# DESIGN AND ANALYSIS OF INTEGRATED WET GRINDER AND MIXER GRINDER

[1]N Roopchand Chowdary, [2]Dr. K. Govindarajulu
[1]PG Student, [2]Principal and Professor,
[1]Department of Mechanical Engineering,
[1]JNTUA College of Engineering (Autonomous), Anantapuramu, India.

***Abstract:*** The individual usage of two products for dry and wet grinding increases cost of the product and occupies more floor space. The gain of popularity of multi-functional products in the market has been rising, the customers are shifting from the existing products to multi-functional products to save money and floor space in the kitchen. The objective of the project is to design a product which is capable of doing multiple tasks which means multipurpose or multi-functional product for dry grinding and wet grinding of lentils and pulses. By using Quality function deployment customer requirements are defined and are converted into engineered product. To know the requirement of customers the data collection is done using the questioners. The target customer's requirements are fulfilled by the product that is designed in this project. The integration of two products is designed on the same platform eliminating multi products based on the customer feedback and customer requirements. The concept of the product integration is first modelled using 3D modelling software and the product is analysed for different loads and stresses acting on it. In this project Autodesk Inventor Professional is used for modelling and static analysis of a product model by assuming the necessary loading conditions and thermal analysis which Includes both steady state thermal analysis and transient state thermal analysis is done using SOLIDWORKS software.

***Keywords* – Multifunctional Product, Quality Function Deployment, Static Analysis, Thermal Analysis.**

## I. INTRODUCTION

Wet grinders are most popular kitchen tools in south India that are used to make batter out of the soaked grains and lentils. The Grains and lentil mixture was poured in with water and the cylinder rotated by the motor to grind the food together. The ground paste is used for various food items like idly, dosa, sevai and vada etc. These electric models were first introduced in restaurants and later moved into the home. The homes use table top wet grinder and the restaurants use heavy duty machines for grinding. Unlike conventional grinders, wet grinders are fast as they run on electricity, save time due to quick mechanism and are simple to use due to less effort required.

A Mixer grinder consists of a blades in the jar which are operated with the help of motor at the bottom of the jar provided. Mixer grinder is essentially used to grind the food items that are feed to the jar into powders by chopping them finely by the blades which are operated at high speeds. The items or food that is feed into the jar chopped with the blades can be controlled according to the purpose. Although Mixer Grinder serves the purpose of grinding of lentils and grains and create batter the taste of the food items differ from mixer grinder and wet grinder. So people love to use wet grinder for the perfect texture and taste of the food items like dosa, idly, chutney etc.

As of now everyone is using mixer grinder and wet grinder individually for their requirement. The idea is to design a mixer grinder which runs on the wet grinder by simply removing the wet grinder drum and placing the designed mixer grinder in place of the grinder drum so that it serves the purpose of both wet grinder and mixer grinder. According to the requirement, speed and torque control is done for the specific process. The aim of the project is to design the mixer grinder which fits exactly on the wet grinder after the drum is removed. To make this possible designing of product which serves the purpose of mixer grinder and fits on the wet grinder is done and structural analysis and thermal analysis is conducted on the designed product for the mixer functioning conditions.

## II. LITERATURE SURVEY

The project of integrating mixer grinder and table top wet grinder requires detail study about design, loading, and other factors that impact the design and the analysis of the product. Therefore we need to research on the various aspects of the project such as materials used, heat produced, design of shaft, design and selection of bearing etc. for the study of this project, the investigation is necessary in terms of materials, modelling, cost analysis, finite element techniques and cost of the product.

**Yasemin Tekmen [1]** conducted an analysis to study about evolution of multifunctional kitchen tools in his study. In his study he started with the history of evolution of kitchen and kitchen tools that become necessary and how they become necessary. He mentioned a lot of kitchen tools and their inventions along with patents from the history.

**Ejaz Saleem et al. [2]** explained Design for manufacturing practices for the development of juicer mixer grinder which is the commonly used household device in kitchens and the study is done in order to reduce the cost of the product and the quality of the product. They approached customers and find the problems related to existing product and they tried to reduce the problems such as better design and the cost of the product such that it will be more attractive to the customers.

**Benjamin Rembold [3**] conducted a temperature analysis on the bearing at different speeds and heat generated in ball bearing due to action of friction which is very useful for our study. In his study he found out that faster the rotational speed of the bearing it reaches faster steady state temperature and the bearings did not reach the critical temperature for every study he conducted.

**Mehrotra et al. [4]** they conducted a study on factors affecting the selection of electrical kitchen equipment with the customers of the Ludhiana city where they selected some of the customers from different colonies and asked about the electrical tools in the kitchen and what factors that affect them buying those. In their study the Time and energy saver gives the most desired feature of the electrical equipment in the kitchen. Then they opted Easy to use of the equipment this comes next followed by time and energy saver.

