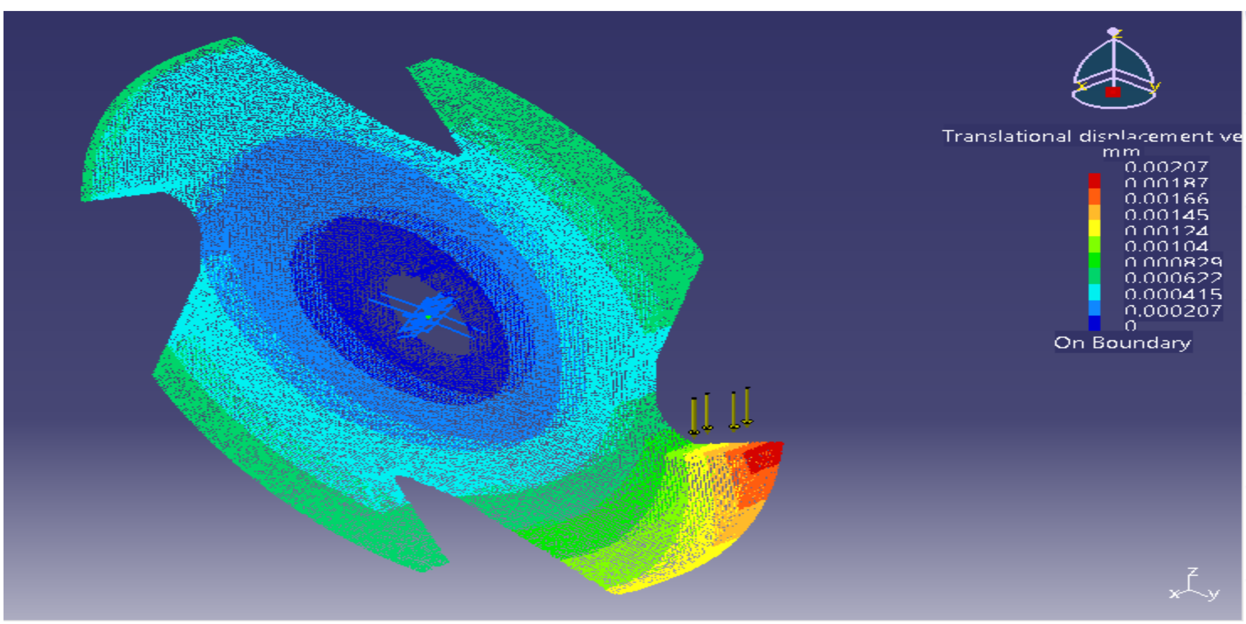
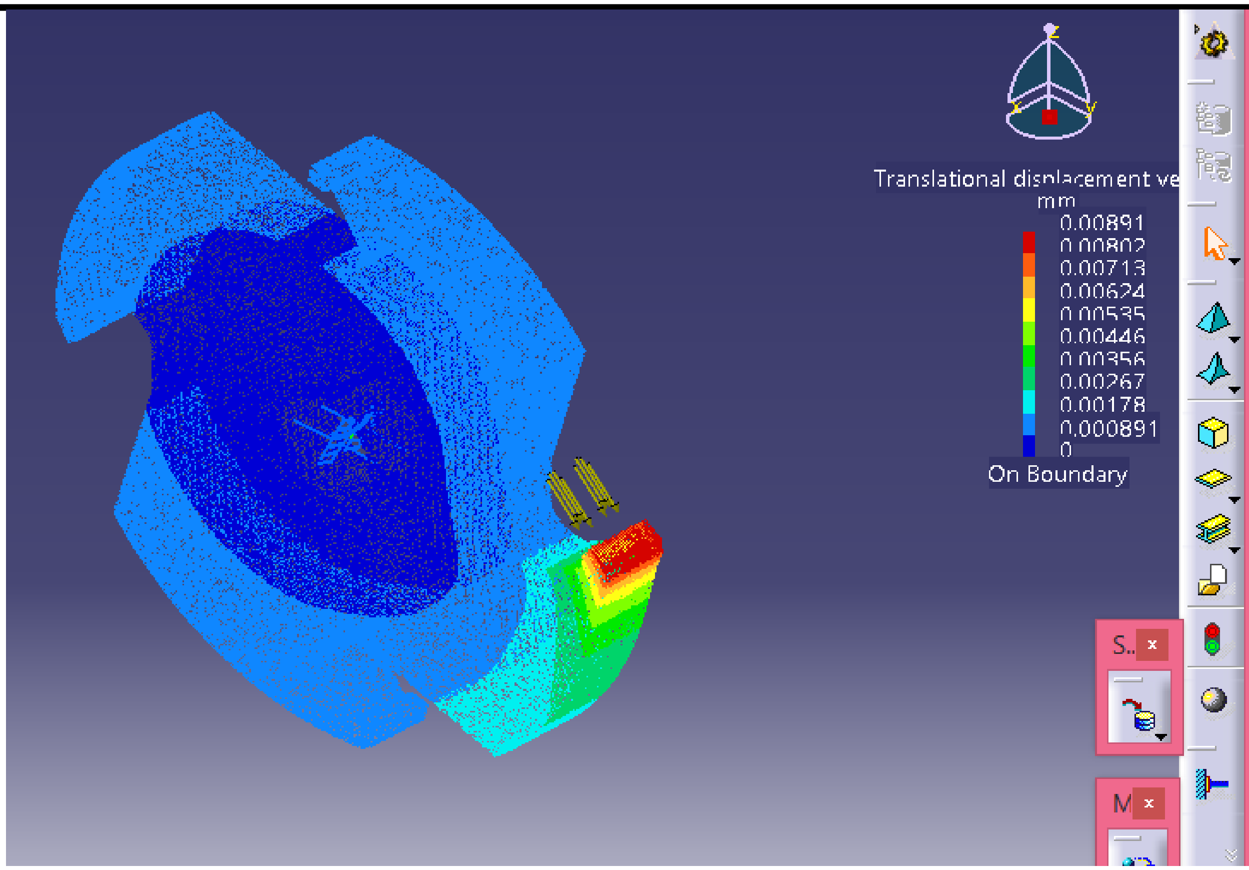


Figure A-16 boundary condition for model 2,3,4 cutters

Figure A-17 deformation for model 2,3,4 