

# Stress and Strain Analysis on Extruder Auger Assembly in Static Condition

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**ABSTRACT:** Ceramic materials can be shaped in a plastic, liquid or pulverized state. For a long time the plastic forming was the only way, in an early stage supported by plastering molds. In 1753 crucibles were produced in a screw press, and in 1745 casting in plaster molds started in England – at first without electrolytes; these were patented in France in 1788. For this process of ceramic molding an instrument which is used in a present days is PUG MILL. It is used to extrude the ceramic clay for producing the raw material of an insulator used in the Electricity Board. This paper summarizes the history of the pug mill, its specification and working conditions. But the actual power requirement to run this pug mill is a main constraints, so in this paper the required power is a calculated by taking constraint parameters.[4][5]

**KEYWORDS:** PUG Mill, Extruder, Pre Pugging, Main Pugging, Auger Assembly

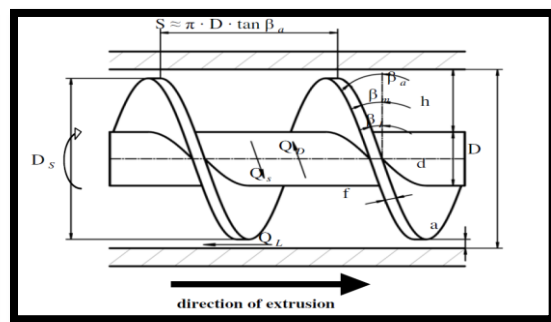
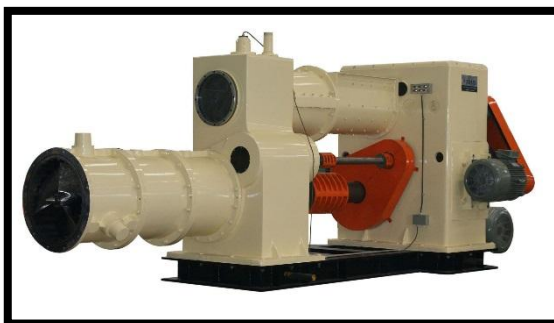
## I. INTRODUCTION

Pug mill is a closed extruder in which, the cake of any required products clay is inserted and at the other end we get the final product in various form shapes which we required, i.e. in circular form, in quadratic shape and many more. Mainly the pug mill is used for the production of ceramic insulator which we are using in the power transmission line, in brick from which having high strength and improved material properties then the normal brick.

Earlier it was used in many countries for chocolate making at home itself and then it used at many places like for brick making, for conveying any semi solid materials from one end to other end by converting into any shape. And now a day's many ceramic industries are using this pug mill for raw material production of ceramic insulator.

But many pug mill manufacturing industries are confused for what the exact amount of motor power is required to run the main auger assembly of the pug mill, and so they are randomly select the motor rating and due to which the manufacturing cost of the pug mill is increased in its initial phase itself.

## CONCEPT



The actual utilization of the pug mill is in ceramic industry for manufacturing of raw material of ant geometrical shaped product. A pug mill has been tested in France in 1800 and as early as 1813 extruded perforated bricks have been produced in England. Across the channel in 1833 the first screw extruder has been invented, and in 1852 it was England again by working with the first piston press. In1855 the German scientist Schlickeysen invented the vertical

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and in 1865 the horizontal working extruder. The deciding breakthrough to the working under vacuum was reached in the United States with a patent (1902) and the first vacuum extruder (1922).<sup>[3]</sup>

## II. PROCEDURE

There are so many ranges of the extruder barrel for production of different ceramic items with different sizes. Only the most important and commonly used types of extruders and combined de-airing extrusion machines have been listed in this contribution. Bearing in mind the vast variety of options available on the market, there is no pretense to completeness. Especially prototype machines or those special designs that are only suitable for specific applications have not been taken into consideration. But the size of the specifically for the ceramic insulator industries the manufacturer are using 700 mm diametrical shape at the final end and they used many types of barrels to minimize the final diameter of the product. And for this power calculation I reviewed both criteria,

1. Analytical Calculation for the auger assembly from which I resolve the force applied on assembly,
2. Applying these force on the auger assembly by using design software's for stress and strain analysis

