Modeling and Stress Analysis of Guide Ways in Automatic CTC Roller Chasing Machine

S.Yuvaraj, Santhosh and S. Sargunasekar

ABSTRACT: **The CTC (crushing, tearing and curling) roller chasing machine is one type of special purpose lathe used to machining the tea crushing rollers. In CTC rollers there is two type of machining process are done chasing, milling to form the tooth of rollers. Here the chasing machine is used to cut vertical teeth along the roller dimension. While in manufacturing of CTC roller in conventional type, they were machining rollers by using multi point chaser tool. After the incorporation of automatic process they use single point cutting tool. Here we have to analyze the stresses effect on guide and process parameters by comparing the single point and multi point cutting tool.**

In this paper describes the study and effect of single point cutting tool over multi point cutting tool in CTC roller chasing machine. With the given cutting speed, feed and depth of cut, calculate the forces, stresses acting while cutting and transmit that to guide ways of machine bed. To analyses and select the optimal process parameters as well as cutting tool for getting accuracy and reduce the machining time.

Keywords: CTC Machine, Chasing, Tea rollers, Control, Cutting forces.

I INTRODUCTION

Tea is produced mainly in two varieties of process namely as Orthodox and CTC. The CTC tea is produced by the process of crushing, tearing and curling when withered leaves are fed in-between a pair of rotating rollers having accurately spaced teeth on their cylindrical surfaces. The machining accuracy of the teeth on the rollers has a great effect on the quality of tea Leaves. Equal spaced concentric circular grooves are formed by chasing operation and helical grooves are formed by milling operation. The pitch accuracy of the annular concentric circular grooves has a large bearing on the quality of CTC tea.

The preprocessed tea leaves are fed into CTC machine wherein a pair of rollers called CTC rollers, having uniform teeth along the circumference, is running in close proximity at different speeds to make CTC tea as final product.

The CTC process is accomplished by meshing of teeth on the pair CTC rollers, rotating in opposite directions at different speeds. Tea leaves are fed between the rollers in the gap of the teeth, which is about 0.05 mm in figure-1.1. The sharp edges of the teeth cut and tear up the leaves while they are crushed between the shoulders of teeth of the matched grooves, and curled due to rubbing action between the flanks of the teeth.

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The processed leaves are discharged on to a moving conveyor belt, which carries the leaves to the next CTC unit for forming finer CTC tea as required. Generally 2 to 3 stages of CTC process is applied on leaves to get the desired grade of tea.

Figure - 1.1. CTC Rollers

A. CUTTING FORCE COMPONENTS AND THEIR SIGNIFICANCES

The single point cutting tools being used for turning, shaping, planning, slotting, boring etc. are characterized by having only one cutting force during machining. But that force is resolved into two or three components for ease of analysis and exploitation. Figure-1.2 visualizes how the single cutting force in turning is resolved into three components along the three orthogonal directions; X, Y and Z. The resolution of the force components in turning can be more conveniently understood from their display in 2-D

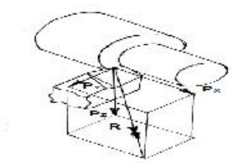


Figure - 1.2. Cutting force R resolved into P_X, P_Y and P_Z

B. LINEAR GUIDEWAYS

The linear guides consist of a mechanism in which steel balls are circulated infinitely to enable an infinite stroke of ball slides theoretically. Balls roll along the ball groove formed on a rail and a ball slide and there, they are scooped at the point A by the tip of an end cap. There, they are forced to change their circulating direction by a return guide of the end cap and guided to a circulating hole is provided inside of the ball slide are shown in figure-1.3.

The balls continue to pass through the hole to the other end of the ball slide and, further, go through the circulation circuit to the tip of the end cap of the other side and then, return to the ball grooves of rail and ball slide. Thus, the balls repeat their endless circulation motion.