cutters material applied stainless steel and tungsten carbide



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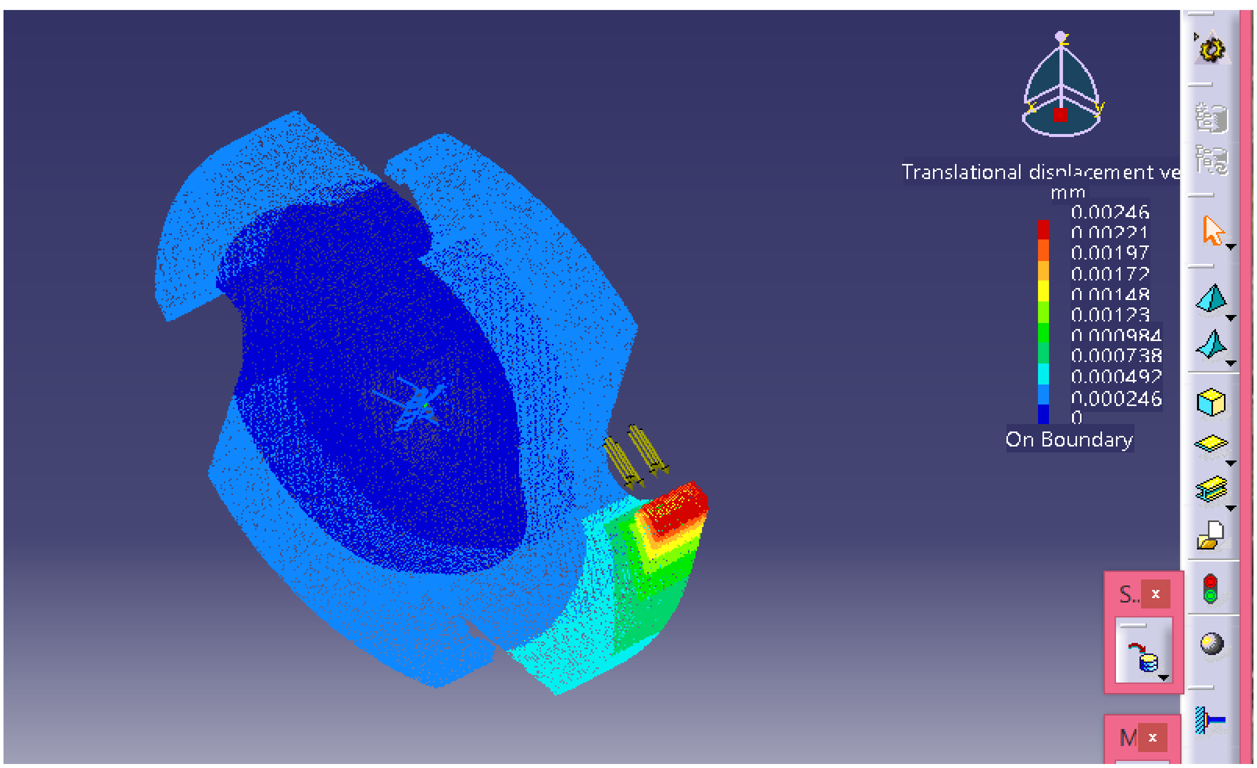
0
On Boundary
S..
