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DESIGN AND THERMOSTRUCTURAL ANALYSIS OF A MOBILE BLANCHER FOR TURMERIC PROCESSING

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ABSTRACT

The design and thermostructural analysis of the turmeric processing plant [TPP] is software tested. The heat transfer media is steam. In this paper the work is carried out to improve the performance of [TPP]. The new design of [TPP] improves rate of energy consumption, process time, turmeric contents and its properties, process handling system and labor cost. The Geometric solid model is designed in UG Software and the thermal and structural analysis is carried out with ANSYS^{TM} Software to simulate the heat treatment process. The Software test of the blancher was found satisfactory for uniform distribution of heat flux, stresses and deflections are within the limits.

Keywords: Design and analysis of turmeric processing plant[TPP], SS 304L material, UG and ANSYS Software.

1. INTRODUCTION

India ranks first in production of turmeric i.e.701.16 Lac tones from 185.32 Lac hectare of area [Varsheney AK-2004]. Maharashtra state produces about 400 MT from 700 hectare area [Vikas. S. 2003]. Turmeric is the dried rhizome of the plant curcuma domestica val.. syn. C. Longa L. The genus Curcuma originated in the Indo-Malayan region [Purseglve, 1968]. Considerable species diversity of curcuma occurs in this region. In India about 40 species of the genus including C. Longa are indigenous to India indicating the Indian origin [Velayudham et. al. 1999].

The use of turmeric has been in India since very ancient days. According to macropola (1280) the spread of turmeric to China took place in AD 700 [Ridley. 1912]. Burki-II (1966) believed that the crop spread to West Africa in the thirteenth and to Ease Africa in seventeenth centuries, respectively. Though turmeric is now grown in Japan, Malasiya, Thailand, Korea, Nepal, East and West Africa etc, India is the major producer and exporter of turmeric at present. Velayudhan et al. (1999) recognized six taxonomic varieties within C. Longa based on numerical taxonomic analysis, namely

C.Longa Var. typica, C.Longa Var. atypica, C.Longa Var. camphora, C.Longa Var. Spiralifolia, C.Longa Var. Musafolia andC.Longa var platitolia. Most of the C.Longa found in India belong to C.Longa Var. typica or atypica.

Turmeric is an erect perennial herb grown above the ground as an annual crop. The plant is erect with leaves and inflorescence. There may be 2-3 Pseudostems (tillers) per plant. The height of the plant varies from 90 to 100 cm, with leaves ranges from 7 to 12. Inflorescence is a cylindrical fleshy, central spike of 10-15 cm length, arising through the pseudostem. Seeds are produced in capsules and there will be numerous sunken capsules in an inflorescence depending on the flowers fertilized. At the base of the pseudostem, below the ground, rhizomes are formed consisting of mother rhizomes, primary, secondary and even tertiary fingers, forming a compact clump. Rhizomes grow symbodically and are of orange brown,pale yellow or redish yellow color. C.Longa is considered to be a triploid with a somatic chromosome number of 63 [2n = 3x = 63].

American Spice Trade Association (ASTA) cleanliness specification effective from may 1997 for turmeric allows only a maximum of three dead whole insects. 5mg/1b Mammalian or other excreta 3% by weight mould, 2.5 % by weight insects infested material and 0.5% by weight extraneous foreign matter in turmeric.

The admissible level of defective Rhizomes allowed in US Turmeric is given below.

Maximum moisture	8-10 % by wt.
Maximum ash	7 % by wt
Maximum acid insoluble	0.5 % by wt
Maximum crude fiber	6% by wt
Maximum vol. oil	5% by wt
Minimum curcumin as color	5% by wt
Volatile oil ml/100gm	< 3.5

Turmeric is valued mainly for its principal coloring pigment curcumin, which imperts the yellow color to turmeric having molecular formula $C_{21}H_2OO_6$. To various food items the specified limit for curcumin to maximum level is 500 mg/kg.