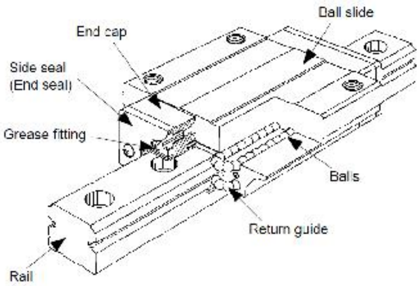


Figure - 1.3. Linear guide ways

II PROJECT OBSERVATIONS

- Tea leaves are fed between the rollers in the gap of the teeth, which is about 0.05 mm
- Roller comprises of stainless steel segments 50.8mm width and outside diameter 215.9 mm to 330.2 mm, snugly fitted on the mandrel side by side for the entire length of 1320.8 mm.
- Number of annular concentric grooves of specifications normally 8 or 10 grooves per inch.
- `V' –chaser the angle used universally is 55° only are shown in figure-2.0.
- Total depth of cut = 2.286 mm
- Hardness of the CTC roller (AISI 301) = 95 RB
- Tensile strength of the material Mt = 73 Kgf /mm²
- Coefficient of friction, μ= 0.3
- Feed of 0.5''/3min, speed of 12rpm
- Guide dimensions
  - ✓ width- 28 mm
  - ✓ height- 25 mm
  - ✓ length- 2006.6 mm

Work piece weight- 300kg to 450kg

A. MACHINING SPECIFICATIONS

- d- diameter of work piece=330.2mm
- n- speed of roller= 12rpm
- l- Length of work piece= 1320.8mm
- k- cutting force for steel(ss301)= 80kgf
- b- width of chip= 1mm
- a- thickness of chip= 0.5mm
- c- mean width of flank wear land= 0.5mm
- P_Z - force acting at Z- direction of cutting
- P_N – Normal force acting at X,Y direction of cutting

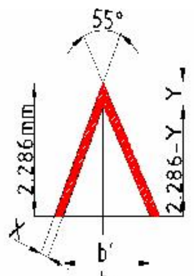


Figure - 2.0. `V' –chaser

III STATIC LOAD CALCULATIONS

At static load condition the work piece weight have to consider. For calculation purpose, normally we take the at maximum conditions.

Static load = work piece weight x g
= 450x9.81
= 4414.5 N

A. DYNAMIC LOAD CALCULATION

From the literature [1]

Data's for single point cutting tool:

Cutting speed range = 20-30 rpm

We taken speeds for calculation = 22, 25, 28rpm

For above speeds the feed is = 1.219, 1.602, 1.905 mm/min

Data's for multi point cutting tool:

Cutting speed range = 10-15 rpm

We taken speeds for calculation = 10, 12, 14 rpm

For above speeds the feed is = 3.92, 4.23, 4.51 mm/min

1. Tangential cutting force:

$$P_z = C_p \times t^x \times S^y \times K$$

where

$$K = K_c \times K_\phi \times K_\gamma \times K_m$$

P_z = vertical plane force, perpendicular to P_x, P_y

C_p =coefficient characterized by the work material and the condition of working such as tool and coolant etc.,

t= depth of cut in mm

S= feed in mm/min

x, y=exponential constants for C_p

K=overall correlation coefficient, consistent to the actual working conditions

K_c = correlation coefficient for coolant

K_ϕ = correlation coefficient depending upon the entering angle

K_γ = correlation coefficient depending upon the back rack angle

K_m = correlation coefficient depending on the material

D = diameter of work piece

2. Moment of cutting forces:

$$M_{cutting} = \frac{P_z \times D}{2}$$

3. Radial cutting force:

Radial cutting force is the forces developed on Y direction while work piece on cutting. It can be calculated as 70% of P_z [9].

$$P_y = 0.7 \times P_z$$

4. Magnitude of bending:

The work piece is mount on the machine as simply supporting beam. Therefore the magnitude of bending can be calculated as [9],

$$M_b = P_z \times l \times \frac{l}{2}$$

5.Power required:

The power required to cut a single teeth on work piece can be determined by the following formulae [9]

$$P = \frac{P_z \times v}{60 \times 102}$$

Where,

v = relative velocity

P_z = vertical plane force, perpendicular to P_x, P_y

D= diameter of work piece

n= speed of work piece revolving

$$v = \frac{\Pi \times D \times n}{1000 \times 60}$$

6.Tool life:

To predict tool life the following formulae were used [9]

$$bt^z = N$$

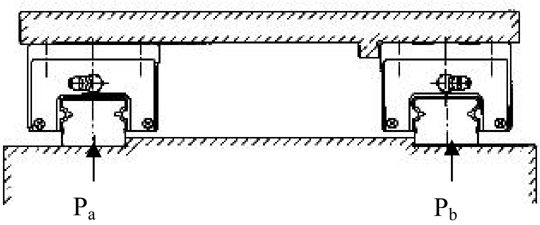
Where,

b=temperature of tool while cutting

N= constant depending on material and working condition

z= exponential constant

7. Average Pressure on guide way:



Average Pressure on guide way can be calculated by using below formulae is given [9]

$$P_a = \frac{W}{a \times l}$$

$$P_b = \frac{W}{a \times l}$$

Where

W- external load on guide

a- width of guide

l- Length between the guide A & B

External load:

$$W = W_t + W_w + W_{Pz}$$

where

W_t - Weight of carriage

W_w - Weight of work piece on guide

W_{Pz} - cutting force contribution

8. Friction force:

From [11] the following standard friction forces for specialized oil servo gear oil of Hp 140, the friction force constant under liquid friction is F = 0.002 to 0.05

We select, F = 0.05

IV MODELING AND MESHING

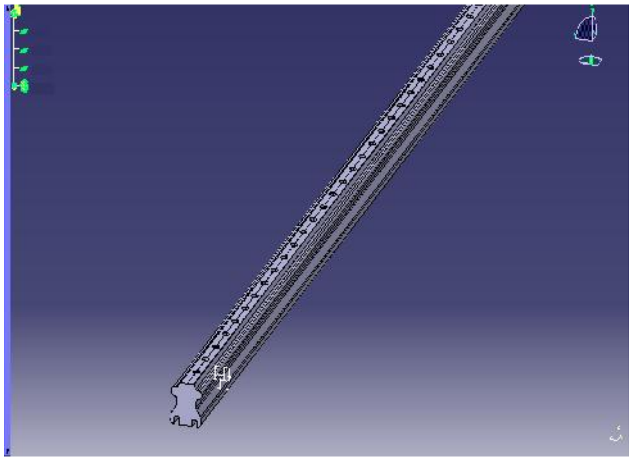


Figure-4.1 Modeling Of Guideway Using Catia Package

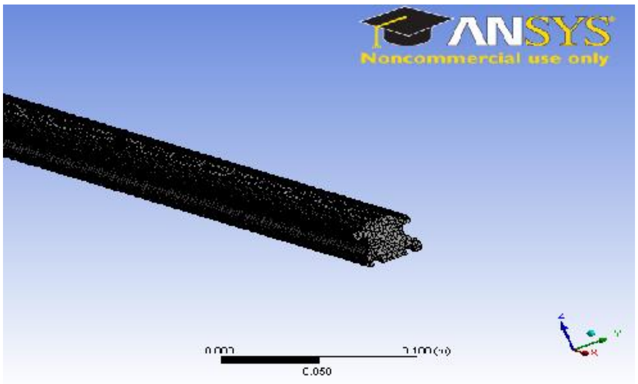


Figure-4.2 Meshing Of Guideway Using Ansys Package

V RESULT AND DISCUSSION

Results of using single point cutting tool in chasing machine at various speeds are as below table-5.1

Table-5.1. Result of using single point cutting tool

Results of using multi point cutting tool in chasing machine at various speeds are as below table-5.2