M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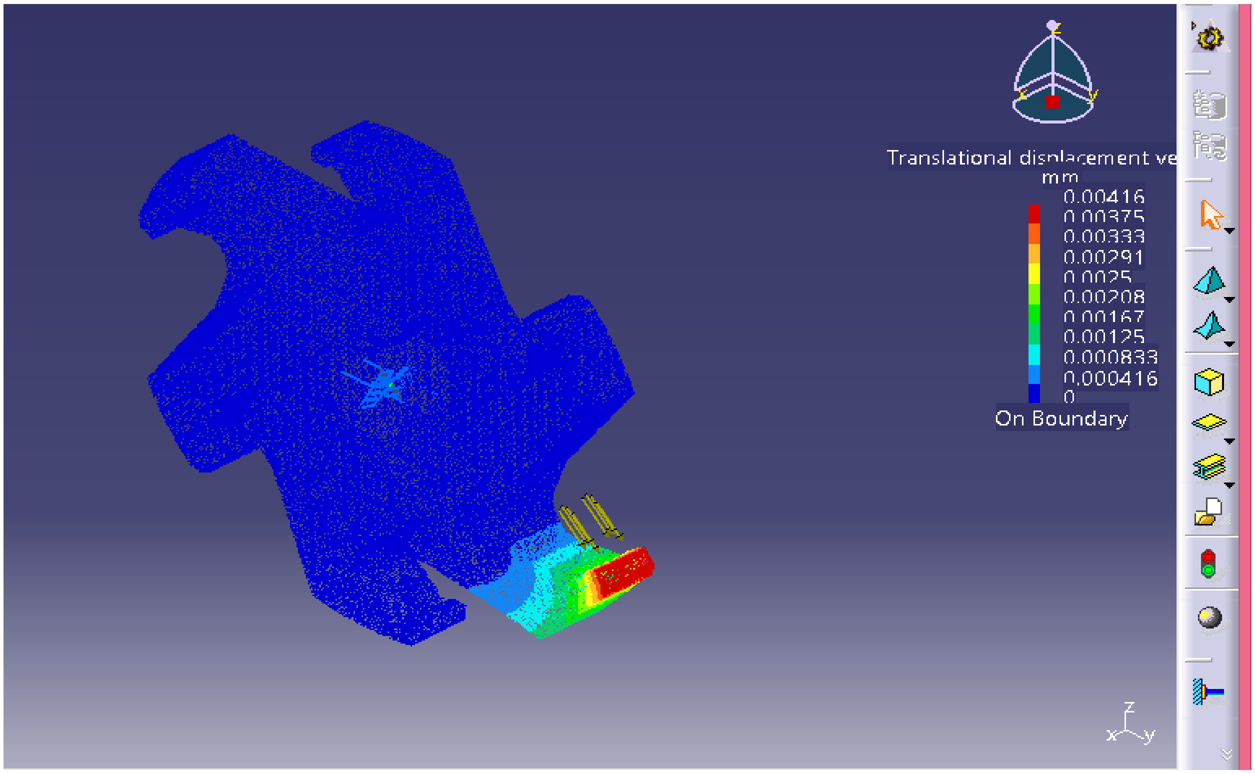
S..
