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Finite Element Analysis of Stacker Mechanism used in Bearing Manufacturing

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Abstract-In order to optimize the stackers of the multi-stacker mechanism, it is very convenient to take the help of ANSYS, which can not only ensure security but also reduces time, power and cost. The multi-stacker mechanism, which is to be used to handle seals and place it on the bearing in a bearing manufacturing company, is an effective way of reducing cost, man/machine interaction and time. Reducing the weight of the component helps in reducing the power consumption and in turn reduces the cost. To maintain the stiffness and hardness of the steel, the static structural analysis of the stacker and the base plate is carried out using finite element analysis software. Through this analysis we have reduced the weight of the stackers keeping into consideration the stresses acting on the stackers.
Key words- ANSYS, base plate, stacker, multi-stacker, optimum, stress, power requirements

I. INTRODUCTION

Whenever there is a need to transport the material in an organized and efficient manner, we need the help of a special branch of engineering known as MATERIAL HANDLING or BULK MATERIAL HANDLING SYSTEMS. This type of material handling system came into existence in the year 1965 for the transportation of iron and cement in the mid - west of South Africa. The easiest way to describe is that it moves the products from one location to another location. The other thing should be noted that material handling also deals with the storage, waste handling and assembly line management.

II. INTRODUCTION TO STACKER

A **stacker** is a large machine used in bulk material handling. Its function is to pile bulk material such as limestone, ores and cereals on to a stockpile. A reclaimer can be used to recover the material. Stackers are nominally rated for capacity in tonnes per hour (tph). They normally travel on a rail between stockpiles in the stockyard. A stacker can usually move in at least two directions: horizontally along the rail and vertically by luffing (raising and lowering) its boom. Stackers are used to stack in different patterns, such as cone stacking and chevron stacking. Stackers and reclaimers were originally manually controlled, with no means of remote control. Modern machines are typically semi-automatic or fully automated, with parameters remotely set. The control system used is typically a programmable logic controller, with a human-machine interface for display, connected to a central control system.

Other than stacking, a stacker has three basic movements:

- Luffing: This is vertical movement. Old stackers used a winch mechanism with metal wire, but newer ones are powered by hydraulic cylinders, generally two.
- Travelling: The stacker moves on a rail track, which may be broad or narrow gauge, enabling it to move around the stockyard as required. For this purpose, traction motors powered by direct current (DC) are connected by bevel gears to between 12 and 22 wheels. For manual control, all the controls are in a controller's cabin above the boom conveyor or boom. Modern stackers can be controlled remotely.
- Slewing: This is rotation of the stacker around its central axis to align or place the stockpile where required. This works mostly by a slew pinion that rotates around a slew base. This type of gear assembly is called a sun and planet gear. The axles may be multiple and are driven by DC-powered axle motors which transmit the torque via bevel or helical gears.

Fig 1. A Stacker-Reclaimer(Source [8])

III. INTRODUCTION TO MULTI-STACKER

A multi-stacker has to be established in the seal pressing station in the assembly section of the HUB channel in a bearing manufacturing company. The seal pressing station currently consists of a single stacker mechanism which has only one stacker that contains around 60 seals at a time and carries one seal at a time to the bearing. With such a mechanism, the worker has to reload the stacker after every 10 min. A multi-stacker would contain 12 such stackers and each stacker would contain 60 seals. So the reloading time of seals will increase from 10 min to 2 hrs. This will result in reduced worker fatigue, reduced man-machine interaction, increased productivity and reduction in overall cost. A multi-stacker consists of the following parts:

1. ***Stacker***- *It is used to hold the seals in vertical direction one above the other with proper centring. The seals are removed from the base of the stacker one by one by the action of gravity.*
2. ***Base plate***- *It is a circular plate consisting of stackers. The stackers are placed on the base plate at same distance from each other and at same distance from the centre of the plate.*
3. ***Supporting plate***- *It is a plate which is placed below the base plate to support the seals of the stackers which are inactive at that moment.*
4. ***Pneumatic pusher***- *It is used to transfer/push the seal from the multi-stacker to the bearing. It is pneumatically operated.*
5. ***AC motor***- *It is used to rotate the base plate from the current stacker position to the adjacent next stacker position when the seals in the current stacker are over.*
6. ***Sensor***- *It is used to sense the seals left in the current stacker. When the seals in the current stacker are over, it sends the signal to the controller and actuates the motor to move to next stacker position.*
7. ***Control panel***- *It controls the overall operation of the multi-stacker.*