The important properties and uses of Turmeric

Turmeric powder is used in mustard paste and curry powder, as color and aroma are important. Turmeric oleoresin is used in the brine pickles and relish formulations, gelatins, in breading of frozen fish sticks, potato croquettes, butter, cheese and icecreams. In Asian countries turmeric powders with other species like chilies are used for making soup, vegetable and meat dishes. Turmeric powder mixed with sesame, coconut or ground nut oil is used for pickling mango, lemon, garlic etc. In foods, the antioxidant property of turmeric was effective in preventing peroxide developments [Khanna, 1999].

Turmeric is credited with medical properties as anti inflammatory, hypocholestremic, choleratic, antimicro bial, antirheumatic, spasmolytic, hypersensative, antibacterial, antiviral, cytotoxic, antidiabetic and antiheptotoxic[Govind.Arajam, 1980]

Turmeric also has meditional uses in digestive disorders, hyper acidity, blood purifier, used for cuts, burns, anti inflammatory effects. It is also used in cosmetics

to glow the skin, traditional bathing in Indian marriages, for fair , soft and smooth skin. [Ramdev Food Products Pvt. Ltd.]

Turmeric processing: The Turmeric can be processed in following steps :

1. Turmeric Rhizomes.
2. Washing
3. Boiling/blanching/cooking
4. Drying.
5. Coloring
6. Grinding/Powdering
7. Packing & Marketing

The Turmeric Rhizomes.[Mother, Primary and Secondary fingers] digged out are kept soaked in water throughout night. The Rhizomes mother (The first round middle part) is separated and usually it is used for seed. The Rhizome Doctor (secondary long and thin like finger) are washed and cleaned for further processing. The method of boiling/ blanching/ cooking is discussed in detail in this research work.

The cooked Rhizomes are cooled and spread slowly in the yard for drying. It takes 10
to 15 days for sun drying. Mother Rhizomes takes more time compared to Doctor Rhizome, so they are separately dried. The complete dried Rhizomes holds 6% moisture. The dried Rhizomes are rubbed against ground to take out hard layer over them and small roots are removed, By this process coloring of Rhizomes becomes bright and shining, machines are also used for polishing. The Rhizomes after polishing and coloring cut into small pieces and milled to get 60-80 mesh powder.

Boiling and cooking : In turmeric processing unit traditional boiling is done with three fourth part of water in metal pots, (pans) covered with leaves and cowdung over the top. The Rhizomes are boiled to around 30 to 45 minutes. The ammonia in the cowdung is reacted with turmeric to produce the final product. For hygienic reasons this method is being discouraged. Also there is loss of large amount of heat and also the properties of Rhizomes.

In another improved method of boiling / cooking, the Rhizomes are treated with 0.1% soda [Sodium Carbonate, sodium bicarbonate or ammonium carbonate] and water solutions and they are boiled in the same way for 30 to 45 minutes. When the white fume comes out, a small grass or wooden stick is easily pierced through the Rhizome, then it is presumed that the turmeric is cooked. With the help of long wooden handle comb the cooked Rhizomes are pulled out of the pan and allowed to leach the water through it. The cooked Rhizomes are spread on a clean open ground for sun drying. Because of shallow open pan heat losses are more due to increase in cooking time and more loss of curcumin and oleoresins. Traditional handling method of cooked Rhizomes causes trampling, mudmixing, scorching, leading to quality and quantity loss. Labor cost is very huge for cleaning Rhizomes, washing, loading, unloading the pan and drying the Rhizomes. Hence the study was undertaken for design, fabrication and testing of [TPP] in the Department of Production Engineering at S.G.G.S. College of Engineering and Technology, Vishnupuri and Department of Agricultural Engineering, M.A.U. Parbhani. A model of Turmeric blancher is made on CAD Software for test.

The Structural and thermal analysis of the model is carried out with Stainless Steel 304 L as material of the blancher. The software test of the blancher was found

satisfactory for uniform distribution of heat flux, thermal and structural stress are within the limits.