## NOMECLATURE

Diameter	Length
D <sub>JB</sub> Diameter of Jacketed Barrel	L <sub>JB</sub> Length of Jacketed Barrel
DRB <sub>1</sub> Diameter of Ribbed Barrel 1	LRB <sub>1</sub> Length of Ribbed Barrel 1
DRB <sub>2</sub> Diameter of Ribbed Barrel 2	LRB <sub>2</sub> Length of Ribbed Barrel 2
DRB <sub>3</sub> Diameter of Ribbed Barrel 3	LRB <sub>3</sub> Length of Ribbed Barrel 3
DCTB <sub>1</sub> Diameter of Taper Barrel 1	LTB <sub>1</sub> Diameter of Taper Barrel 1
DDTB <sub>1</sub> Diameter of Taper Barrel 1	
DCTB <sub>2</sub> Diameter of Taper Barrel 2	LTB <sub>2</sub> Length of Taper Barrel 2
DDTB <sub>2</sub> Diameter of Taper Barrel 2	
DPB <sub>1</sub> Diameter of Plain Barrel 1	LPB <sub>1</sub> Length of Plain Barrel 1
DPB <sub>2</sub> Diameter of Plain Barrel 2	LPB <sub>2</sub> Length of Plain Barrel 2
DPB <sub>3</sub> Diameter of Plain Barrel 3	LPB <sub>3</sub> Length of Plain Barrel 3
Volume	Frictional Area
V <sub>JB</sub> Volume of Jacketed Barrel	F <sub>AJB</sub> Frictional Area of Jacketed Barrel
VRB <sub>1</sub> Volume of Ribbed Barrel 1	FARB <sub>1</sub> Frictional Area of Ribbed Barrel 1
VRB <sub>2</sub> Volume of Ribbed Barrel 2	FARB <sub>2</sub> Frictional Area of Ribbed Barrel 2
VRB <sub>3</sub> Volume of Ribbed Barrel 3	FARB <sub>3</sub> Frictional Area of Ribbed Barrel 3
VTB <sub>1</sub> Volume of Taper Barrel 1	FATB <sub>1</sub> Frictional Area of Taper Barrel 1
VTB <sub>2</sub> Volume of Taper Barrel 2	FATB <sub>2</sub> Frictional Area of Taper Barrel 2
VPB <sub>1</sub> Volume of Plain Barrel 1	FAPB <sub>1</sub> Frictional Area of Plain Barrel 1
VPB <sub>2</sub> Volume of Plain Barrel 2	FAPB <sub>2</sub> Frictional Area of Plain Barrel 2
VPB <sub>3</sub> Volume of Plain Barrel 3	FAPB <sub>3</sub> Frictional Area of Plain Barrel 3
Weight	
W <sub>JB</sub> Weight of Material in Jacketed Barrel	
WRB <sub>1</sub> Weight of Material in Ribbed Barrel 1	
WRB <sub>2</sub> Weight of Material in Ribbed Barrel 2	
WRB <sub>3</sub> Weight of Material in Ribbed Barrel 3	
WPB <sub>1</sub> Weight of Material in Plain Barrel 1	
WTB <sub>1</sub> Weight of Material in Taper Barrel 1	
WTB <sub>2</sub> Weight of Material in Taper Barrel 2	
WPB <sub>2</sub> Weight of Material in Plain Barrel 2	
WPB <sub>3</sub> Weight of Material in Plain Barrel 3	
Other	
ρ <sub>max</sub> Maximum Density of Ceramic Material (3200 kg/m <sup>3</sup> )	

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$\rho_{min}$ Minimum Density of Ceramic Material (2800 kg/m <sup>3</sup> )
g Gravitational Force
L/D Pressure Ratio of Extruder
Fmax Total force exerted on shaft
(Mt)f Torque Transmitting by Friction
$\mu$ Coefficient of Friction

Before calculating the force acting on the auger assembly the data of density which we used for the ceramic insulator material is 3200 kg/m<sup>3</sup> maximum and minimum is 2800 kg/m<sup>3</sup> which is authenticated by CGCRI.

