Optimization of Tablet Press Components

A. Rajput V., B. Sharma D.S and C. Bhojawala V. M

A. PG student, Nirma University, Ahmedabad
B. Professor, Mechanical Engg. Dept, Institute of Technology, Nirma University, Ahmedabad
C. Asst. Professor, Mechanical Engg. Dept, Institute of Technology, Nirma University, Ahmedabad

***Abstract*-- The preferred drug delivery system today is represented by tablets, which are manufactured using high speed rotary presses where the powder material is compressed in a die between rigid punches.**
The body and middle plate of the rotary tablet press contribute largely in overall weight of the machine. Hence, it is felt that these components can be optimized for reduction in weight under the most severe operational load conditions. The topology optimization of the said components is carried out with limiting deflection as the constraint and keeping comparable machine structure accuracy.
***Index Terms*-- rotary tablet press, topology optimization**

I. Introduction

Tablet is a pharmaceutical dosage form. It comprises a mixture of active substances and excipients, usually in powder form, pressed or compacted from a powder into a solid dose. There are two types of tablet presses, Single punch and Rotary tablet presses. A single punch tablet press has one station of tooling and operates at speeds from 1-60 tablets per minute. A rotary tablet press has multiple stations of tooling mounted on a rotary table which is referred to as a turret and when the turret rotates the tablet tooling is guided from one position to another by cams.

Levin M. [1] has given general principle of tablet press machine. Motazedian F. [2] has explained the effect of different parameters during tablet press operation. Tousay M. and Tousay C. [3][4] have provided complete idea of tableting and effect of that on machine. Mudbidri A. [5] has explained tablet compression principle for dry and wet granulations. Huang and Lee [6] has developed hybrid modeling method for meshing. Bakhtiary N. [7] has explained the different approach of sizing, shape and topology optimization. Bendsoe M. [8][9][10] has given the idea of homogenization method and solid isotropic microstructure with material penalization (SIMP) method for topology optimization. Xie Y et al. [11] have worked on structure with the multiple load cases using evolutionary procedure of optimization. Weiss, D. et al. [12] explained work on topology optimization to analyze different engine hood topologies regarding their head impact performance. Birath F. and Nilsson A. [13] have done a work on topology optimization of stamping die to reduce the weight of the stamping tool.

II. Description of Machine

The main constituents of tablet press are head assembly, turret assembly, middle plate, body, bottom plate, lower press roll assembly and drive assembly (Refer Figure 1).

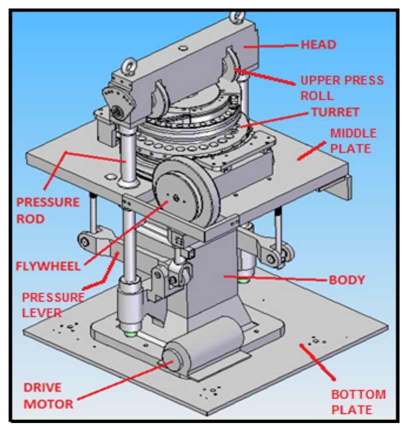


Fig.1. Structure of tablet press machine

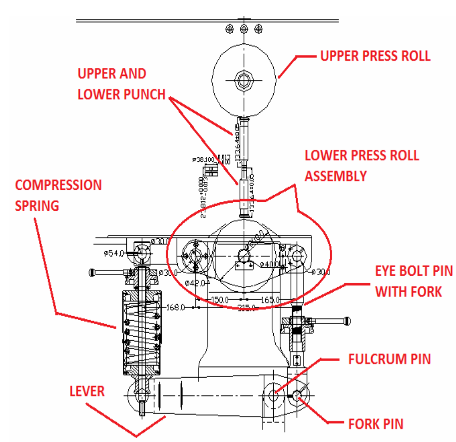


Fig.2. Spring lever with lower press roll carrier

The head assembly consists of head, two upper press roll and upper press roll shaft, while turret assembly includes turret, bearings, die and punches. The center shaft holds turret and keep turret assembly orientated during tablet making process. The cam that guides upper punches is mounted on center shaft. The middle plate on which center shaft is bolted, supports force feeder assembly, worm shaft assembly, electrical controls etc. The main body supports head assembly and holds the lever for lower press roll carrier assembly. Lower press roll carrier assembly creates the pressure on the lower punch during tablet making. The pressure can be adjusted by the control panel as per the powder formulation, volume and hardness required. Drive units, control panels and main body are bolted on the bottom plate.