2. MATERIAL PROPERTY DETAILS

The details of the structural material SS 304 L of which blancher is made are mentioned in table 1.1. The analysis is being attempted with existing material test reports. The tensile stress, yield stress, elongation values are considered for test. The isometric view of the [TPP] is shown in fig. 1.1.

Table 1.1 Material Properties of SS 304 L

Sr.	Material specifications	Typical values
1	Young's Modulus (N/mm2)	196200
2	Poissions ratio	0.29
3	Density (kg/mm3)	8.00E-06
4	Coefficient of thermal expansion (mm/mm/^{0}C)	17×10E-06
5	Thermal conductivity (W/mmK)	0.0163 and 0.0214 at 25^{0}C and 500^{0}C
6	Specific heat (J/kgK)	500 and 563 at 25^{0}C and 400^{0}C
7	Emissivity	0.11 (polished surface)
8	Tensile strength (MPa)	554 (from material test certificate)
9	Yield strength (MPa)	281 (from material test certificate)
10	Elongation (%)	44 (from material test certificate)

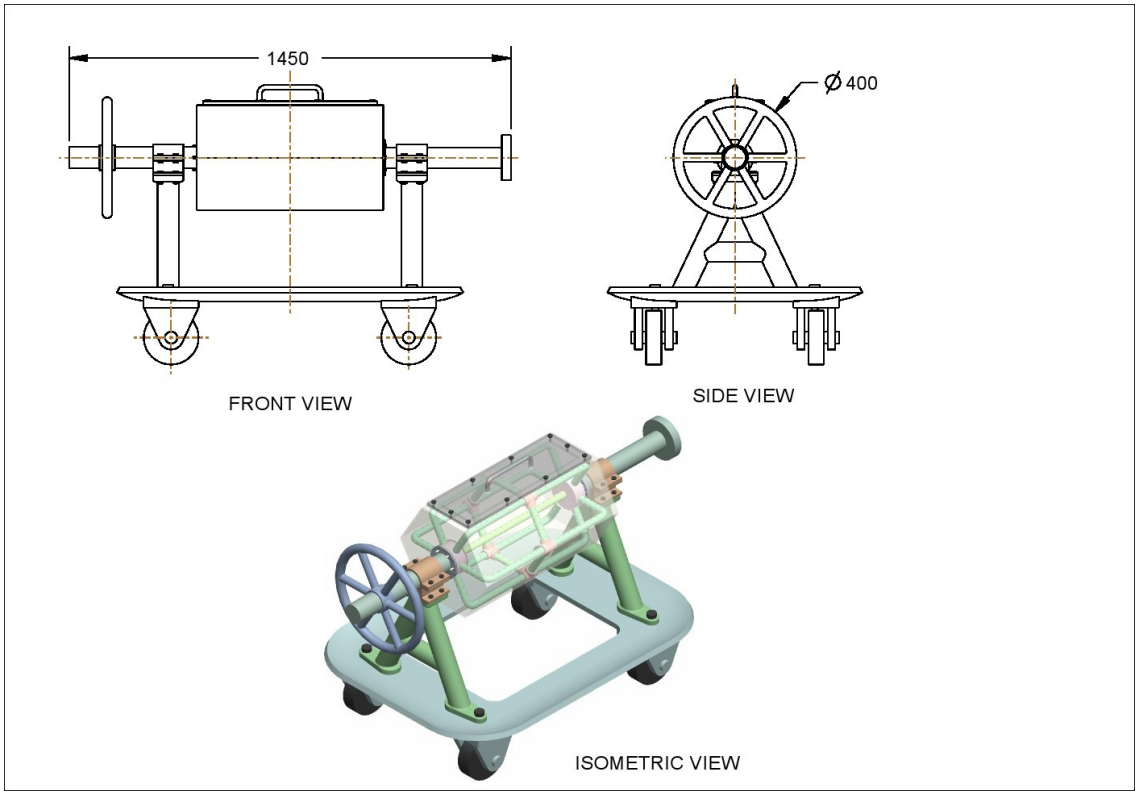

Fig. 1.1 Isometric View

3. BOUNDARY AND LOADING CONDITIONS OF [TPP]

The complete blancher model is made of steel, the thickness and size of various components of [TPP] are as listed in the table 1.2. Based on the process requirements the turmeric processing machine is designed for 50kg of turmeric in single batch. The finite element model is generated with the quadrilateral, 2D shell and 3D brick elements using Hypermesh^{TM} software. The self weight is considered 1G [9.81 m/s^2 and 760 Torr] Total number of 2D and 3D elements used for meshing the blancher are 72, 391 and 18289 respectively, and total number of elements are 90680. The thermal analysis is carried out within temperature limits 120^{0}c to 210^{0}c and pressure limits 3 bar to 9 bar. The analysis is carried out using ANSYS^{TM}.

S.N	Component Name	Size in mm
1	Hexagonal casing	600 x 350
2	Steam pipe	Inner dia. 20
3	Hallow shaft	Inner dia. 55
4	Hand wheel	Total dia. 400
5	Cylinder block	Outer dia.120, Inner dia. 70
6	Gasket	Outer dia.120, Inner dia. 70
7	T-Joints	Inner dia. 24
8	Steam pipe holes	dia 5
9	Plumber block	Inner dia. 35

Table 1.2 Suitable dimensions adopted during the pre-processing of blancher