Table-5.2. Result of using multi point cutting tool

parameters	Speeds in rpm		
	20	25	30
Feed	0.964 mm/min	1.602 mm/min	2.107 mm/min
Tangential cutting force	118.2 N	165.43 N	212.67 N
Radial cutting force	82.94 N	115.8 N	148.87 N
Moment of cutting force	1951.48 N.mm	2731.33 N.mm	3511.18 N.mm
Magnitude of bending	103.1x10^6 N.mm	144.3x10^6 N.mm	185.5x10^6 N.mm
Cutting velocity	0.345 m/sec	0.431 m/sec	0.518 m/sec
Power required	0.0066 kw/cycle	0.012kw/cycle	0.018 kw/cycle
Total tool life	1.50x10^9 min	1.50x10^9 min	1.50x10^9 min
Average weight on guideways	4630.8 N	4678.1 N	4725.27 N
Average pressure on guideways Y and Z axis	0.74 N/mm^2 and 0.75 N/mm^2	0.75 N/mm^2 and 0.75 N/mm^2	0.75 N/mm^2 and 0.77 N/mm^2

Resulting by dynamometer using single point cutting tool in chasing machine at various speeds are as below table-5.3

Table-5.3. Result by dynamometer of using single point cutting tool

parameters	Speeds in rpm					
	10		12		15	
	Tested	Calculated	Tested	Calculated	Tested	Calculated
Feed	3.92 mm/min	3.92 mm/min	4.23 mm/min	4.23 mm/min	4.65 mm/min	4.65 mm/min
Tangential cutting force	3401.2 N	3384.8 N	3627.6N	3617.87 N	3859.7 N	3850.95 N
Radial cutting force	2380.8 N	2368.8 N	2539.32N	2532.23 N	2701.8 N	2695.66 N
Average pressure on guideways	1.28 N/mm^2	1.28 N/mm^2	1.32 N/mm^2	1.31 N/mm^2	1.35 N/mm^2	1.35 N/mm^2

Resulting by dynamometer using multi point cutting tool in chasing machine at various speeds are as below table-5.4.

Table-5.4. Result by dynamometer of using multi point cutting tool

parameters	Speeds in rpm		
	10	12	15
Feed	3.92 mm/min	4.23 mm/min	4.65 mm/min
Tangential cutting force	3384.8 N	3617.87 N	3850.95 N
Radial cutting force	2368.8 N	2532.23 N	2695.66 N
Moment of cutting force	55883.04 N.mm	59731.11 N.mm	63579.18 N.mm
Magnitude of bending	2952.4x10^6 N.mm	3115.7x10^6 N.mm	3359.01x10^6 N.mm
Cutting velocity	0.172 m/sec	0.215 m/sec	0.259 m/sec
Power required	0.095 kw/cycle	0.12kw/cycle	0.162 kw/cycle
Total tool life	1.50x10^9 min	1.50x10^9 min	1.50x10^9 min
Average weight on guideways	7897.4 N	8130.5 N	8363.55 N
Average pressure on guideways Y and Z axis	1.11 N/mm^2 and 1.28 N/mm^2	1.13 N/mm^2 and 1.31 N/mm^2	1.16 N/mm^2 and 1.35 N/mm^2

A. ANALYSIS RESULT FOR THE ABOVE PRESSURE ON GUIDEWAYS CALCULATED AND DISCUSSION

For using single point cutting tool at different pressure range the boundary condition, total deformation on guide, vonmises stress are as below.

The figure-5.1 represents the common boundary condition for all conditions. In the figures 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.10, 5.11, 5.12, 5.13 A1, A2, B1, B2, C1,

parameters	**Speeds in rpm**					
	20		**25**		**30**	
	Tested	**Calculated**	**Tested**	**Calculated**	**Tested**	**Calculated**
Feed	0.964 mm/min	0.964 mm/min	1.602 mm/min	1.602 mm/min	2.107 mm/min	2.107 mm/min
Tangential cutting force	125.2 N	118.2 N	171.3 N	165.43 N	220.5 N	212.67 N
Radial cutting force	87.6N	82.74 N	119.9 N	115.8 N	154.4 N	148.87 N
Average pressure on guideways	0.75 N/mm^2	0.75 N/mm^2	0.76 N/mm^2	0.75 N/mm^2	0.77 N/mm^2	0.77 N/mm^2

C2 represents the total deformation and vonmisses stress on guide by using single point cutting tool. And I1, I2, J1, J2, K1, K2 represents the total deformation and vonmisses stress on guide by using multi point cutting tool.