III. FINITE ELEMENT ANALYSIS OF BODY AND MIDDLE PLATE

The static force analysis has been carried out for each machine component of rotary tablet press by considering the severe loading condition. The various machine components are modeled using CAE soft ware. The meshing of the various components is done using Hypermesh. The displacement and force boundary conditions are applied and stress and displacement fields obtained using finite element analysis software. The constraints and loading conditions for body are shown in Fig. 3. The deformation and von Mises stress plots for body are shown in Fig. 4 and Fig. 5 respectively.

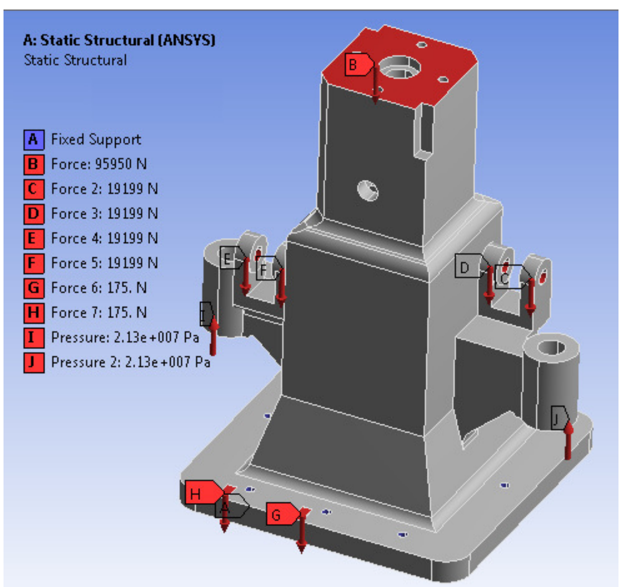


Fig.3 loading and Constraints for body

Middle plate supports load of the turret assembly, center pillar, head assembly, lower press roll carrier and compression spring. The required constraints and loads are imposed on finite element meshed model of middle plate and deformation and von Mises stresses are obtained as shown in Fig. 6 and Fig.7 respectively.