### III. CALCULATION

Volume	Frictional Area
V <sub>JB</sub> = 0.4477 m <sup>3</sup> , Total volume of jacketed barrel	F <sub>AJB</sub> = 1.3923 m <sup>2</sup> , Frictional Area of Jacketed Barrel
V <sub>RB1</sub> = 0.2161 m <sup>3</sup> , Total volume of ribbed barrel 1	F <sub>ARB1</sub> = 1.3872 m <sup>2</sup> , Frictional Area of ribbed Barrel 1
V <sub>RB2</sub> = 0.2129 m <sup>3</sup> , Total volume of ribbed barrel 2	F <sub>ARB2</sub> = 1.914 m <sup>2</sup> Frictional Area of ribbed barrel 2
V <sub>RB3</sub> = 0.2099 m <sup>3</sup> Total volume of ribbed barrel 3	F <sub>ARB3</sub> = 2.2165 m <sup>2</sup> Frictional Area of ribbed barrel 3
V <sub>PB1</sub> = 0.2209 m <sup>3</sup> Total volume of plain barrel 1	F <sub>APB1</sub> = 1.1781 m <sup>2</sup> Frictional Area of plain Barrel 1
V <sub>TB1</sub> = 0.1252 m <sup>3</sup> Total volume of tapered barrel 1	F <sub>ATB1</sub> = 1.536 m <sup>2</sup> Frictional Area of tapered Barrel 1
V <sub>TB2</sub> = 0.0517 m <sup>3</sup> Total volume of tapered Barrel 2	F <sub>ATB2</sub> = 0.9135 m <sup>2</sup> Frictional Area of tapered Barrel 2
V <sub>PB2</sub> = 0.0452 m <sup>3</sup> Total volume of plain Barrel 2	F <sub>APB2</sub> = 0.4532 m <sup>2</sup> Frictional Area of plain Barrel 2
V <sub>PB3</sub> = 0.0452 m <sup>3</sup> Total volume of plain Barrel 3	F <sub>APB3</sub> = 0.4532 m <sup>2</sup> Frictional Area of plain Barrel 3

Weight of the material inside the barrel (For Max. Density):
W <sub>JB</sub> = 14054.20 N
W <sub>RB1</sub> = 6783.81 N
W <sub>RB2</sub> = 6683.35 N
W <sub>RB3</sub> = 6589.18 N
W <sub>PB1</sub> = 6934.5 N
W <sub>TB1</sub> = 3930.27 N
W <sub>TB2</sub> = 1622.96 N
W <sub>PB2</sub> = 1418.91 N
W <sub>PB3</sub> = 1418.91 N
<b>Total weight inside the barrel: 49.436 KN</b>

Total force exerted on shaft is equal to the total maximum weight of material inside the barrel is 49.436 KN. There is provision of screen plate having a 614 no. of holes with size of 20 mm from total size of 700 mm, so the total area of passing the clay is only 1.75% of the 700 mm. So the back force is applied on the auger assembly is,

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$$49.436 \times 1.75 = 86513.16 \text{ KN}$$

This Screw extruder is working as a friction disk with number of springs so the pressure can be assumed to be uniformly distributed over the entire surface of the extruder disk (i.e. An Auger Assembly). So from the uniform pressure theory the torque transmitting capacity is calculated by the equation.<sup>[2]</sup>

$$(M_t)_f = \left(\frac{\mu P}{3}\right) \times \frac{(D^3 - d^3)}{(D^2 - d^2)} \times n$$

Where,  $(M_t)_f$  = torque transmitting by friction

D = Outer Diameter of friction disk in meter = 0.730 m

d = Inner Diameter of friction disk in meter = 0.215 m

P = Total Operating Force in Newton = 86513.16 N = 86.513 KN

$\mu$  = Coefficient of friction between SS Liner & ceramic raw material i.e. 0.4

n = Number of extruder disks = 4

$$(M_t)_f = \left(\frac{0.4 \times 86513.15}{3}\right) \times \frac{(0.730^3 - 0.215^3)}{(0.730^2 - 0.215^2)} \times 4$$

$$(M_t)_f = 35938.71 \times 3 = 107816.14 \text{ N.m}$$

So required motor power in KW is

$$P = 2\pi \times 8 \times 107816.1460 \times 103$$

$$P = 90.32 \text{ KW} \approx 95 \text{ KW}$$

Now same as for the minimum density

Weight of the material inside the barrel (For Min. Density):
$W_{JB} = 12297.42 \text{ N}$
$W_{RB1} = 5935.83 \text{ N}$
$W_{RB2} = 5847.93 \text{ N}$
$W_{RB3} = 5765.53 \text{ N}$
$W_{PB1} = 6067.68 \text{ N}$
$W_{TB1} = 3438.99 \text{ N}$
$W_{TB2} = 1420.09 \text{ N}$
$W_{PB2} = 1241.55 \text{ N}$
$W_{PB3} = 1241.55 \text{ N}$
<b>Total weight inside the barrel: 43.202KN</b>

$$43.202 \times 1.75 = 75.60 \text{ KN}$$

And so on the torque transmitting capacity for the minimum dense material is,

$$P = 78.93 \text{ KW} \approx 80 \text{ KW}$$

In real practical aspects the industries are preferring the power source on random basis, means they are choosing either 120 KW, 150 KW or many more. So from the above two calculations we can reviewed that the existence practice is increases the manufacturing cost of equipment from the initial level.

