Design and Analysis of Rotary Kiln Tyre Rigging System Using FEA

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***Abstract*—Heavy kiln tyre Lifting, rigging and assembly with kiln shell can be managed safely by the kiln tyre suspender equipped by four jaws. In this research paper, a holding mechanism is used for self-adjusting in the defined range of the tyre thickness. The proposed model of kiln tyre suspender beam is comprises of four jaws coupled by steel rope mechanism to the spreader beam and spreader coupled by steel rope to crane hook. The pull chain mechanism is used for to convert into clamping force between jaws by the clamping system. The 3-D CAD model of kiln tyre lifting system is done using CATIA software. Further, finite element analysis is done using FEA software. The obtained results are validating with the experimental result both the results show close resemblance.**

Keywords— Heavy Kiln Tyre, holding mechanism, CAD, FEA

I.INTRODUCTION

Rotary Kiln is a heart of the production industry like cement industry and tyre plant. The kiln is a vessel of cylindrical shape, inclined slightly to the horizontal, which is rotated slowly about coaxial. The raw material to be processed is fed into the end of the cylinder which is upper end. As the kiln moves, material moves down gradually towards the lower end, and may undergo a particular amount of stirring and mixing. Hot gases pass along with the kiln, the hot gases generated in an external furnace, or may be generated by a flame provide inside the kiln. Such a flame is projected from a burner-pipe which is placed in outlet end.

Kiln Shell is made up of mild steel plate, normally thickness of plate between 15 and 30 mm at different are of heating area are fabricated to form a cylinder which we having 68m in length and 4.6 m in diameter. This will be usually situated on an east/west axis to prevent unwanted disturbing currents.[6]

Kiln Tyres or Riding Rings and Supporting Rollers Tyres, normally consist of a single steel casting, smooth machined cylindrical surface, which is attach loosely to the Rotary kiln shell through a number of "chair" attachment. These require perfection of design, since the tyre must fit the shell properly, but also allow thermal displacement. The tyre rides on pairs of bearing steel rollers, and machined to a smooth cylindrical surface. The rollers must support the rotary kiln, and permit rotation that is as nearly frictionless as possible. The mass of a typical 4.6 Dia. x 68 Length m kiln , including refractory bricks and feed, is around 750 tonnes, and would be carried on three tyres and sets of roller bearings, spaced along the length of the kiln. The kiln have 6 sets of rollers. Kilns usually rotate at approximately 5 rpm. The bearings of the rollers have to withstand the large static and live running loads are involved, In addition part to support rollers, there are normally upper and lower "thrust rollers" bearing against the side of tyres, that restrict the kiln from slipping off the support rollers showing in them fig-1.

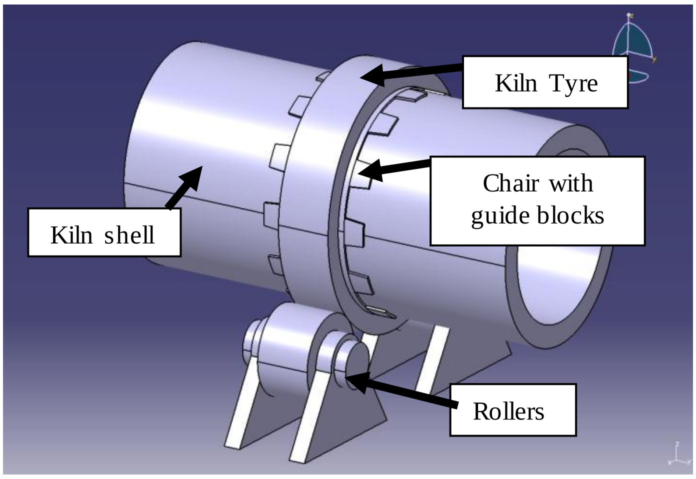


Fig-1 General arrangement of Rotary kiln

In this paper area of constrained only with the assembly of rotary kiln shell and its tyre this is heavy engineering for which having 4.6 x 68 m [6] rotary kiln shell and its tyre are assembled manually by use of multiple heavy crane and human Labour, which is time consuming, and it may damage while transportation is taking place and unsafe work practice because of heavy weight. Therefore, the assembly of kiln shell and its tyre having very tedious job because of expansion gap between them is very small and the length of heavy kiln shell varies with different tyre shell height so it is assembled by following methods.