The demand and development of these stackers is increasing rapidly. Various techniques are being evolved in manufacturing of these stackers to reduce the cost of manufacturing and the running cost.
Reducing the weight of the component is one of the most effective and simple ways of optimizing the design of the component. Reducing the weight has many advantages like ease of handling, installing, less power consumption, less cost etc. Electricity is essential for growth and development of the industries. India is a developing country and the demand of electricity in the country will be more and more, we have to put our sincere efforts to reduce the cost of generation of the electricity. One of the solutions for this is by reducing the auxiliary power consumption in the power station.

Traditional design methods which relies to experience with too much emphasis on security often causes large dimensions and contour, so it is not easy to find vulnerabilities in the product (Mu, 1998). ANSYS is international popular software of finite element analysis which can study and analyse structure, thermal, fluid, electromagnetism, acoustics and architecture. It is widely used in industry, railway, transportation, automotive, aerospace, automotive, mechanical engineering and so on (Lan and Zhang, 2000). By using the finite element method, early in the production design, we will be able to find and solve problems and defects for the design and optimization of pivotal products with a lot of convenience (Yu, 2005).

IV. PROBLEM DEFINITION

The work of the stacker in the stacker system of the seal pressing machine in the bearing manufacturing company is just to hold the seals in vertical position one above the other with proper centring. So there are no forces acting on the stacker. The weight of the current stacker in the stacker machine is about 5 kgs, which is too much for the purpose it is serving. More the weight of the stacker, more will be the power requirements to run the machine.
Thus the idea is to reduce the weight of the stacker by removing the excess material of the stacker and minimizing it as much as possible. The FEA analysis is carried out to find out the optimum size of the stacker rods which can serve the purpose. Finally, the power requirements are calculated for the old design and the new design of stacker and compared.

V. WORK METHODOLOGY

A. Geometry creation and meshing

Geometry of the STACKER is required to carry out this analysis. Solid model of the STACKER was created in solid modelling environment called CATIA V5.Solid model is the base for carrying out any FEA analysis. Solid model of the STACKER that was created in CATIA V5 is shown in the figure below. This model is not required to be imported in to the ANSYS. Just one rod of the stacker is imported into the ANSYS and the forces and constraints are applied on it. Solid model used in any FEA analysis can be very simple and at the same time it reflects the physical reality of the STACKER. Solid model will have to be turned into to FEM model by dividing the solid model into number of small elements. This process is called discretization.

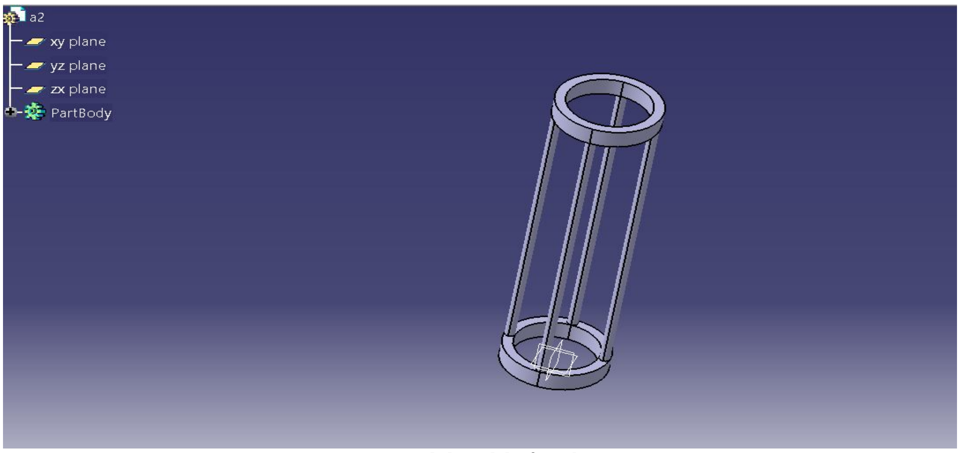

Fig. 2 Solid model of stacker

B. Typical FEM procedure to carry out this analysis

1) Dividing the solid model into number of elements and then connecting these elements with each other meshing and thereby obtaining the finite element model.
2) Applying boundary conditions.
3) Solving the problem.