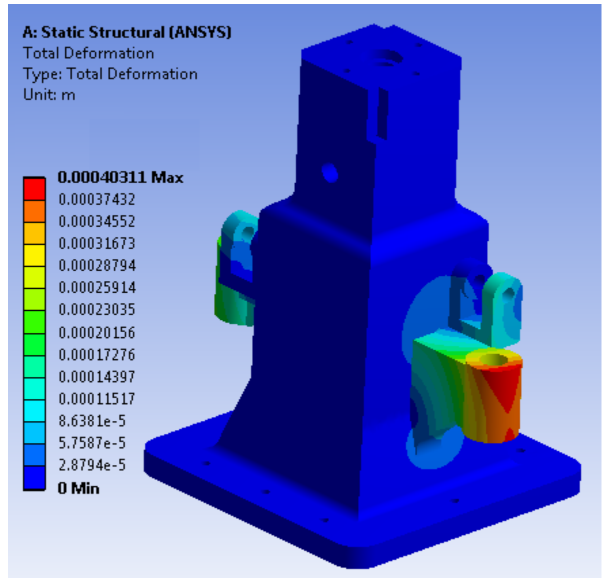


Fig.4 Deformation for body

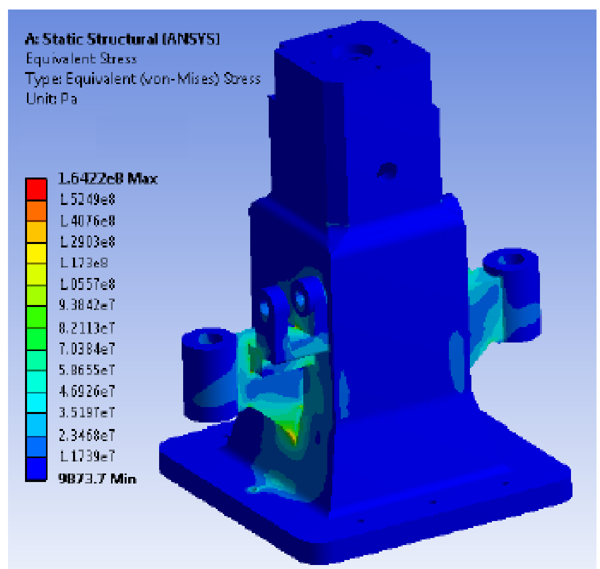


Fig.5 von Mises stress plot for body

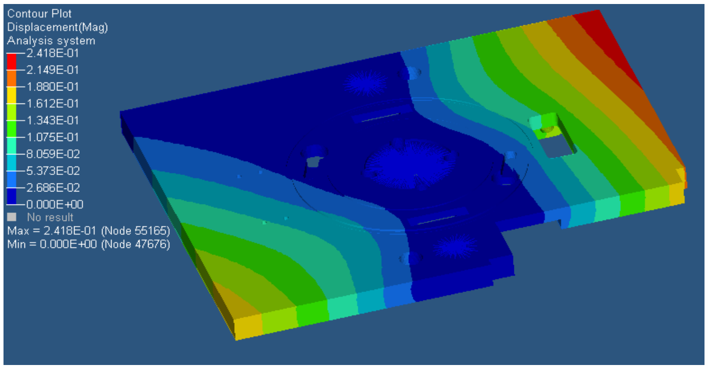


Fig.6. Deformation for the middle plate

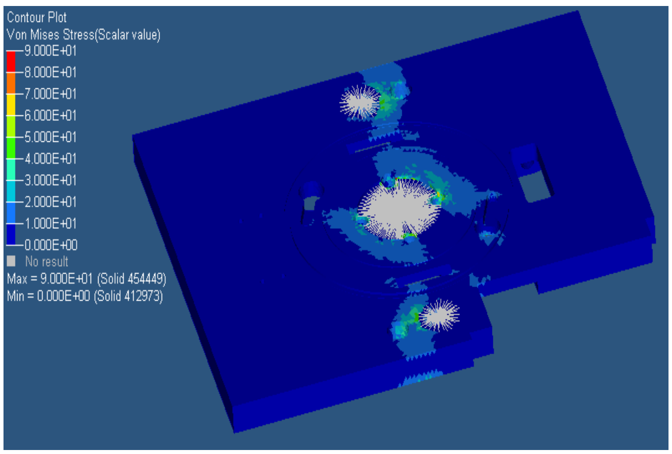


Fig.7. von Mises stress plot for the middle plate.

IV. Optimization and Modification

For the purpose of optimization, material is taken homogenous, iso-tropic, linear and temperature independent. The solid model is meshed using HyperMesh with second order solid element 10 node tetras, and OptiStruct is used to obtain the optimal material distribution. For the optimization purpose of body; design and non design areas are defined. Areas where component is bolted, rod supports, lever hinge and upper most portion of body less than 10 mm thickness are defined as the non design area.