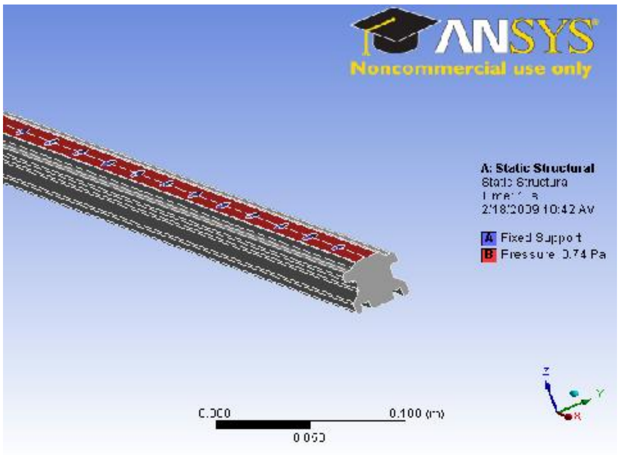


Figure- 5.1 boundary conditions to guide way

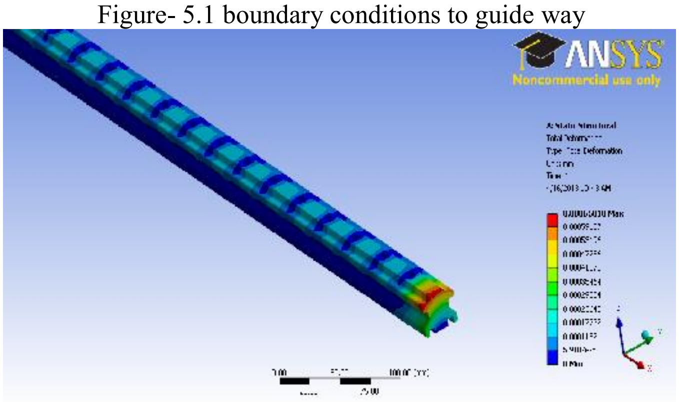


Figure- 5.2 Total Deformation at A-1 Condition

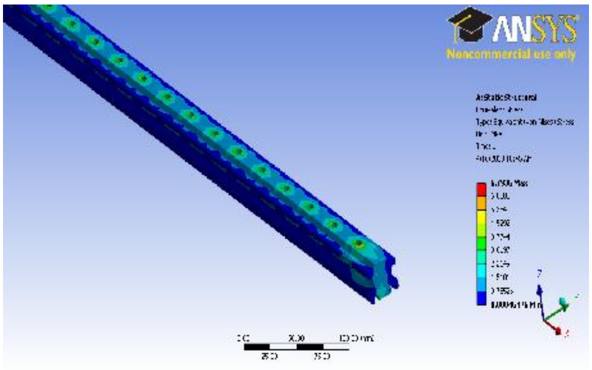


Figure-5.3 Equivalent Stress at A-2 Condition

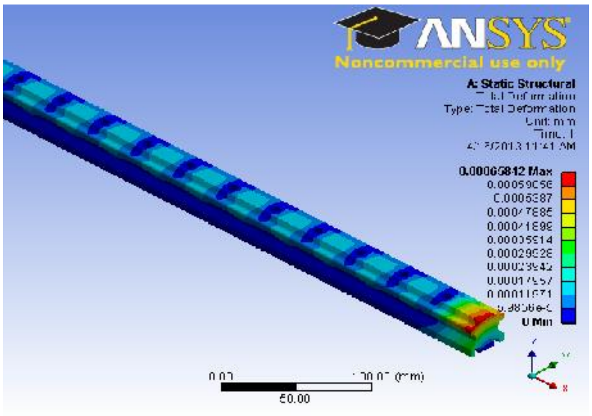


Figure- 5.4 Total Deformation at B-1 Condition

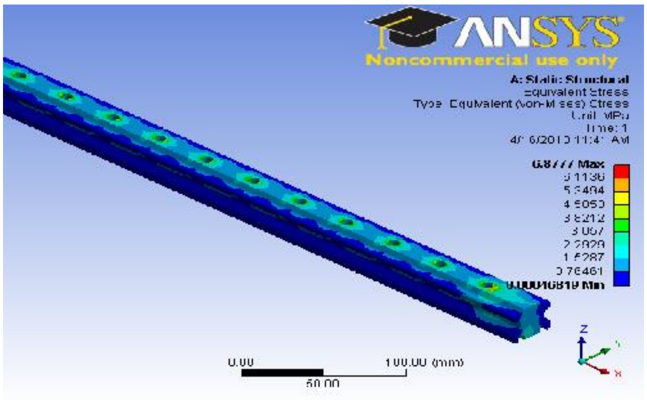


Figure-5.5 Equivalent Stress at B-2 Condition

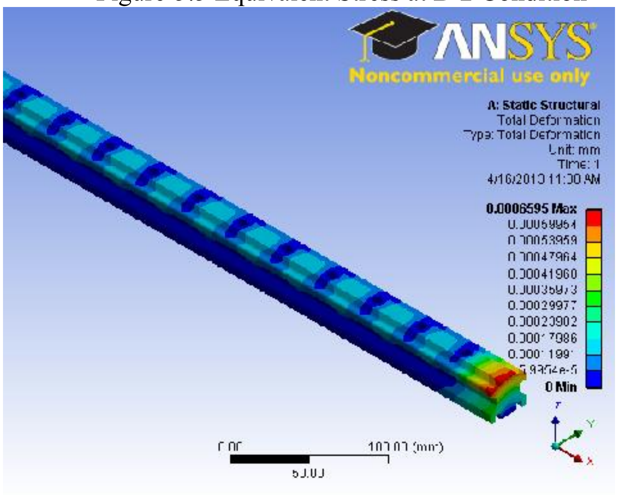


Figure- 5.6 Total Deformation at C-1 Condition

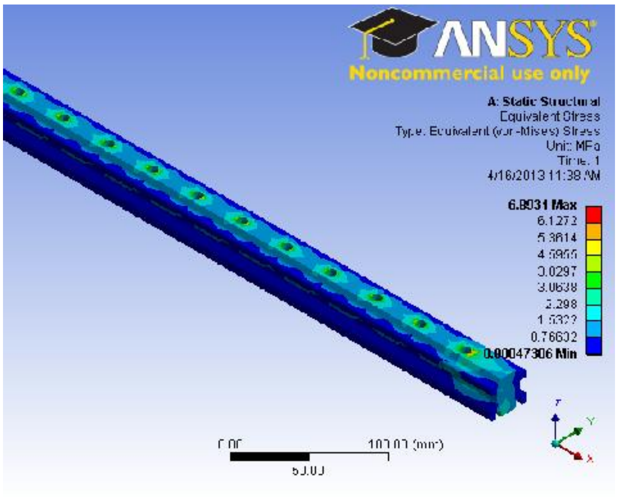


Figure-5.7 Equivalent Stress at C-2 Condition

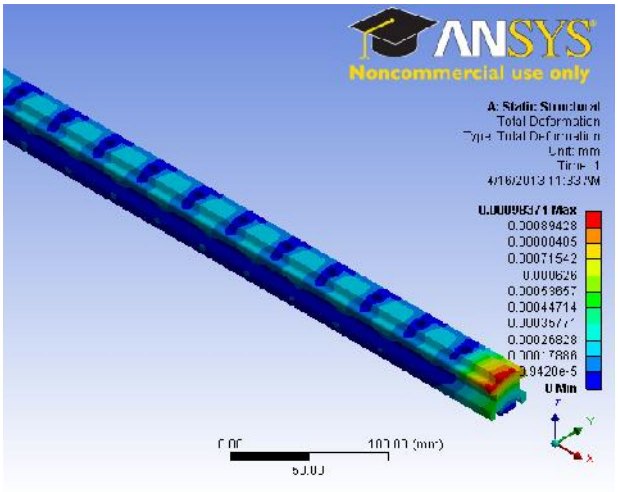


Figure- 5.8 Total Deformation at I-1 Condition

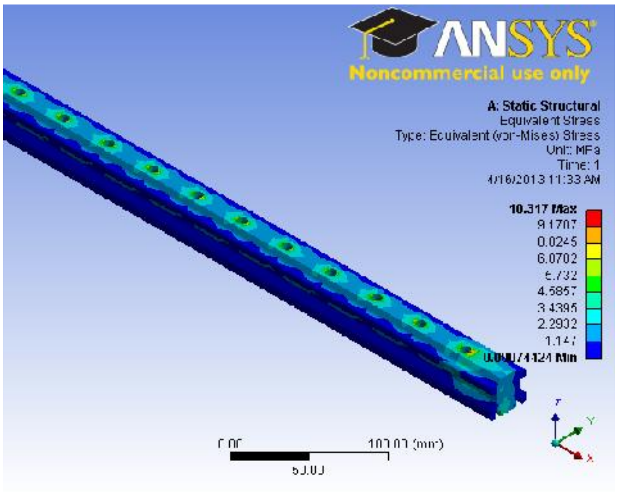


Figure-5.9 Equivalent Stress at I-2 Condition

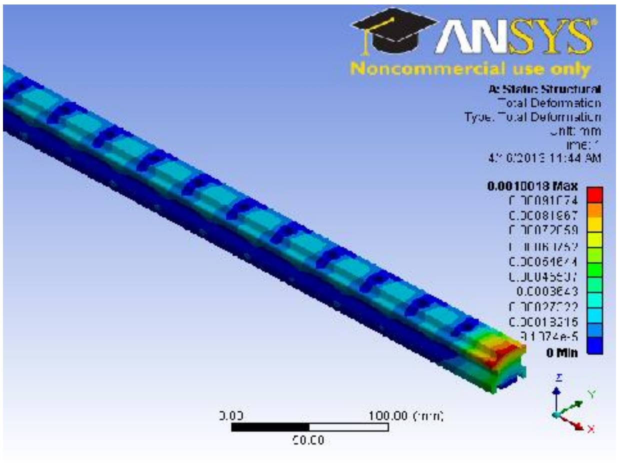


Figure- 5.10 Total Deformation at J-1 Condition