4. RESULTS OF THE ANALYSIS

Temperature [Designed 120^0 c] [Maximum (106.667^0 c]

Pressure Bar	Deflection in mm				Stress in mm			
	Assembly		Housing		Assembly		Housing	
	Design	Maximum	Design	Maximum	Design	Maximum	Design	Maximum
3	0.1843	0.1638	0.1551	0.1432	60.990	54.214	40.723	36.204
6	0.2757	0.2450	0.1729	0.1510	83.648	74.356	43.390	38.581
9	0.3672	0.3265	0.1973	0.1757	124.780	110.926	46.300	41.167

Temperature [Designed 150^0 c] [Maximum (133.33^0 c]

Pressure Bar	Deflection in mm				Stress in mm			
	Assembly		Housing		Assembly		Housing	
	Design	Maximum	Design	Maximum	Design	Maximum	Design	Maximum
3	0.1817	0.162	0.1522	0.1402	69.500	61.740	43.280	38.477
6	0.2730	0.243	0.1701	0.1539	82.663	73.483	46.139	41.018
9	0.3650	0.324	0.1945	0.1732	123.794	110.045	49.081	43.632

Temperature [Designed 180^0 c] [Maximum (133.33^0 c]

Pressure Bar	Deflection in mm				Stress in mm			
	Assembly		Housing		Assembly		Housing	
	Design	Maximum	Design	Maximum	Design	Maximum	Design	Maximum
3	0.1857	0.1650	0.1492	0.1372	83.103	73.475	45.999	40.693
6	0.2710	0.2410	0.1672	0.1510	84.535	75.146	48.894	43.465
9	0.3626	0.3223	0.1919	0.1710	123.669	109.931	51.864	46.105

Temperature [Designed 210^0c] [Maximum (186.667^0c]

Pressure Bar	Deflection in mm				Stress in mm			
	Assembly		Housing		Assembly		Housing	
	Design	Maximum	Design	Maximum	Design	Maximum	Design	Maximum
3	0.2072	0.1482	0.1462	0.1342	96.743	85.999	48.733	43.324
6	0.2690	0.2392	0.1644	0.1481	90.122	87.223	51.660	45.924
9	0.3607	0.3206	0.1893	0.1690	124.556	110.718	54.656	48.585

Table 1.3 Temperature distribution, deflection and stress results of Assembly and Housing of [T.P.P.] at different temperature and pressure.

Uniform temperature of the [T.P.P.] is studied at 120^0c, 150^0c, 180^0c and 210^0c. The results were tabulated in the table 1.3. It was found that the temperature of the [T.P.P.] is within the limits, which indicates that there is uniform temperature and heat distribution throughout the assembly. Fig 1.2 shows the result of temperature distribution along the assembly housing at 210^0C and pressure 9 bar.