**L.Initha et al. [5]** studied about quality in Wet Grinder Manufacturing Industry through Customer Complaint Investigation. They analysed the problem that customers mentioned and tried to resolve the problem by improving the quality in wet grinding. This steady makes us make some design considerations about our mixer base so that it can efficiently work. The analysis is mainly about longer grinding time which consumes more time and energy of the grinder.

## III. METHODOLOGY

The project is started by collecting the data from the customers and giving them questioners which consists of the features and other questions that are related to the mixer grinders and wet grinders. According to the result that obtained from the review of customers we are designing the product which is helpful for grinding grains, lentils and spices to powder with the help of grinder. The grinder drum is replaced by the product that we design can convert wet grinder into a mixer grinder.

### 3.1. Data Collection

The data collection is the way by which we can understand the design deficiencies in the parts, product, and features from the user's point of view. So collecting the data from the different user by ethnography we can analysis the problem in different way by observing it. After deciding the target customer in the product context study a questionnaire was submitted to some of the wet grinder and mixer grinder users.

### 3.2. QFD (Quality Function Deployment)

QFD is a systematic study & schematic representation of the customer's requirements and the future needs of the customers. This basically fulfil the gap between the customer's requirement and the final product. The features and the benefits of the product for the customers is taken into account. Thus QFD provides a formalized method of linking customer-valued attributes to the engineering, manufacturing, and process decisions that the organization has to implement.

### 3.3. Conversion of customer voice into technical voice

Interviewing the customers the customer's voice was documented and customer's aspiration, frustrations & requirements were understood. Then the customer's voice is converted in technical voice as shown below.

| Customer voice | Need statement | Technical voice |
|---|---|---|
| Multi-purpose | Easy to use | Other accessories easy attachment |
| Move the grinder after use for clean | Easy to carry | Portable |
| Speed | Adjust the speed | Add new feature |
| Attractive | Good looks | Aesthetics |
| Maintenance | Easy to maintain | Spares & service |
| Colour | Good look | Mixing colours |
| Long life | Lost long | Durability |
| More weight | Less weight | Portable |
| Should not harmful to health | Health | Eco friendly |
| Cheap | Economical | Affordable |
| It should have enough strength to with stand, if it falls down | Not easy to break | Material |
| Need assistance for move one place to another place | Less weight | Portable |
| Use like mixer | Provide both option | Using same motor run mixer and grinder |
| Need not buy two | Buy one | Two option |

Table 1. Conversion of technical voice into technical voice

## IV. MODELLING

The model consists of different parts modelled in Autodesk Inventor Professional and assembled together in the same software. The parts that are modelled for the assembly are Mixer Casing, Ball Bearing, Shaft and Coupling, Coupling for Mixer jar The casing is the external part of the model which is placed of the wet grinder rotating part and the motion is transmitted to the shat through coupling. Ball bearing is used to transit the motion from the wet grinder to Mixer grinder. The bearing used for this project is deep grove ball bearing. The selected bearing is SKF6205. The shaft hold the bearing and is connected to the motor output through the coupler provided at the bottom of the shaft as shown in the figure. This coupling is used to transmit motion from wet grinder motor to the mixer jar that is placed on this coupling through the shaft shown in the figure

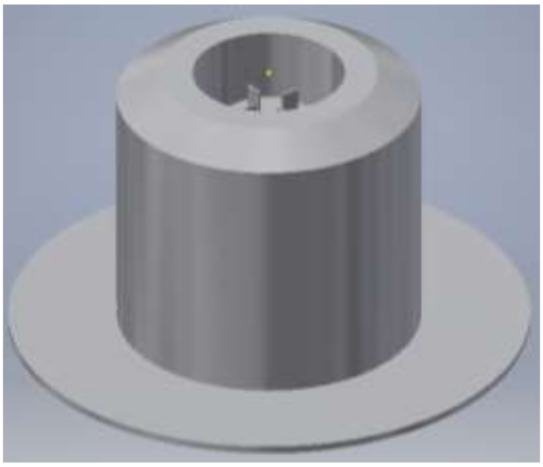

Fig 1. Mixer grinder model

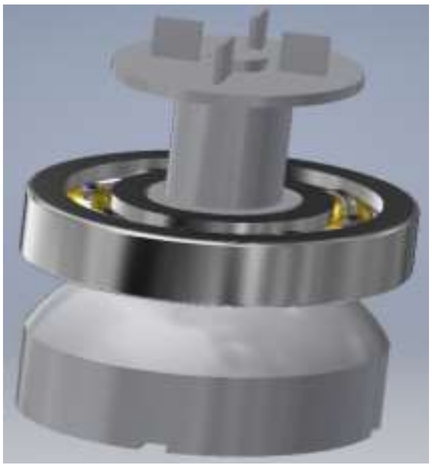

Fig 2. Mixer grinder model with casing visibility off

## V. PROBLEM CALCULATIONS

### 5.1. BEARING CALCULATIONS

The bearing used for this project is deep grove ball bearing. The selected bearing is SKF6205. The assumptions made are axial forces and radial forces acts on the bearing. The magnitude of axial force is 20N. The radial forces magnitude is 20N acting on the bearing.