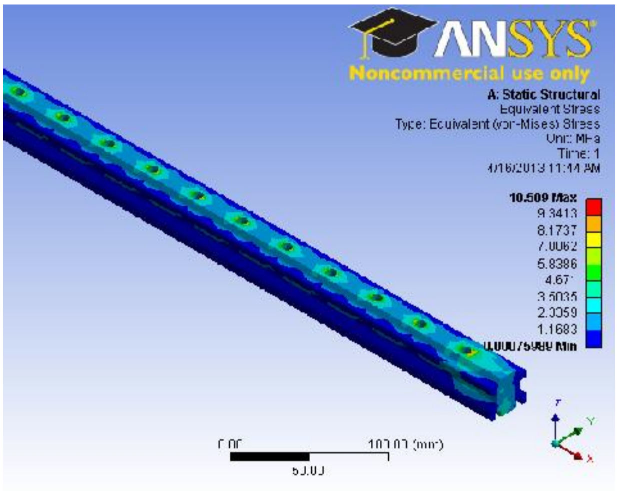


Figure-5.11 Equivalent Stress at J-2 Condition

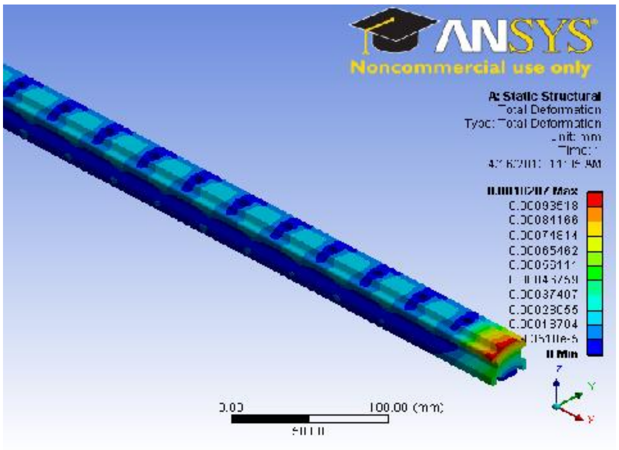


Figure-5.12 Total Deformation at K-1 Condition

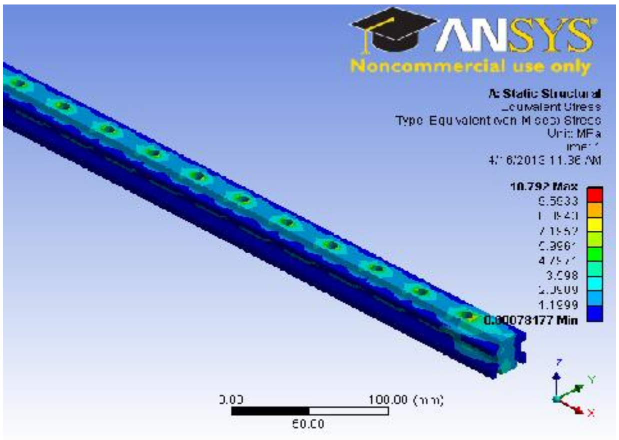


Figure-5.13 Equivalent Stress at K-2 Condition

Machining experiments were carried out on the prototype. The following are the brief description of experiments and observations. Due to the corrosive environment of machining process involved in CTC tea making, CTC rollers made of Austenitic Stainless Steel AISI 304 are commonly used. Austenitic stainless steels are characterized by their high work hardening rate and low thermal conductivity, are greatly regarded as more difficult to machine steels than carbon and low alloy steels.

It was necessary to standardize the tool material and process parameters for automatic cycle operation and ease of changing worn out tools without disturbing the