C. Loading the STACKER ROD

The application of boundary conditions plays a vital role in the finite element analysis. The bottom portion of the STACKER ROD is fully constrained as it is attached to the base plate and force of the ring is applied on top of the rod.

D. Static Analysis

Static analysis calculates the effect of steady load conditions on a structure while ignoring inertia and damping effects, such as those caused by time varying loads. A static analysis therefore can include steady inertia loads (such as gravitational and rotational velocity). Static analysis is used to determine the displacements, stresses, strains and forces in the structures or components caused by loads that do not induce significant inertia and damping effects. The kind of loading that can be included in static analysis are:

- Externally applied forces and pressure
- Steady state inertia forces (such as gravity and rotational velocity)

The analysis of the stacker rod was done with 3 different diameters of the c/s of the stacker rod i.e. 5 mm, 2.5 mm and 3.5 mm.

1) Stacker rod with 5 mm diameter:

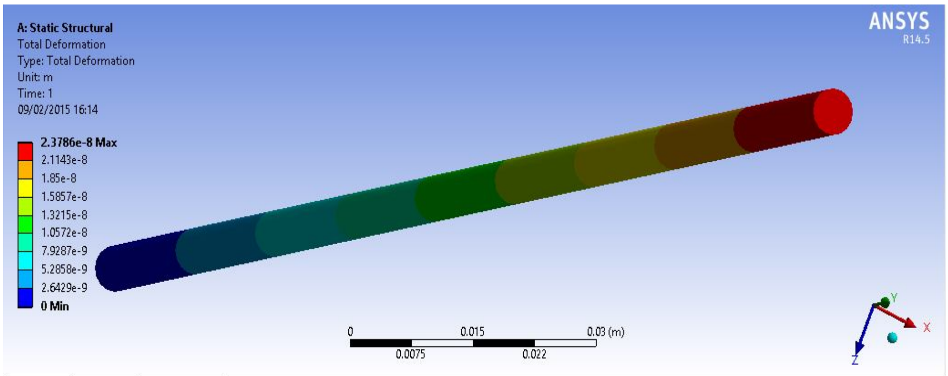

Fig. 3 Deformation in stacker rod

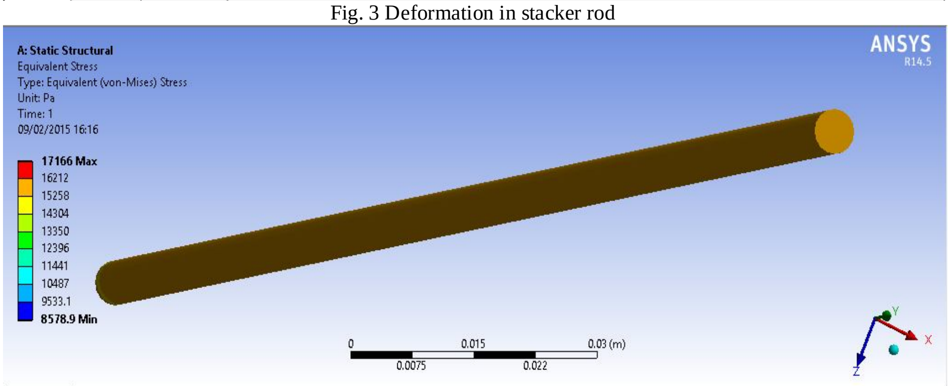

Fig. 4 Stresses in stacker rod

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2) Stacker rod with 2.5 mm diameter:

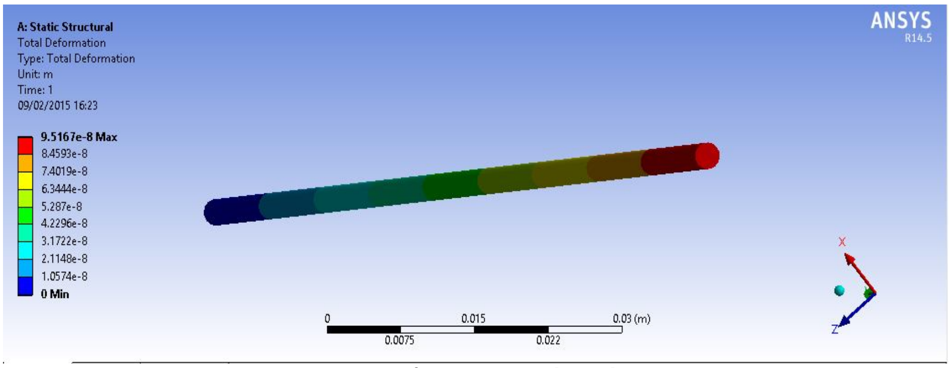

Fig. 5 Deformation in stacker rod

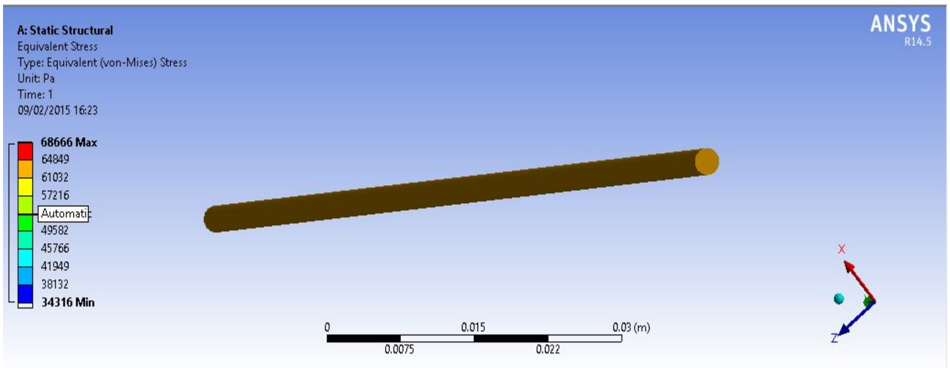

Fig. 6 Stresses in stacker rod

3) Stacker rod with 3.5 mm diameter:

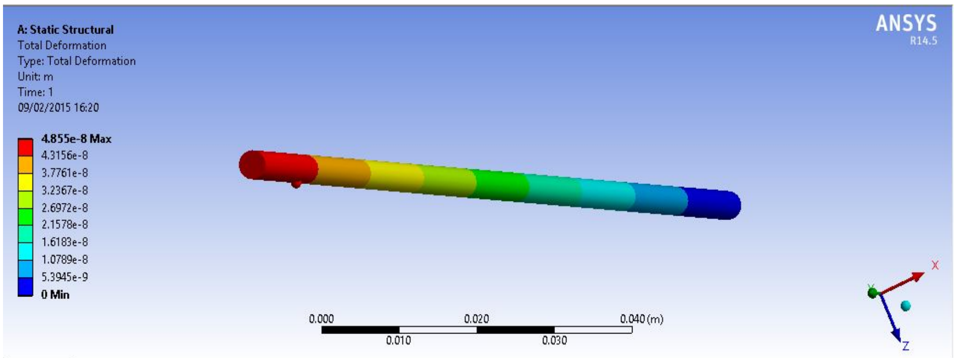

Fig. 7 Deformation in stacker rod

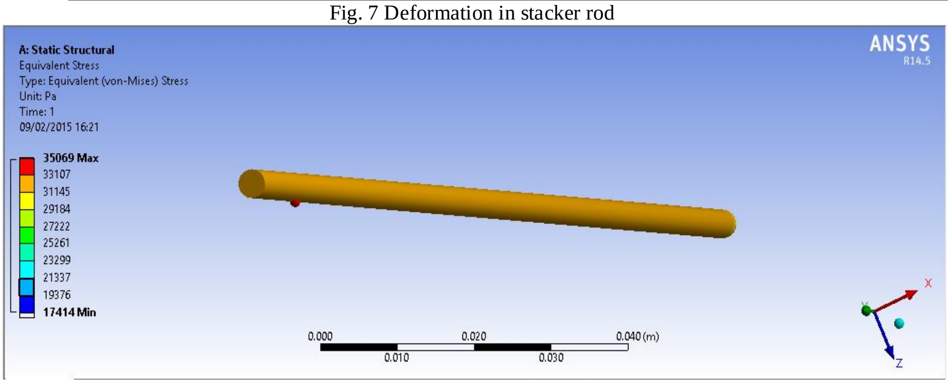

Fig. 8 Stresses in stacker rod

E. Comparison of results of 3 different diameter stacker rods

A review on the analysis of 3types of stacker models has been carried out to ensure the performance of all the models. From the observation it is clear that the performance of the 5 mm rod is better than the other two. The deformation is not much in all the cases but the stresses in the 5 mm diameter rod is within the considerable level.