The following steps are used to calculate the bearing capacity and decide whether bearing can be used or not.

**Step-1: Selection of Bearing**

The select a Deep grove ball bearing for given axial and radial loading and for given speed. The diameter of bearing can be chosen by the diameter of the shaft which is 25mm.

Material: Chrome Steel
Outer diameter = 52mm,
Inner diameter = 25mm,
Width = 15mm,
From the design hand book the values of
X – Radial factor
Y- Thrust factor
$F_a$ - Thrust Load
$F_r$ – Radial Load
e – Bearing constant
Co – Basic static load rating for radial ball or roller bearing
C - Basic dynamic load rating for radial and angular contact ball or radial roller bearing

$L_h$ – Life of bearing in hours – 365*2*15 = 10950 hrs.
Life in hours is calculated for 15 years assuming that it runs two hours a day.
Speed in Rpm – 18000rpm

**Step – 2: Calculation of Equivalent load (P)**

P = (X $F_r$ + Y$F_a$) S
S – Service factor
For rotary with no impact s = 1.1 – 1.5
So we take maximum value for designing
Co = 7800N and C = 14000N from data Hand book
X = 0.56 and Y = 1.0 and $F_a$ / Co = 0.5 from data Hand Book
P = (0.56 * 20 + 1 * 20)1.5 P = 46.8 N

**Step – 3: Checking Bearing Capacity:**

From C/P table in Data hand book using life of bearing and speed in rpm we can evaluate C/P value as 22.9
C/P = 22.9
C = 22.9 * 46.8 = 1071.72 N
1071.72< 14000
1071.72 N is calculated value of Dynamic load rating it is less than dynamic rating from data book. So bearing is safe for this purpose.
So SKF6205 is selected.

**Step – 4: Bearing Reliability:**

For 95% Reliability we can take $p_{10} = 0.95$ and p = 0.90
b - weibull exponent = 1.34

$$\frac{L}{L_{10}} = \left(\frac{\ln\left(\frac{1}{p}\right)}{\ln\left(\frac{1}{p_{10}}\right)}\right)^{1/b}$$

$$\frac{L}{L_{10}} = \left(\frac{\ln\left(\frac{1}{0.95}\right)}{\ln\left(\frac{1}{0.90}\right)}\right)^{1/1.34}$$

$$L_{10} = 10950$$

L= 6399.38 for 95% reliability

From C/P table in Data hand book using life of bearing and speed in rpm we can evaluate C/P value as 18.4 for life of bearing taken as 6399.38 hrs.

C/P = 18.4

C = 18.4 x 46.8

C = 861.12

**5.2. SHAFT CALCULATION**

The objective is to find the deflection of the shaft for the given conditions and check whether it is suitable or not. The bearing is mounted on the shaft.

The material used for the shat is Pet Plastic. The material can with stand forces and deflection.

The Shear Modulus (G) is 123.9 x $10^7$ N/$m^2$

Torque (T) = $\frac{P*60}{2\pi N}$

Power (P) = 750 W

Speed (N) = 18000 Rpm

Torque (T) = $\frac{750*60}{2\pi*18000}$ = 0.397 N m

T = 0.397 N m

The angle of deflection ($\theta$) can be determined by using and equation $\theta = \frac{TL}{JG}$

Here T – Torque

L – Length of the Shaft

J – Polar Moment of Inertia

G - Shear Modulus

The shaft we used has different diameters shaft so the shaft is divided into two parts with

Length $L_1$ = 32mm

Outer diameter $D_1$ = 25mm

Inner diameter $d_1$ = 15mm

Length $L_2$ = 15.46mm

Outer diameter $D_2$ = 21mm

Inner diameter $d_2$ = 15mm

Shear Modulus (G) = 123.9 x $10^7$ N/$m^2$

Polar Moment of Inertia (J) = $\frac{\pi}{32}(D^4 - d^4)$

Where D is outer diameter and d is inner diameter.