## IV. ANALYSIS OF CRITICAL COMPONENT

In the pug mill the most critical component is an auger assembly so when the maximum load will apply on the auger assembly that time the maximum possibility of failure of this auger assembly by failing the auger face or bay breaking the shaft from its auger connection point during the ongoing process due the excessive starting torque of the prime mover by preferring randomly and so here after reviewing the analytical values the analysis has been carried out by using design software.

### Materials Specification of Critical Component:

Material Properties of Shaft Material	
Material Name: EN8	
Type	Isotropic
Density	7.8e-09 kg/mm <sup>3</sup>
Young's Modulus	2e+08 KPa
Poisson's Ratio	0.27
Conductivity	43012.5 mm kg / (sec <sup>3</sup> C)
Specific Heat	4.73341e+08 mm <sup>2</sup> / (sec <sup>2</sup> C)
Thermal Expansion	1.17e-05 (/C)
Shear Stiffness	7.87402e+07 KPa
Failure Criteria	None

For the minimum force 75600 N

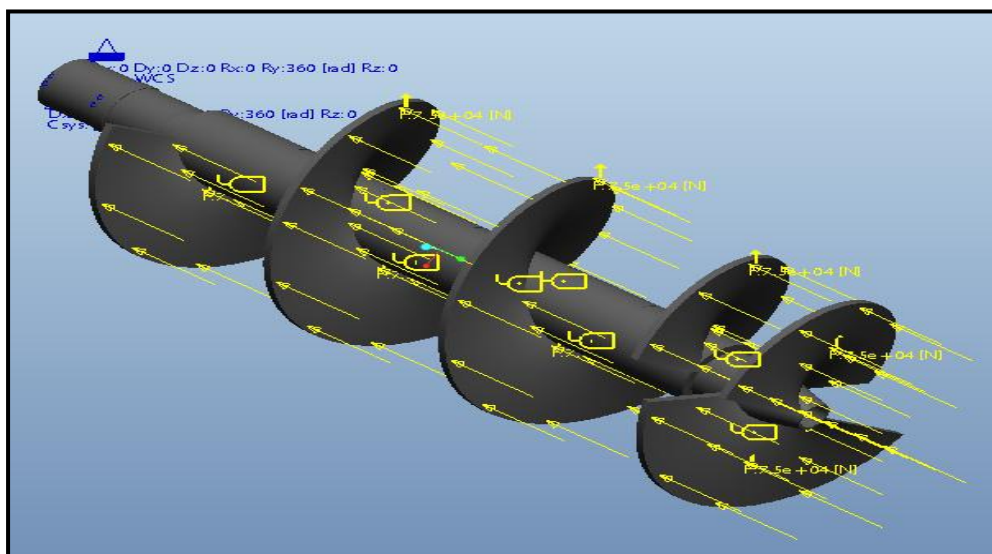


Fig. 4.1 Loading condition at 75600 N

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Loading conditions on Structure	
Type	Force/Moment
Coordinate System	WCS
Distribution	Varying Load
Spatial Variation	Uniform
Force Components	Fx = 0, Fy = -75600 N, Fz = 0
Constraint applied to Component	
Type	Displacement
References	Surface of SHAFT
Coordinate System	WCS for AUGERSASSWMBLY
Displacement	Dx : Fixed Dy : Fixed Dz : Fixed
Rotation	Rx : Fixed Ry : 360[rad] Rz : Fixed
Properties	Angular and Axial : Fixed