Table1. Stress and deflection with change in rod diameter

Different Diameter rods	Max. Stress(N/mm^2)	Max. Deformation(mm)
5 mm	17166	$2.37*10^{-8}$
2.5 mm	68666	$9.51*10^{-8}$
3.5 mm	35069	$4.85*10^{-8}$

F. Static analysis of base plate

The results of the stacker rod showed that it is optimum to use a 0.5 mm diameter rod for the new design of the stacker. However, taking into consideration the factor of safety, we have come up with the final design of stacker with the stacker rod diameter of 10 mm. Now we will be analysing and comparing the deformation and stress induced on the base plate when the previous stackers are loaded on the base plate to that of the new stackers.

G. Calculations

1) *Mass of all rods:*

Radius of the rod= 5 mm
Length of the rod= 300 mm
Volume of the rod= $\pi*r^2*h$ = 22/7*5*5*300 = 23571.4285 mm^3
Density of mild steel= $7.85*10^{-6}$ kg/mm^3
Mass= Density*Volume
= $7.85*10^{-6}$*23571.4285 = 0.185 kg
Mass of all rods= 12*4*0.185 = 8.881 kg

2) *Mass of all rings(ring is used to join 4 stacker rods to make 1 stacker):*

Outer radius of upper ring= 46 mm
Inner radius of upper ring= 40 mm
Width of upper ring= 10 mm
Volume of the rod= $\pi*(R^2-r^2)*h$ = 22/7*516*10 = 16210.618 mm^3
Mass= Density*Volume
= $7.85*10^{-6}$*16210.618 = 0.127 kg
Mass of all rings= 12*0.127 = 1.527 kg

3) *Total weight of 12 stackers:*

Mass of 12 stackers = Mass of all rods + Mass of all rings = 8.881 + 1.527 = 10.408 kg
Weight of 12 stackers = 10.408*9.81 = 102.102 N