M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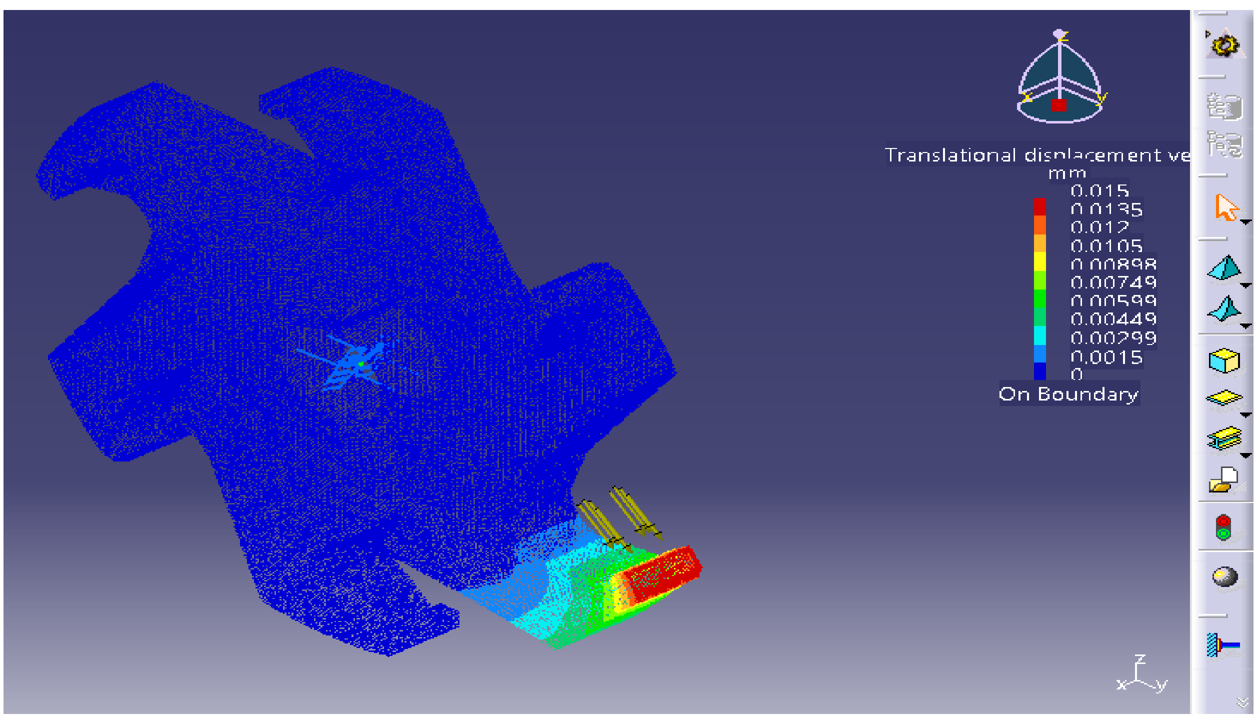
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