tool setup. Thus, to investigate the use of different tool and process parameters for low Machining vibrations and minimum machining forces for selected parameter range study was carried out. Comparative studies are made to select the process parameters for chasing operation on CTC roller by measuring cutting forces. The goal of this study is to find better alternative machining parameters like single or multi tipped tools, feed value and cutting speed for minimum vibrations and cutting forces.

B. EXPERIMENTAL SETUP

VI CONCLUSION

In this project "Modeling and Stress Analysis of Guide Ways in Automatic CTC Roller Chasing Machine" has been carried out and following are the conclusions made.

A through literature study of single and multi point cutting tool used and the parameters that are influencing the machining process of CTC roller chasing machine has been carried out.

The forces like radial force and tangential forces were calculated under static and dynamic conditions and the calculated values are validated by the experiments. The calculated and tested results are shown in table 5.1, 5.2, 5.3, 5.4.

For these calculated forces and pressure on the guideways, the analysis to finding total deformation and vonmises stress were carried out, and the results were shown in figures 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.10, 5.11, 5.12, 5.13.

Radial force (Py) and tangential force (Pz) are recorded through piezoelectric force dynamometer (Kistler-9272). Vibration analyzer (type IRD- 880) along with Accelerometer (IRD-970) was employed to measure the tool Vibrations during chasing. The vibration during chasing operation are found to be, 15 microns while using single point cutting tool and 25 microns while using multi point cutting tool.

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