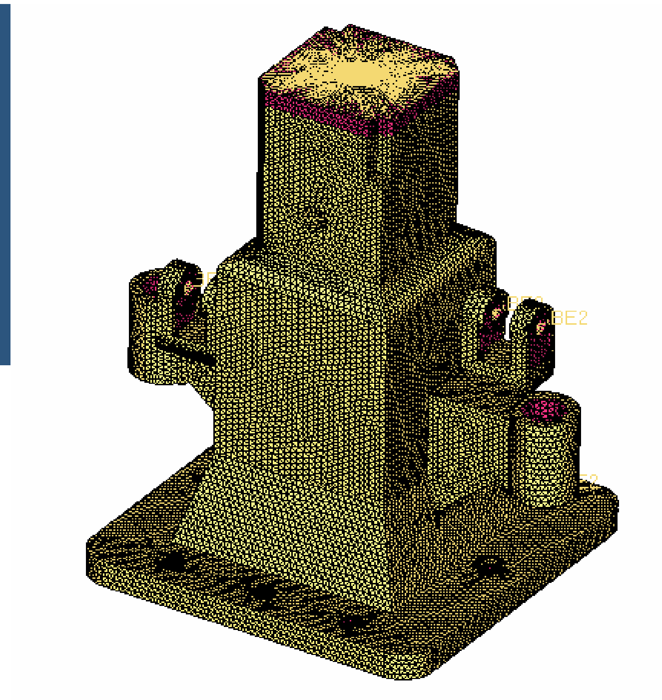


Fig.8 Mesh model of Body

Body is a symmetric component, so the advanced option pattern grouping is used which generates the symmetric design across two orthogonal planes. Maximum deformation of the body is 0.403 mm and it is at the pressure rod supporting area which is cantilever structure.

Eighty iterations were required to solve the optimization problem. Fig. 9 shows density distribution of body when density threshold is 0.3. Density threshold is defined as 0.3 to keep the material connectivity in optimized result. From the result of topology optimization, geometry modifications have been done to alter the original geometry. Table 1 shows geometry modifications to reduce the weight of body.

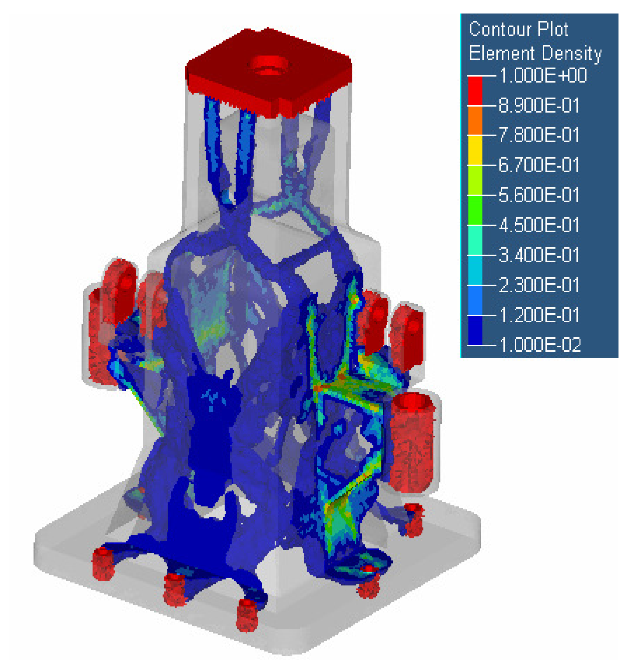


Fig.9 Density distribution in Body (Density threshold 0.3)

Table 1 - Modification in original geometry of Body

Modifi -cation	Description	Weight (Kg.)
1	Wall thickness 30 mm, Pockets were created , Section modulus of rod support increased	269.7
2	Wall thickness 30, Pockets size were increased	266.0
3	Wall thickness 30 mm, Pocket pattern was changed.	264.5
4	Wall thickness 30 mm, Pocket pattern was altered again.	261.3
5	Wall thickness 30 mm, Pocket pattern modified again.	264.6
6	Wall thickness reduced to 27.5 mm, Pocket pattern modified again	253.5
7	Wall thickness reduced to 25 mm, keeping the same Pocket pattern.	242.0
8	Wall thickness reduced to 22.5 mm, keeping the same Pocket pattern.	230.5
9	Wall thickness reduced to 20 mm, keeping the same Pocket pattern.	219.3
10	Wall thickness 20 mm, Pocket pattern modified.	220.5

The meshed model of the middle plate is shown in figure 10. The lugs which support lower press roll carrier assembly and helical spring are defined as the non design area.