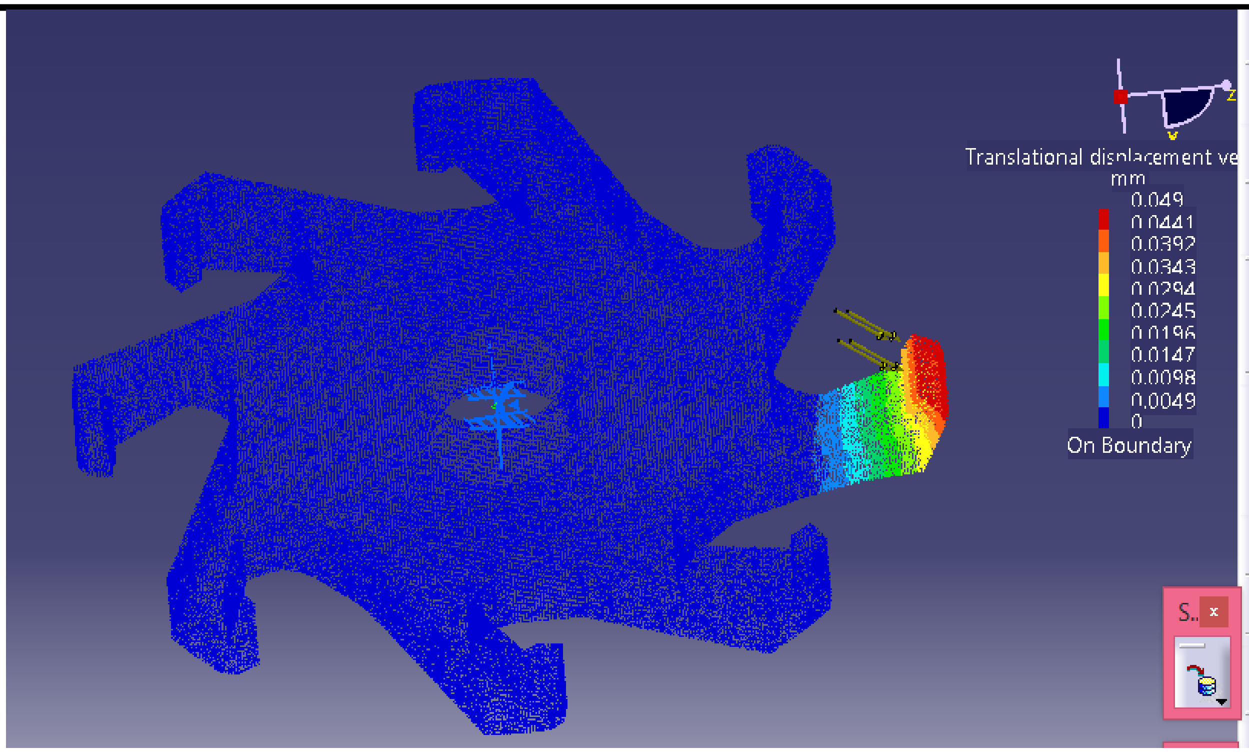
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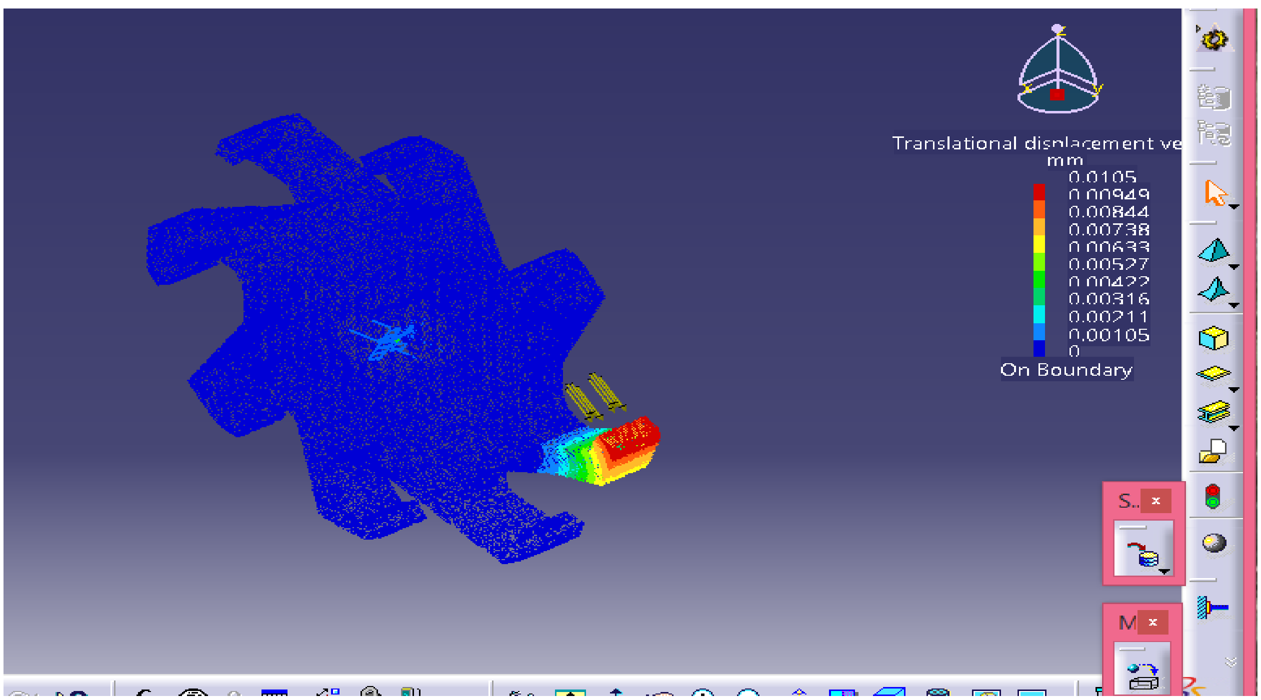