$J_1 = \frac{\pi}{32}(25^4 - 15^4) * 10^{-12}$ = 1.412 * $10^{-8}$ $m^4$

$J_2 = \frac{\pi}{32}(21^4 - 15^4) * 10^{-12}$ = 3.3379 * $10^{-8}$ $m^4$

The angle of deflection of shaft can be determined as

$$\theta = \frac{TL_1}{J_1 G} + \frac{TL_2}{J_2 G} = \frac{T}{G}\left(\frac{L_1}{J_1} + \frac{L_2}{J_2}\right)$$

$$\theta = \frac{0.397}{123.9 \text{ x } 10^7}\left(\frac{32 * 10^{-3}}{1.412 * 10^{-8}} + \frac{15.46 * 10^{-3}}{3.3379 * 10^{-8}}\right)$$

$$\theta = 8.74 * 10^{-4^o}$$

The angle of deflection of shaft where torque (T) is transmitted through it is determined as $\theta = 8.74 * 10^{-4^o}$which has minimal deflection because of the load applied.

**5.3. HEAT GENERATION IN BEARING DUE TO FRICTION**

The bearing selected for this project was SKF6205 bearing. The heat generated in the bearing was due to the rolling action of balls and the inner ring and outer ring. So the heat generated is calculated by using the formula

$Q_g$ = μ x W x V

$Q_g$ – Amount of heat generated in N-m/s (or) J/s (or) Watt

μ - Coefficient of friction

W - Load applied on the bearing

V – Rubbing velocity in m/s = $\frac{\pi dN}{60}$

d – Diameter of inner ring

V = $\frac{\pi*25*10^{-3}*18000}{60}$ = 23.56 m/s

Coefficient of friction (μ) for the deep groove ball bearing is 0.0015

W = 46.8N

$Q_g$ = 0.0015 x 46 .8x 23.6 = 1.65 J/s (or) watt

Heat generated in the bearing is $Q_g$= 1.65 J/s

The heat is dissipated into the air by free convection.

The coefficient of convective heat transfer is taken by considering it as free convection so the convective heat transfer coefficient is taken as 25 W/$m^2$-k.

The ambient temperature is taken as $25^o$C.

## VI. MATERIAL PROPERTIES

The materials used for different parts of the model are different. The material used for the bearing is chrome steel, and the material used for the mixer coupling is pet plastic, material used for shaft is also pet plastic. The material used for the mixer casing is analyzed for different materials which are pet plastic, ABS plastic and stainless steel the properties of all these materials are listed in the following tables

**ABS Plastic**

| | |
|---|---|
| Density | 1051.8364 kg/$m^3$ |
| Poisson's Ratio | 0.38 |
| Young's Modulus | 2.24(Gpa) |
| Shear Modulus | 80 x $10^7$ N/$m^2$ |
| Tensile Strength | 20 (Mpa) |
| Yield Strength | 29 (Mpa) |

Table 7.1. Mechanical Properties of ABS Plastic

**Pet Plastic**

| | |
|---|---|
| Density | 1550.0747 kg/$m^3$ |
| Poisson's Ratio | 0.42 |
| Young's Modulus | 27.57 (Gpa) |
| Shear Modulus | 123.9 x $10^7$ N/$m^2$ |
| Tensile Strength | 55.1 (Mpa) |
| Yield Strength | 54.3 (Mpa) |

Table 7.2. Mechanical Properties of Pet Plastic

**Chrome Steel**

| | |
|---|---|
| Density | 7726934 kg/$m^3$ |
| Poisson's Ratio | 0.3 |
| Young's Modulus | 204 (Gpa) |
| Shear Modulus | 80 (Gpa) |
| Tensile Strength | 400 (Mpa) |
| Yield Strength | 250 (Mpa) |

Table 7.3. Mechanical Properties of Chrome Steel

**Stainless Steel**

| | |
|---|---|
| Density | 7999.49kg/$m^3$ |
| Poisson's Ratio | 0.3 |
| Young's Modulus | 192.9 (Gpa) |
| Shear Modulus | 85.9 (Gpa) |
| Tensile Strength | 539 (Mpa) |
| Yield Strength | 250 (Mpa) |

Table 7.4. Mechanical Properties of Stainless Steel

## VI. STRUCTURAL ANALYSIS PROCEDURE:

The stress analysis is done in the Autodesk Inventor Professional software. After modelling the product the stress analysis is started with the following steps.

1. After the modelling is done the stress analysis setup is made in the environments option. The environment contains different options. There are different options available like frame analysis, stress analysis, inventor studio etc. from there select stress analysis. After that create a study on clicking create study.
2. To define the material properties select the part which we need to define the material and then select the material from the material menu. There are different varieties of materials available for analysis.
3. After selecting the material properties define the mesh properties from the mesh menu and click the mesh view which create the mesh for the given model.
4. The boundary conditions such as fixture are applied and then loadings like pressure, force and moment are applied for the model and then run a simulation to study the model.

## VII. MESHING THE MODEL:

The process of splitting the given geometry into smaller subdomains made up of geometric primitives like hexahedral, tetrahedral in 3D and triangles in 2D in order to study with more details of the geometry is called meshing. The subdomains are called often elements or cells and the collection of all the cells or elements is called as a mesh or grid.