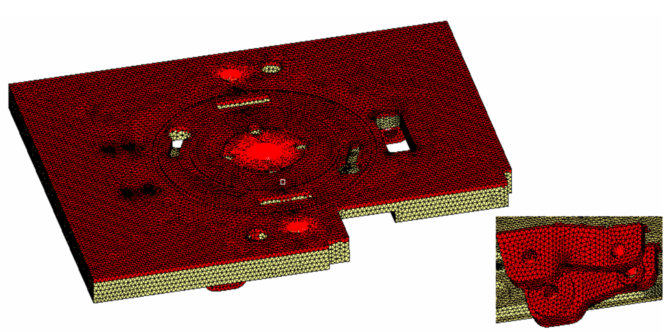


Fig.10. Mesh model of Middle Plate

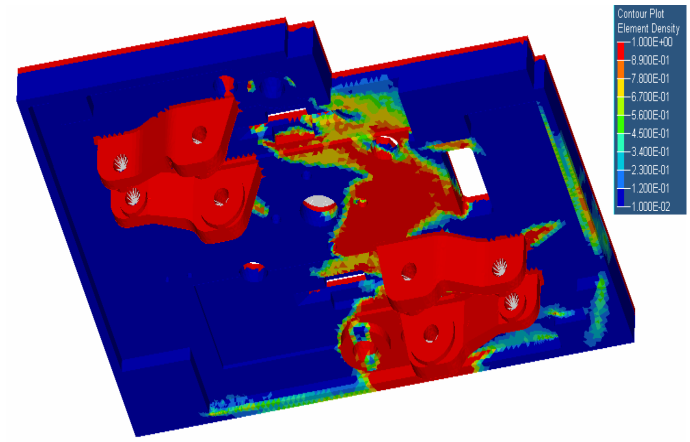


Fig.11. Density distribution in middle plate

Figure 11 shows the element density distribution in middle plate at 23rd iteration. From the result of topology optimization, geometry modifications have been done to alter the original geometry. Table 2 shows geometry modifications to reduce the weight of the middle plate.

Table 2 - Modification in original geometry of middle plate

Modifi-cation	Description	Weight (Kg.)
1	Thickness reduced from 35 mm to 20 mm	178
2	Thickness reduced from 20 mm to 15 mm	166
3	Thickness reduced from 15 mm to 12.5 mm	160
4	Thickness reduced from 12.5 mm to 10 mm	156.5

V. Results and Discussion

Results of finite element analysis of body and middle plate are shown in table 3. For various modified geometry of body and middle plate, the finite element analysis is carried out and results for deformation and von Mises stresses are shown in the table 4 and table 5 respectively. In original component the result of static analysis shows the high value of stresses in limited region and at all other places magnitude of stresses are quite low. The geometry of component is modified by providing fillets in the region of high stresses. The pockets are created in the region where the magnitude of stresses is low. While deciding the position and size of the pocket manufacturing constraint are taken care of.

Table 3 - Deformation and stresses

Component	Displacement (mm)	von Mises stress (MPa)	Maximum Principal stress(MPa)
Body	0.403	162.50	154.62
Middle Plate	0.241	90.00	106.12

Table 4- Deformation and stress for different geometry of body

Component	Displacement(mm)	von Mises stress (MPa)	Maximum Principal stress (MPa)
Original	0.403	162.50	154.62
Modification-1	0.183	116.56	84.87
Modification-2	0.185	116.54	85.33
Modification-3	0.196	119.89	103.20
Modification-4	0.189	119.00	103.31
Modification-5	0.182	117.22	85.42
Modification-6	0.204	122.85	85.47
Modification-7	0.230	127.45	85.50
Modification-8	0.262	131.13	86.75
Modification-9	0.310	125.61	101.57
Modification-10	0.303	118.00	101.77

Table 5 - Comparison of deformation and stress contours of various modifications of Middle Plate

Component	Displacement (mm)	von Mises stress (MPa)	Maximum Principal stress (MPa)
Original	0.242	90	106.10
Modification-1	0.261	107	127.60
Modification-2	0.266	110.90	126.40
Modification-3	0.268	111.20	131.90
Modification-4	0.268	128.90	175.50

To check the rigidity of body and middle plate, modal analysis is carried out. Results for natural frequency for body and middle plate are shown in table 6 and 7 respectively. It can be seen that the natural frequency for modified component are close to the original component. There is sufficient margin between natural frequency of modified component and operating frequency.