### Stress analysis at 75600 N

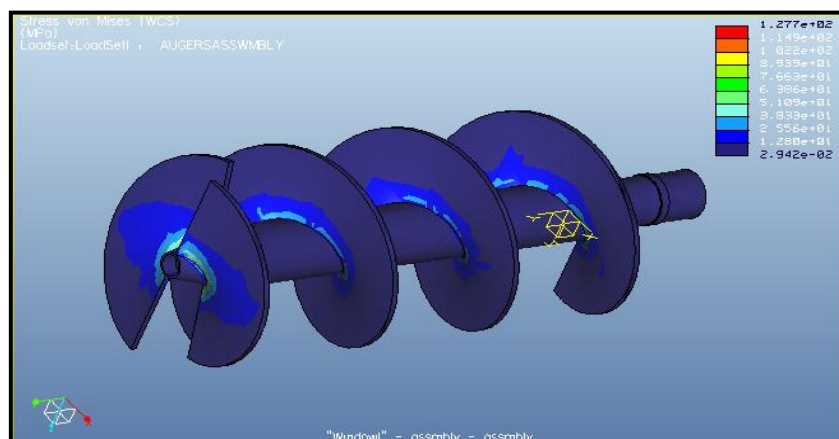


Fig 4.2 Stress analysis at 75600 N

Generated Results of Stress Analysis at 75600 N	
Maximum Principal Stress	174321 Mpa
Maximum Von Mises Stress	127690 Mpa
Maximum stress along XX axis	-90057.5 Mpa
Maximum stress along XY axis	-41733.8 Mpa
Maximum stress along XZ axis	-33974 Mpa
Maximum stress along YY axis	152445 Mpa
Maximum stress along YZ axis	-54034 Mpa
Maximum stress along ZZ axis	-102036 Mpa
Minimum Principal Stress	-162453 Mpa

**Displacement Analysis at 75600 N**

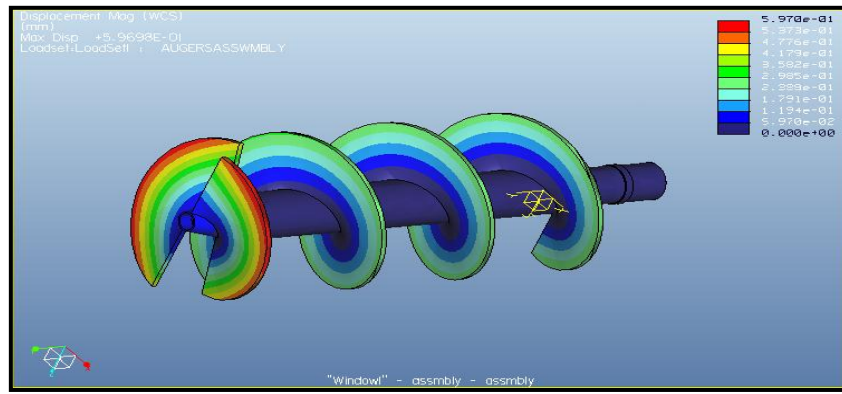


Fig 4.3 Displacement analysis at 75600 N

Generated Results of Displacement Analysis at 75600 N	
maximum displacement Magnitude	0.596978 mm
Maximum displacement in X Direction	-0.32353 mm
Maximum displacement in Y Direction	-0.532691 mm
Maximum displacement in Z Direction	-0.266805 mm

**For the maximum loading condition:**

Loading conditions on Structure	
Type	Force/Moment
Coordinate System	WCS
Distribution	Varying Load
Spatial Variation	Uniform
Force Components	$F_x = 0, F_y = -86500 \text{ N}, F_z = 0$