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On Boundary

Figure A-18 Detail drawing of cutter blade number four

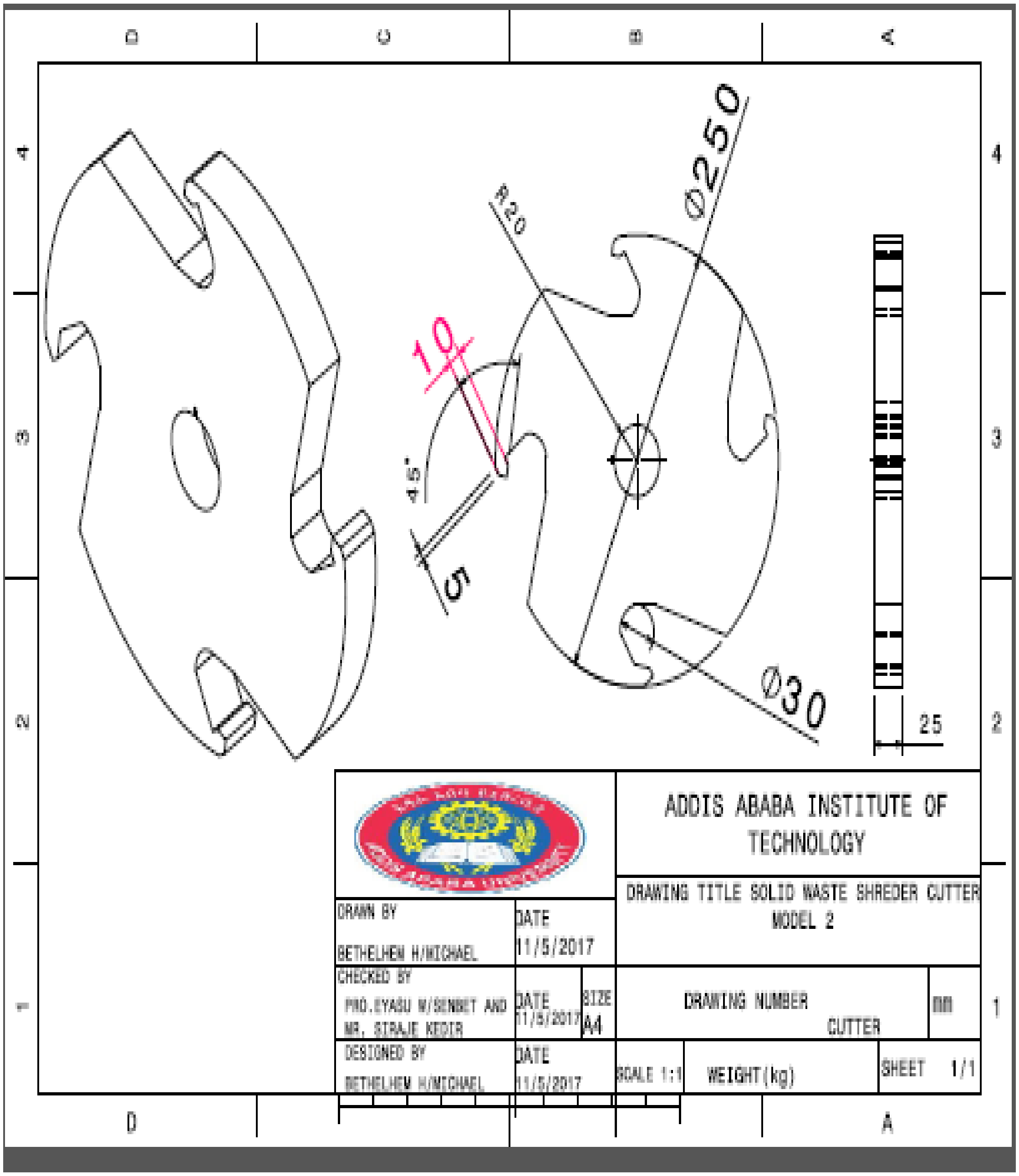


Figure A-19 Detail drawing of cutter blade number six

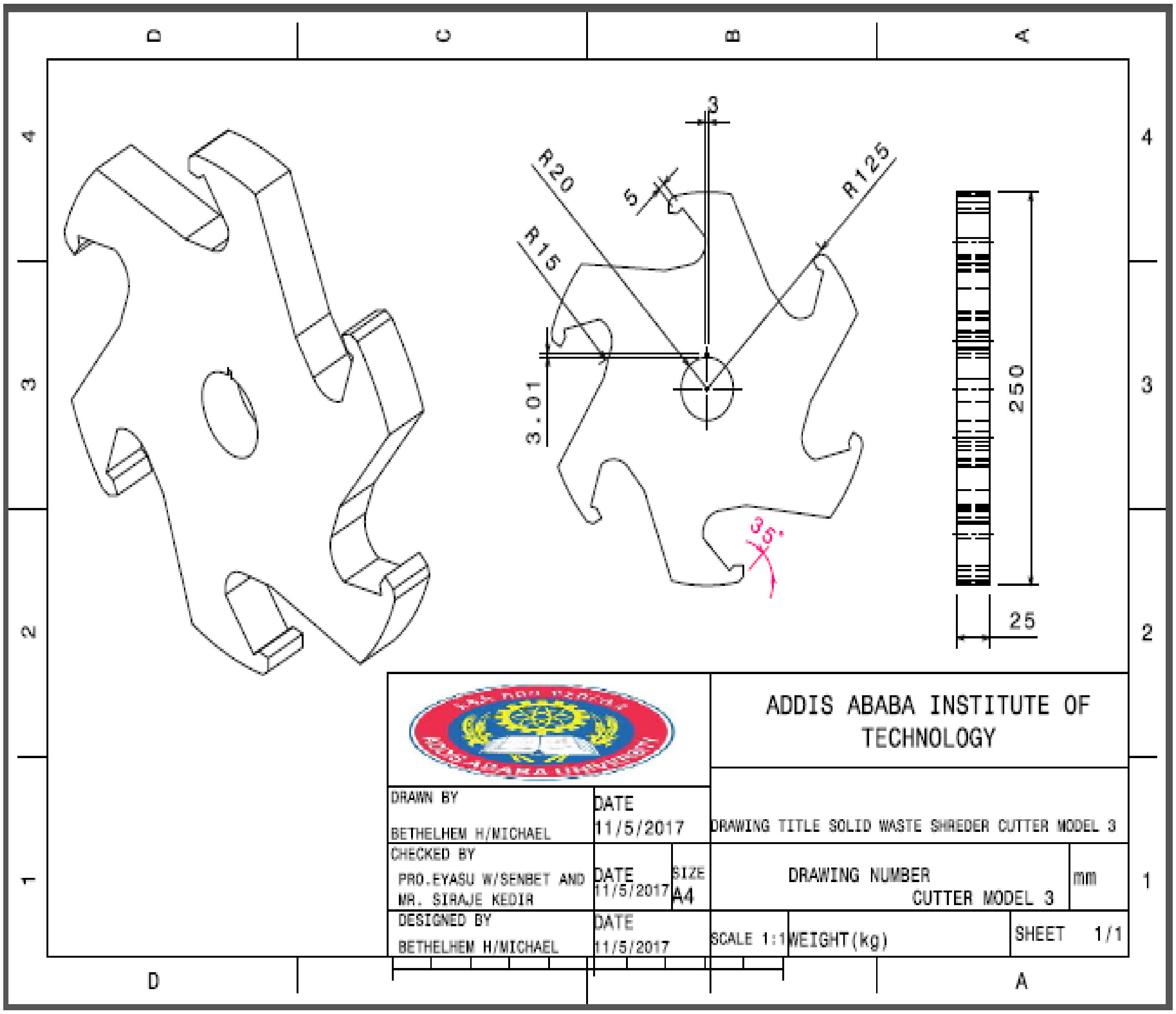