The elements or cells that are produced in meshing in the Autodesk Inventor Professional software are tetra 10(4 physical points and 10 nodes for the interpolation). These are volumetric element with no shell and no beam.

The 3D mesh in Autodesk Inventor Professional is produced by clicking the Mesh view in the main menu as shown in the figure below. The mesh is produced with given settings such as average element size, maximum turning angle etc. The mesh density automatically increase in the intricate shapes.

Type of element: Solid tetra 10
Number of Nodes: 148079
Number of elements: 92614

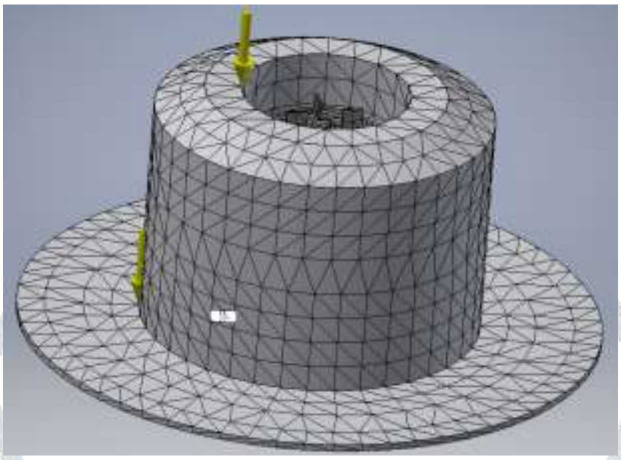

Fig 3: Mesh Model of the Mixer grinder

## VIII. BOUNDARY CONDITIONS AND LOADS

The boundary conditions for this models are fixtures and gravity acting on the model. The loads acting are the load that is applied on the top of the model. In this case load is the mixer jar with lentils in it. The load is assumed as 30N of the top of the model. Another load is moment load at the coupling of the shaft. The moment is calculated as 397 N-mm. Boundary conditions are Gravity: as 9.81 m/$s^2$ and a fixture at the bottom.

| Load Type | Value |
|---|---|
| Force | 30 N |
| Moment | 397 N |

Table 6: Loads acting on the model

## IX. STRUCTURAL ANALYSIS

The structural analysis procedure is explained in the structural analysis procedure. The analysis is done using Autodesk Inventor Professional software. The first step in the analysis is meshing the meshing. After meshing the boundary conditions like fixtures of the model, gravity that is applied on the model, loads such as Force, Moment are applied on the model. The force is assumed as 30 N. and the moment is calculated as 397 N-mm.