The results of deflection and stress analysis shows that the deflection is less at pressure 3 bar and it increases with increase in pressure up to 9 bar. The Deflection and stress values are increasing gradually with increase in pressure and their results are within the limits. Fig. 1.3 and 1.4 shows the results of deflection and stress along the assembly at 210^0C and 9 bar. The actual value of steam pressure is not more than 5 bar hence the design is safe.

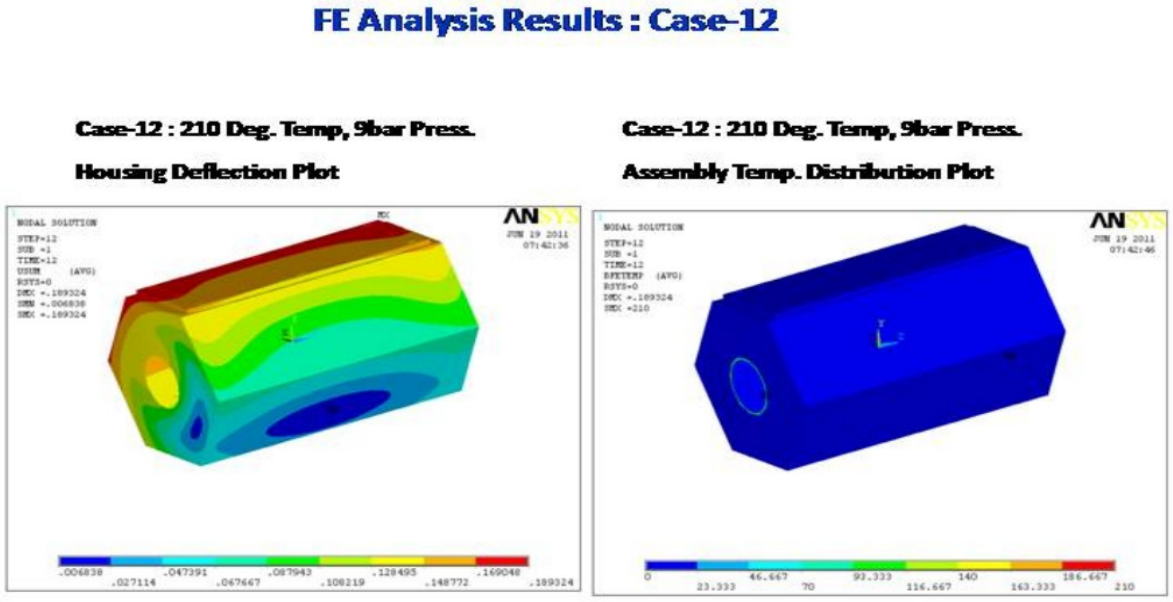

Fig 1.2 Temperature Distribution Plot

From the above results at different conditions, it is observed that the design is adequate to sustain temperature from 120^0c to 210^0c and pressure 3 bar to 9 bar with turmeric weight 40 kg. The deflection and stress values are quite lower than the yield strength of stainless steel. [SS 304 L].