1] By using wire rope in horizontal position. [Fig-2]

2] By using holding structure in vertical position. [Fig-3]

These methods are time consuming and against the safety norms in fig-2 horizontal position the tyre is to be mounted on the shell but it requires multiple cranes for assembly purpose.

Fig.2 By using wire rope in horizontal position.

And in other method showing fig-3 holding structure in vertical position requires one crane but if the shell height may vary at different height of kiln tyre shell then structure is turns to scrap it having no use.

Fig.3 By using holding structure in vertical position.

Hence because of these reasons new scheme or mechanism should be evolved for lifting kiln tyre for fast and safe handling.

1) Principles of operations

Principle of operation of lifting kiln tyre for which design is carried out on the basis on the encompassing and self-actuating jaws. The proposed lifting beam system in which spreader beam is also required for the This arrangement provides four places of attachment to the object being lifted, thus avoiding the risk of overstretching if a single attachment were used shown in fig.4 This also allows for a straight lift on the object instead of a tilted lift.in this method the position of kiln shell should be in vertical and the kiln tyre inserted by using this mechanism with ease. Without spreader beam maintain centre of gravity of kiln tyre, without spreader beam assembly of kiln tyre and its shell is not carried out because of height of shell. [9]

2) Assembly of Kiln Tyre Rigging System

The assembly consist of:

- Self-actuating jaw
- Spreader or lifting beam

Many of the research from worldwide have an attempt to develop gripper model for e.g. At the present moment this system adequately defines the grasping principles capable to perform the required operational work together with some basic usual recommendations. However, finding a way to evaluate every possibility, including the variety of the objects. Since the system is related on a set of rules that can be easily modified, in future it could work as a self-learning system [1]. Jacopo et al. [2] discussed the new concept in the design, selection and testing of a gripping device for heavy and deformable materials handling. The present model is developed only to gripping a light weight equipment such as jute coffee sacks. However, being at the prototype phase, such grippers can be modified, in order to enhance their features, the ones with bad results. Further part study, one of the gripper with the highest scoring value has been selected to be fully analysed. The concept resulted to be simple and reliable, the design satisfies all the requirements and both the force exerted and the actuation time the unloading requirements. Unfortunately, at present manufacturing related issues and the lack of suitable components restrict an extreme downscaling process of the gripper.