### 9.1. Von Mises stress:

**a. Mixer grinder with pet plastic casing**

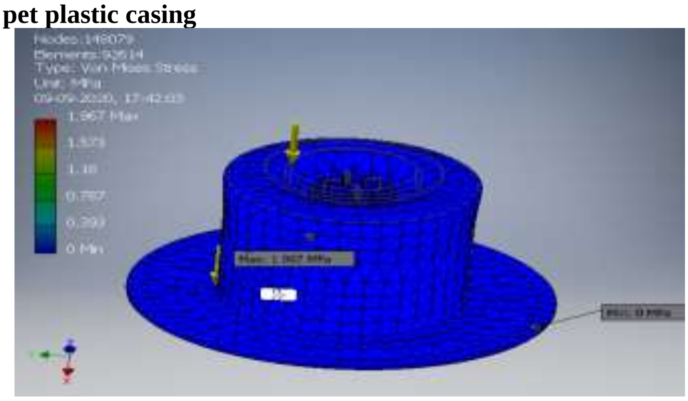

Fig: 4. Vonmises stress contour of mixer grinder with pet plastic casing

**b. Mixer grinder with ABS plastic casing**

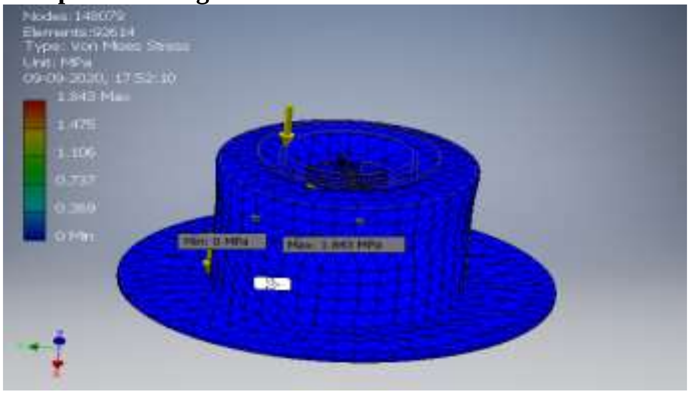

Fig: 5. Vonmises stress contour of mixer grinder with ABS plastic casing

**c. Mixer grinder with stainless steel casing**

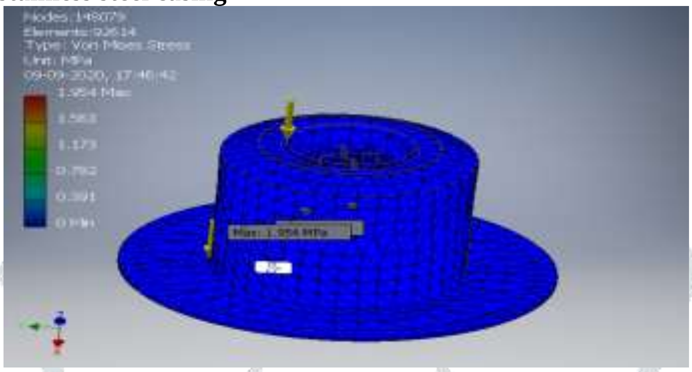

Fig: 6. Vonmises stress contour of mixer grinder with stainless steel casing

**9.2. Displacement:**

**a. Mixer grinder with pet plastic casing**

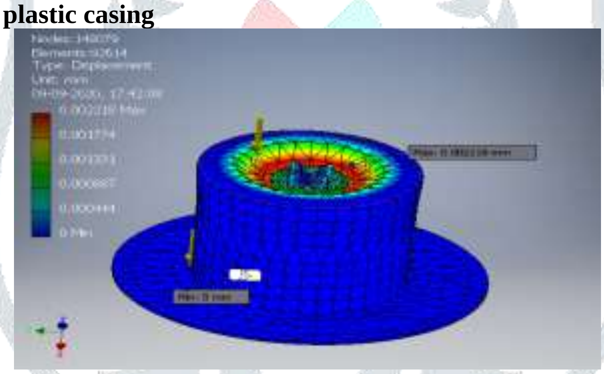

Fig: 7. Displacement contour of mixer grinder with pet plastic casing

**b. Mixer grinder with ABS plastic casing**

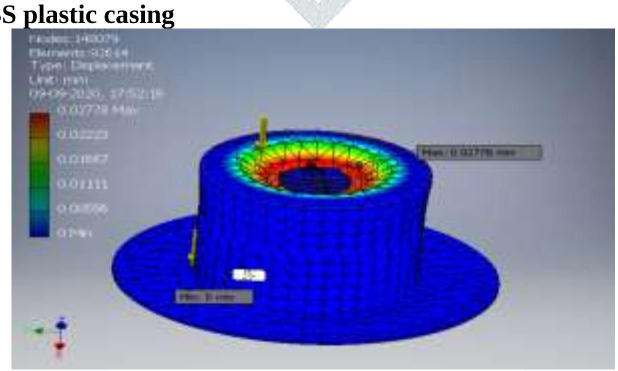

Fig: 8. Displacement contour of mixer grinder with ABS plastic casing

**c. Mixer grinder with stainless steel casing**

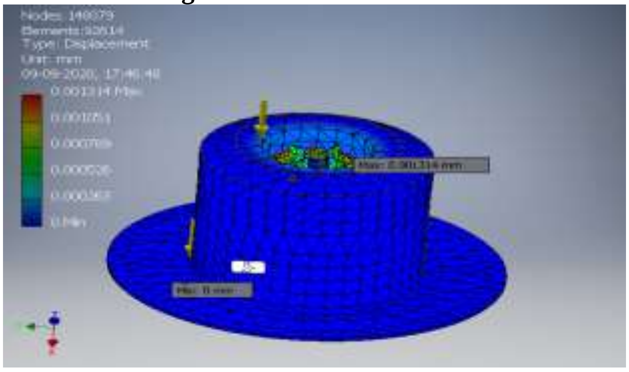

Fig: 9. Displacement contour of mixer grinder with stainless steel casing

## X. THERMAL ANALYSIS

For this project we are using SOLID WORKS for the thermal analysis. We did both steady state and transient state analysis for the bearing inner ring in order to find out the maximum or critical temperature. The boundary conditions applied are the heat generated in the bearing and the convective heat transfer into the air.

The heat generated is due to the friction in bearing and is calculated in the above calculations and is found that heat generated is $Q_g$= 1.65 watt. The calculated heat generation and the convection coefficients which is due to free convection of air were applied now to the model.

### 10.1. Steady State thermal analysis:

The boundary conditions that are applied are heat generated is $Q_g$= 1.65 watt at the inner groove part of the ring where friction occurs due to the rolling action of balls and the inner ring. The convection is assumed as free convection with air and the convection coefficient is 25 W/$m^2$-k. The ambient temperature is taken as $25^oC$.