H. Static analysis

1) *Analysis with previous design of stacker:*

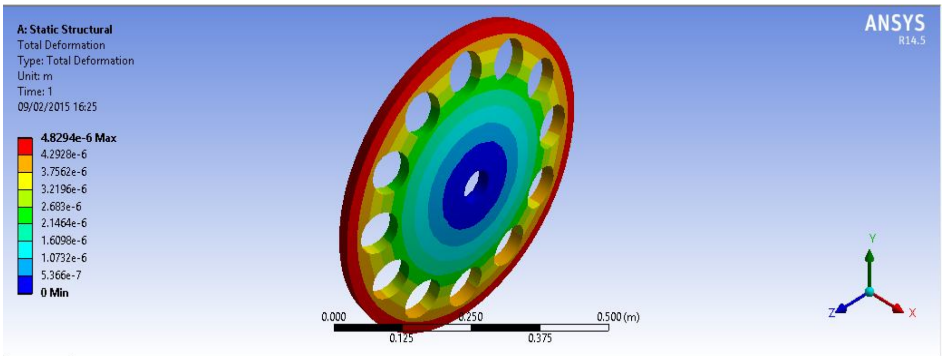

Fig. 9 Deformation of base plate

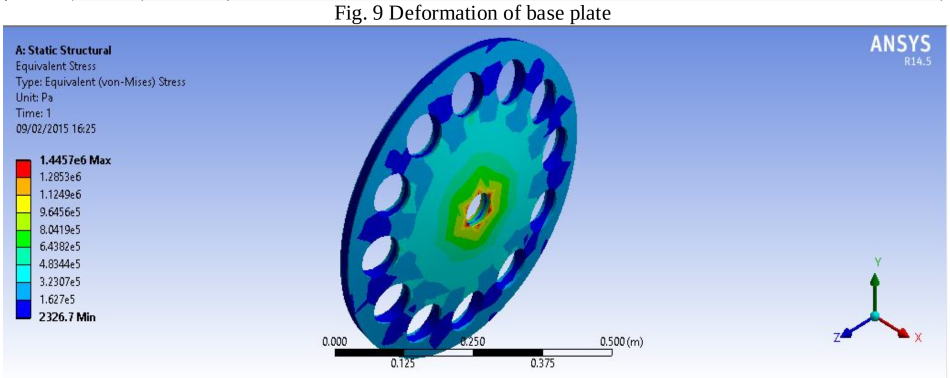

Fig. 10 Stresses in base plate

2) *Analysis with new design of stacker:*

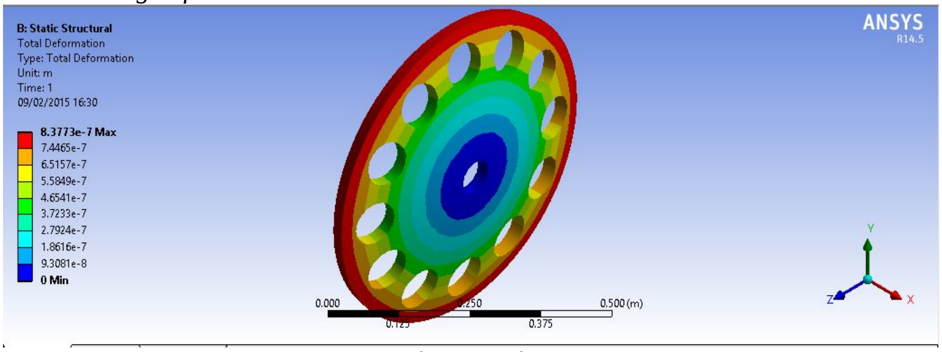

Fig. 11 Deformation of base plate

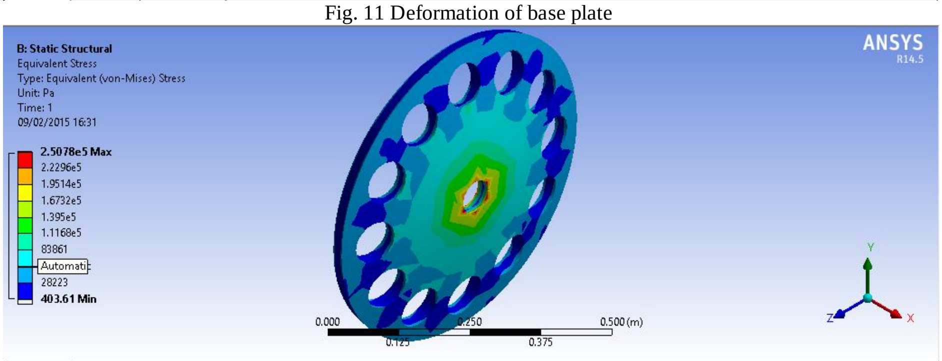

Fig. 12 Stresses in base plate

I. Comparison of results of 2 models of base plate

The deformation is not much in both the cases but the stress in the base plate with new design of stacker has reduced by almost 10 times

Table2. Stress and Deflection with old and new stacker

Base plate models	Stress(N/mm^2)	Deformation(mm)
Old stacker base plate	$1.445*10^6$	$4.829*10^{-6}$
New stacker base plate	$2.507*10^5$	$8.377*10^{-7}$

J. Power requirements in both cases

Specifications of multi-stacker:
Distance moved by base plate = 0.152 m
Time taken = 2 sec

1) *Power requirements with old stacker:*

Force= Mass*Acceleration
= 112*9.81= 1098.72 N
Work done= Force*Distance
= 1098.72*0.152= 167 Nm
Power= Work done/time taken
= 167/2= 83.5W
Safety factor= 1.3
Total power required= 83.5*1.3
= 108.55 W

2) *Power requirements with new stacker:*

Force= Mass*Acceleration
= 62.408*9.81= 612.22 N
Work done= Force*Distance
= 612.22*0.152= 93.057 Nm
Power= Work done/time taken
= 93.057/2= 46.528W
Safety factor= 1.3
Total power required= 46.528*1.3
= 60.487 W

VI. CONCLUSION

The study shows the structural analysis of the stacker rod and the base plate of the multi-stacker mechanism. The result of the analysis of the stacker rod gives us the optimum diameter of the stacker rod. The new design of the stacker rod has reduced the stress value on the base plate by considerable amount. With the new design of the stacker the power requirements have also reduced by considerable amount.

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