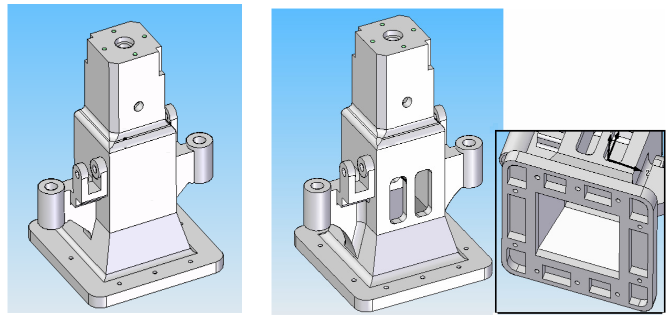
Table 6- Natural frequency for modified geometry of Body

Component	Natural Frequency (Hz)			
	1	2	3	4
Original	272.7	283.89	582.11	755.80
Modification-3	263.21	291.62	714.12	812.11
Modification-6	257.91	285.71	691.78	775.92
Modification-7	254.44	281.57	674	746.36
Modification-8	249.48	275.61	649.54	707.05
Modification-9	243.02	268.17	615.95	658.31
Modification-10	250.02	271.07	629.92	665.89

Table 7- Natural frequency for modified geometry of Middle Plate

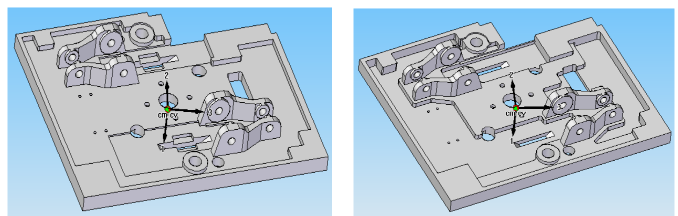
Component	Mode Shape – Frequency (Hz)			
	1	2	3	4
Original	142.89	157.86	224.44	237.32
Modification-1	140.03	152.43	203.95	210.59
Modification-2	141.59	152.57	203.12	213.44
Modification-3	141.46	148.90	200.00	213.36
Modification-4	139.80	145.24	198.83	213.55

The original geometry and the modified geometry of body and middle plate are shown in figure 12 and figure 13 respectively.



[A] **[B]**

Fig.12. [A] Original Geometry [B] Modified Geometry



[A] **[B]**

Fig.13. [A] Original Geometry [B] Modified Geometry

VI. SUMMARY

The body and middle plate of rotary tablet press are analysed for severe operation loads using conventional finite element software (ANSYS 12.0) and stresses and deflections are obtained. The topology optimization of the said components is carried out and substantial reduction in weight, stresses and displacements is observed. The reduction in weight, von Mises stress and deformation for body are 26.69%, 27% and 24.43% respectively. For the middle plate, reduction in weight obtained is about 20.08%.

VII. REFERENCES

[1] Levin M., *Tablet press instrumentation*, Encyclopedia of Pharmaceutical Technology, page – 12001-12030, 2002.

[2] Motazedian F., Sinka I. and Pitt K., *The effect on processing parameter on pharmaceutical technology.* Journals of Powder Technology, pages 276-284, 2009.

[3] Tousey M. and Tousey C. *A tablet making training resources for tablet making professionals.*

[4] Tousey M., *Optimal tablet press operations machine vs. granulations,* Pharmaceutical Technology, 2002

[5] Mudbidri A., *Tablet compressions principles*, Pharma Times, Vol.42, No.11, 2010.

[6] Huang D. and Lee J., *On obtaining machine tool stiffness by CAE technique,* International Journal of machine tool and manufacturers. Vol. 41, page 1149-1163, 2001.

[7] Bakhtiary N., *A new approach for sizing, shape and topology optimization.* International congress and exposition, 1996.

[8] Bendsoe M. and Sigmund O. *Topology optimization – Theory methods and applications*, Springer, 2004.

[9] Bendsoe M., *Generating optimal topologies in a structural design using homogenization method.* Computer methods in applied mechanics and engineering pages 197-224, 1988.

[10] Bendsoe M. *Recent developments in topology design of materials and mechanisms.* EDP sciences, page 41-60, 2002.

[11] Xie Y.M. and et'al, *Optimal design of multiple load cases structures using an evolutionary procedure.* Engineering computations, pages 295-302, 1994.

[12] Weiss D., *Geometry bases topology optimization – improve head impact performance of an engine hood*. 7th eurpean LS-DYNA conferences.

[13] Birath F. and Nilsson A., *Topology optimization of stamping Die*, Lund university, Sweden.