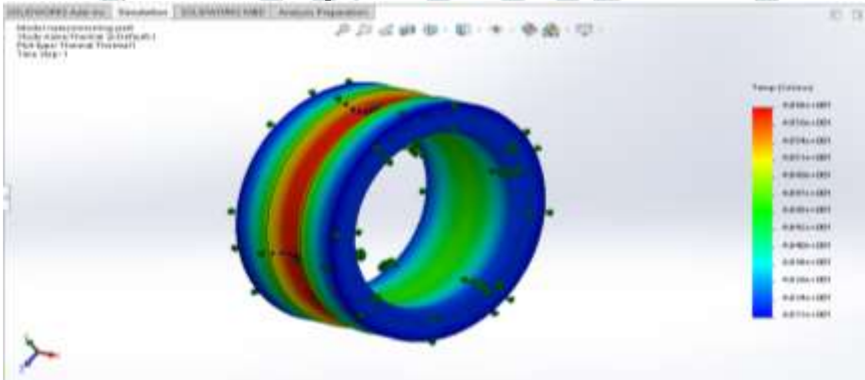

Fig 10. Results of steady state thermal analysis of bearing inner ring.

The maximum temperature occurred at the groove in the inner ring which is $48.58^oC$ which is comparatively low and is in the range of operating temperature of bearing. Generally ball bearings are heat stabilized up to $120^oC$. So the bearings are in the stabilized condition as the temperature generated is low.

### 10.2. Transient State thermal analysis:

The boundary conditions that are applied are heat generated is $Q_g$= 1.65 watt at the inner groove part of the ring where friction occurs due to the rolling action of balls and the inner ring. The convection is assumed as free convection with air and the convection coefficient is 25 W/$m^2$-k. The ambient temperature is taken as $25^oC$. The properties are changed and the transient state is selected and the time is given as the 180seconds which is the normal operating time of the mixer grinder and maximum suggested time. The increment time is given as 15 seconds we get 12 steps in this study.

The maximum temperature after 15 sec in transient state thermal analysis is shown as the $28.37^oC$. The temperature is in the operating range of the bearing so the effect of thermal is minimal in this case. The maximum temperature after 180 sec in transient state thermal analysis is shown as the $38.09^oC$. Even after 180 sec of operation time the temperature is in the operating range of the bearing so the effect of thermal is minimal in this case also.

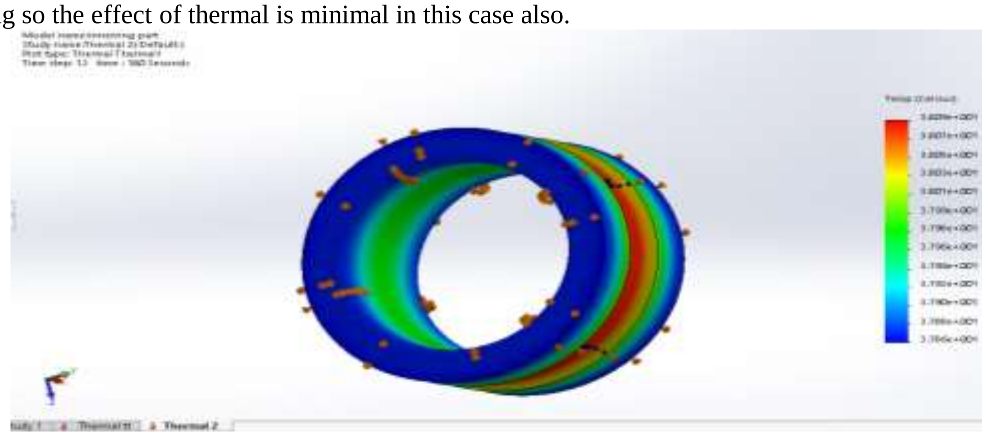

Fig 11. Results of Transient state thermal analysis of bearing inner ring at 180sec.

## XI. RESULTS AND DISCUSSION

The mixer is designed and analysis is done for different material for the casing the different materials used in the analysis are Pet Plastic, ABS Plastic and Stainless Steel.

The Stress concentration for the given load on the material ABS plastic is low compared to stainless steel and Pet Plastic. Even though the displacement is high in ABS Plastic comparatively its minimal displacement. So on the basis of the stresses that applied on the model. Due to the mass constraint and the poor electrical properties stainless steel cannot be used for the casing and the impact resistance, heat, chemical and abrasion resistance of the ABS plastic the casing material is taken as ABS plastic. So the final selected materials for the model are

Mixer casing: ABS Plastic
Shaft: Pet Plastic
Mixer Coupling: Pet Plastic
Bearing: Chrome Steel

| | Pet Plastic | ABS Plastic | Stainless Steel |
|---|---|---|---|
| **Stress (Mpa)** | 1.967 | 1.843 | 1.954 |
| **Displacement(mm)** | 0.002218 | 0.02778 | 0.001314 |
| **Mass (Kg)** | 0.8086 | 0.6269 | 3.2484 |