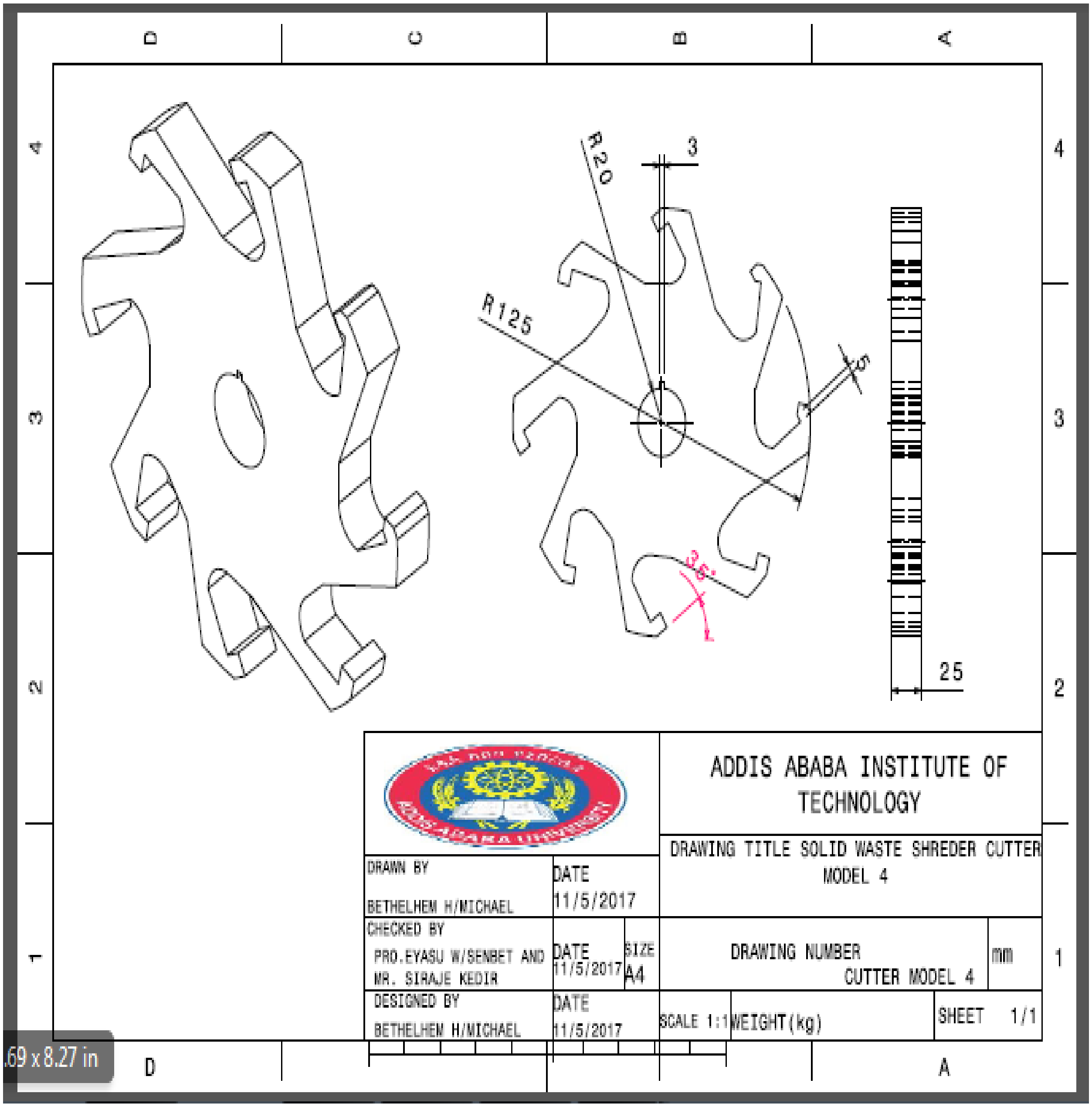


Figure A-20 Detail drawing of cutter blade number eight



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