**Loading condition at 85000 N**

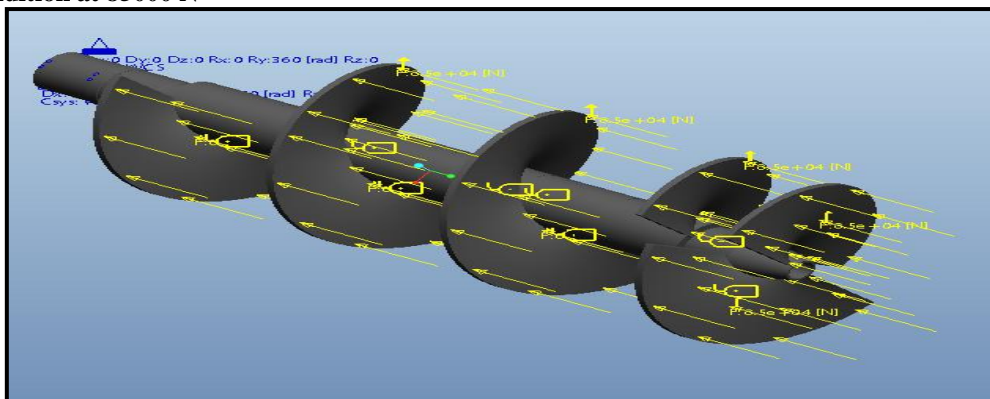


Fig 4.4 Loading condition at 86500 N

**Stress analysis at 86500 N**

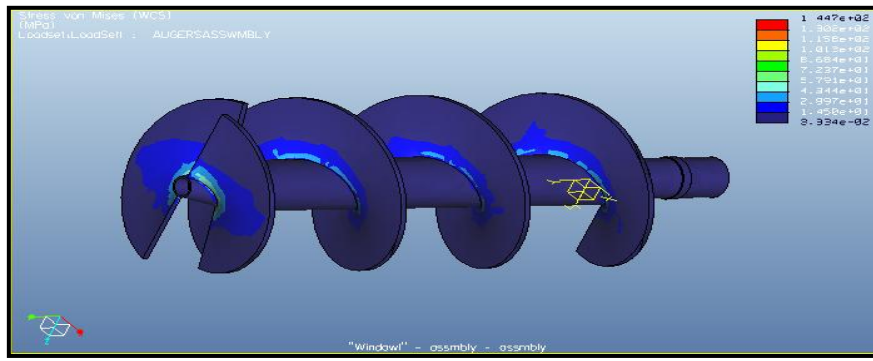


Fig 4.5 Stress analysis at 86500 N

Generated Results of Stress Analysis at 86500 N	
Maximum Principal Stress	197564 MPa
Maximum Von Mises Stress	144715 MPa
Maximum stress along XX axis	-102065 MPa
Maximum stress along XY axis	-47298.3 MPa
Maximum stress along XZ axis	-38503.8 MPa
Maximum stress along YY axis	172771 MPa
Maximum stress along YZ axis	-61238.5 MPa
Maximum stress along ZZ axis	-115641 MPa
Minimum Principal Stress	-184114 MPa

**Displacement Analysis at 86500 N**

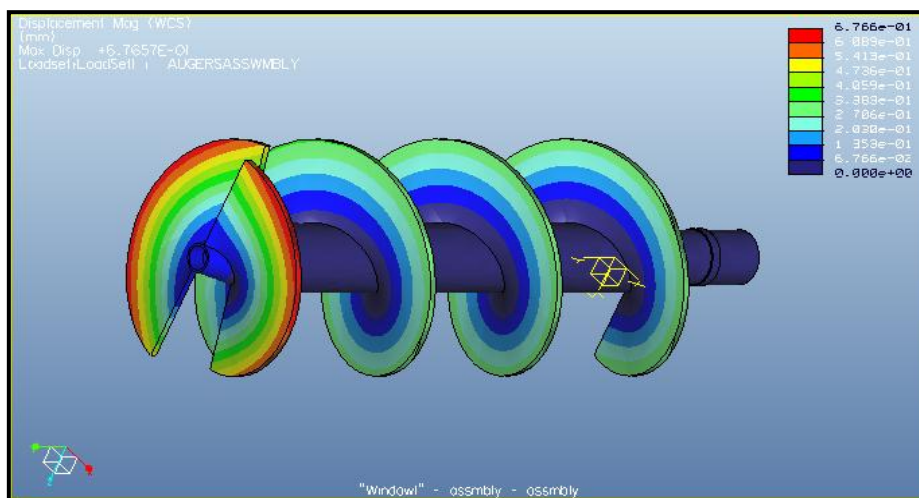


Fig 4.6 Displacement analysis at 86500 N



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Generated Results of Displacement Analysis at 86500 N	
maximum displacement Magnitude	0.676575 mm
Maximum displacement in X Direction	-0.366667 mm
Maximum displacement in Y Direction	-0.603717 mm
Maximum displacement in Z Direction	-0.302379 mm

## V. RESULT AND DISCUSSION

From analysis chapter we resulted the following table.

Parameters	Force appying on Auger Assembly of 75600 N	Force appying on Auger Assembly of 86500 N	Actual Value Of Yield Strength & Displacement for SS 431
<b>Von Mises Stress Value</b>	127.690 Mpa	144.715 MPa	448 MPa
<b>Displacement Value</b>	0.596978 mm	0.676575 mm	Negligible

From above table we say that the stress generated due to these two loading conditions is within the limit so we say that the design of critical component is in safe condition and as well as the displacement criteria is also negligible so there will not any fracture happened in the critical component for same loading conditions.

## VI. CONCLUSION

From above two results we conclude that as per ASME the maximum yielding stress for SS 431 is 448 MPa which is very higher than the minimum stress(i.e. 127.70 MPa) & maximum stress (i.e. 144.70 MPa).

## VII. FUTURE WORK AND SCOPE

1. The future work on this thesis is by adding or reducing the barrels for final product, shapes & sizes & also by using different raw material instead of ceramic items, which having different properties & also having different coefficient of friction force with the barrel material.
2. The dynamic analysis of system due to induced thermal stresses in the system when the material is passes through the barrels.

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