Table 7. Results of stress analysis for different models

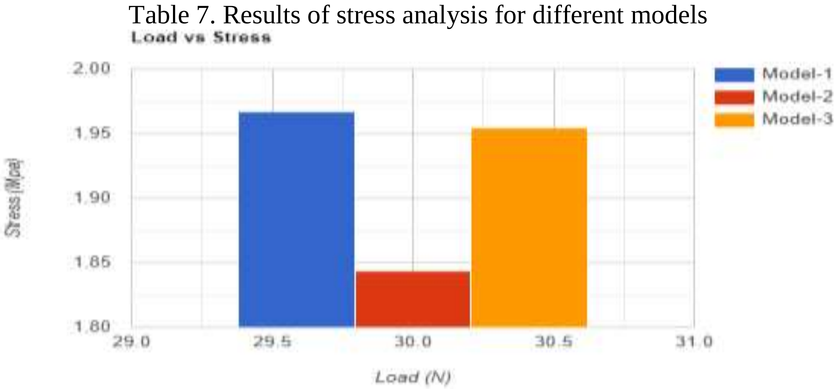


Fig 12. Load vs. Stress graph

The thermal analysis on the inner ring of the bearing is done where the friction is present between balls and the inner ring. The maximum temperature rise at the ball and the inner ring due to the heat is taken from the thermal analysis and it is found as $48.58^{o}$C. The bearings are heat stabilized up to $120^{o}$C. So the design is in below the range of critical temperature.

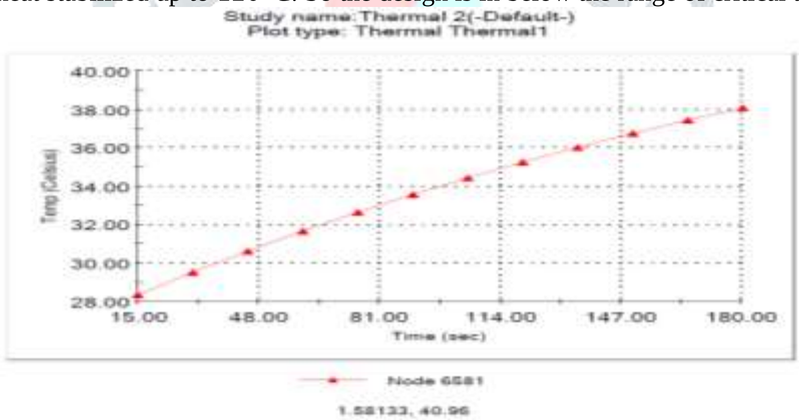


Fig 13. Plot of Temperature vs. Time at the point of maximum heat generated

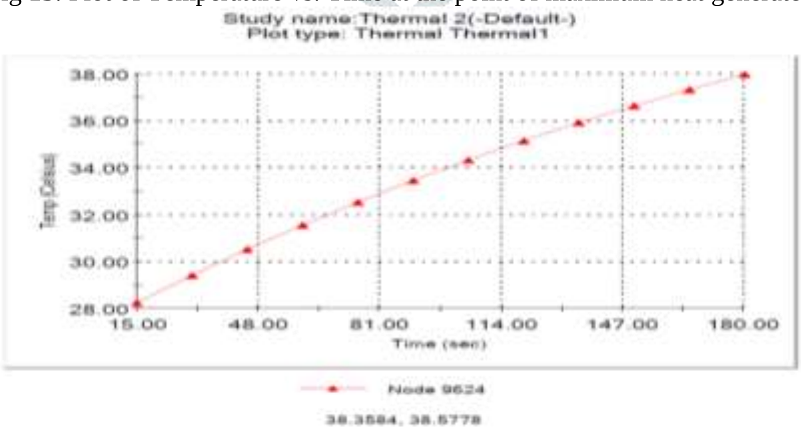


Fig 14. Plot of Temperature vs. Time at the point of minimum heat generated

The plots were taken at the point of contact of the ball and inner ring where maximum heat is generated. The plots are a part of transient state thermal analysis so the plot is made for time vs. Temperature. At the start of the study the inner ring is at ambient temperature at the end of the study the temperature reaches to $38.09^{o}$C. As mentioned earlier the bearings are heat stabilized up to $120^{o}$C. The model is in the range of safe temperature.

## XII. CONCLUSIONS

The mixer is designed which can make the wet grinder multifunctional kitchen tool which is used for both wet grinding and dry grinding can be done by choosing drum for wet grinder which is the existing product and the dry grinding can be done by using the designed product.

The materials are chosen as ABS plastic for the casing which is impact resistance and electrical proof. The bearing chosen is SKF6205 bearing which is made of chrome steel. The shaft and the mixer coupling materials chosen are pet plastic.

The thermal analysis results shown that the product is operated under the critical temperature which is safe for the operation.

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