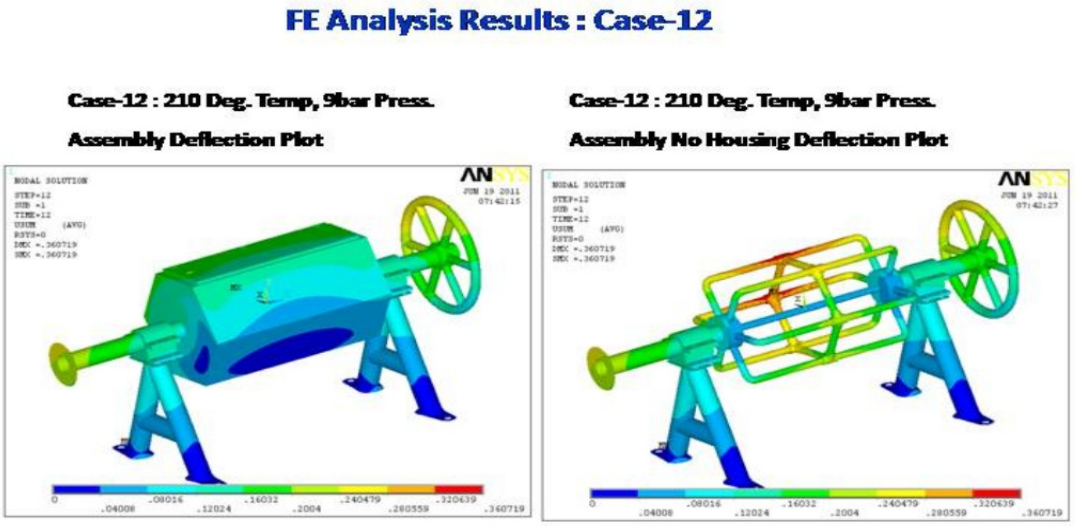

Fig. 1.3 Assembly Deflection Plot

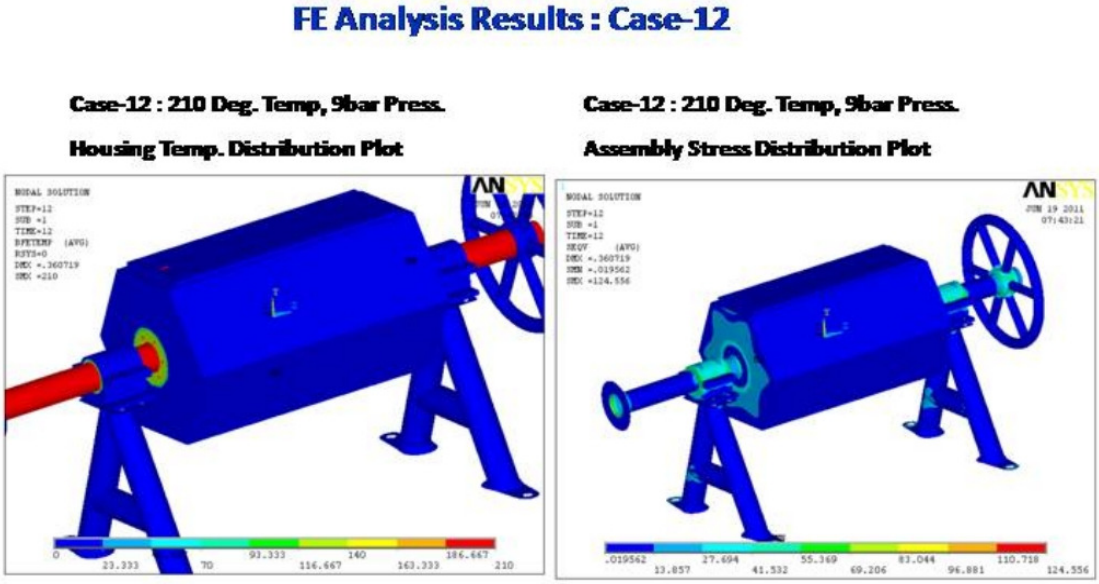

Figure 1.4 Assembly Stress Distribution Plot

5. CONCLUSION

The purpose of this paper is to design and perform analysis of a new [T.P.P.] to reduce heat losses and processing time, to achieve uniform cooking of Rhizomes and to improve quality. The new [T.P.P.] is designed, the thermal structural analysis of the SS-304L TPP assembly had been carried out using ANSYS^{TM}. The design was found safe under temperature limits 120^0C to 210^0C, pressure limits 3 bar to 9 bar with turmeric weight 50 kg. The deflection and stresses are quite lower than the Yield strength of stainless steel. The new [T.P.P.] is recommanded for fabrication and after test it can be used as future [T.P.P.]

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