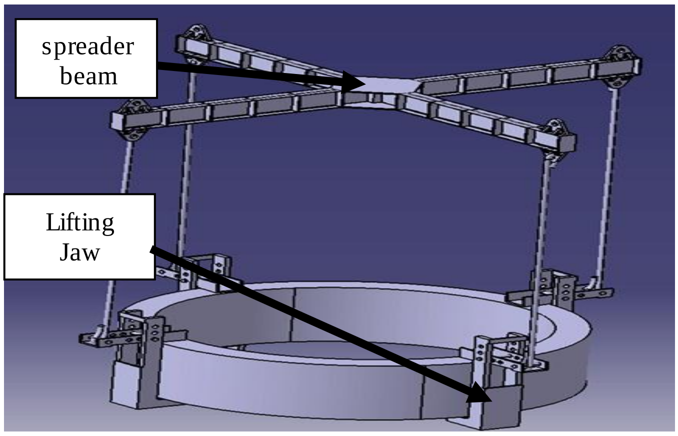


Fig.4 Kiln Tyre Rigging System

Ho Choi and Muammer Koc [3] discussed the existing grippers types and its design strategies, in the design of a flexible gripper based on the inflatable rubber pockets concept. It was found that rubber material does not affect the part weight limitation, but rubber contain butyl showed a superior durability and consistent expansion under cyclic inflation tests compared with neoprene. Thus, selection of rubber material is crucial for accuracy and maintenance aspects. Further, their study revealed that design of other elements of the flexible gripper may also affect the accuracy of part handling, elasticity and thickness of the side plates (jaws), and the top side plate and its joint to side plates play a vital role in decreasing the deflection of the side plates are applied pressure into the rubber pockets, thus, onto the side plates. A.M. Zaki et al. [4] presented with designed and application of efficient intelligent robotic gripper by which, a robotic gripper design and implementation was presented. Robotic gripper performance efficiency appears at handling unknown objects with different masses, dimensions, and coefficients of friction. Verifying highly recommended guide lines described, in gripper implementation had proved the gripper efficiency. The merits of using one fixed finger and the other flexible appears in the need for only one motor for actuation and also easier control when avoiding mechanical system. Khadeeruddin et al. [5] Discussed the design and analysis of jaw actuated pneumatic gripper. The force and torque for the gripper have been designed for dissimilar set of situations. CAD modelling by using Solid works and analysis with ANSYS tool. Authors concluded that the pneumatic gripper makes pick and drop work easier and much faster than the conventional techniques. Such Pneumatic grippers are generally cost-effective methods because valves, air hoses, and added pneumatic devices are easy to maintain. Peter Kostal et al. [6] from the Indian standard dimensions and materials of cement rotary kiln and its components gives the standards of designed dimensions. [7] pointed that the assembly of the grippers for industrial robots has a specific state in manufacturing process as assembly imply major portion work in term of their portion in manufacture total time. For technically complex and actual assembly is performing manually too, because assembly has large reserves of automation aided. One of the causes of automation assembly lag is higher manipulating ability requirement for assembly devices by joining parts. Often some assembly operations, which are suffering free reachable by manual, by automation are requested very complex and highly exclusive device. Robotized workshops are used at a number of industrial branches. Request to effective and competitive manufacturing generate pressure to robotics design centres. Fashions in this area is a continuous accuracy increasing and develop a new method to gripper design.

CheSoh et al. [8] developed an adjustable gripper for robotic picking and placing operation. An autonomous robot with flexible gripper that achieve pick and place operation was successfully build. The robot was able to pick the object and place it effectively. The robot was also able to lifting up and down position smoothly. By using PIC microcontroller, the robot performed it tasks perfectly according to program. Beside than that, the adjustable gripper with sensors was able to open its grip respect to size of the object. Due to this advantage, the robot can pick the object within the gripper limitation. David T. Ricker [9] Designed and Fabricate Lifting beams (also known as spreader beams) are used to help in the hoisting method. Most erectors and riggers accumulate an assortment of lifting beams during the actual work time. Gualitiero Fantoni et. al. [11] discussed with the choosing the different methods of supporting the selection of robot and adequately described grasping principle with the fundamental recommendations. Lambsiya Vimal et. al. [12] Designed and analysed the heavy shell tilting fixture was carried out for weight of 110MT.this analysed fixture is valid for Stationary as well as neutral position.

II.DESIGN OF KILN TYRE RIGGING SYSTEM

Traditional method for design of kiln tyre rigging system is tedious and time consuming. It requires expert person and it is very costly procedure. Therefore, in this present paper a simple design for kiln tyre rigging system is given. The details of designing of klin tyre rigging system are given below. (It is taken from industry standard data) [6]

Inside Diameter of kin tyre – 4830 mm

Outside Diameter kiln tyre – 5685mm

Height – 1300 mm

Forces on kiln Jaw

Tyre weight = 72149.1 kgs

= 707781 N

= 707781/4 (For single jaw)

We are used four jaws for the purpose of lifting.

Tyre weight = 176945.4 N (For single jaw)

Scaled model = 176945/5 (5 times scale down)

= 35.3 KN

Forces on Spreader bar

Tyre weight + Jaw weight=72149 kg + 1186.5 kg

= 707781 N + 11639.5 N

=719420.5 N

= 719420.5 / 4 (For single bar)

= 179855.1 N

Scaled Model = 179855.1 /5 (5 times scale down)

= 35.9 KN

TABLE I

Mechanical properties of mild steel[11]

Properties of material	Metric
Density	7850 kg/m³
Poison's ratio	0.28-0.30
Modulus of elasticity	210 GPa
Yield Value	290 MPa
Elongation	25%
Ultimate Stress Value	390MPa

1.Design of Lifting Jaws

Generally, the jaws are made of mild steel material. In proposed model the encompassing jaws are used. using CATIA software.

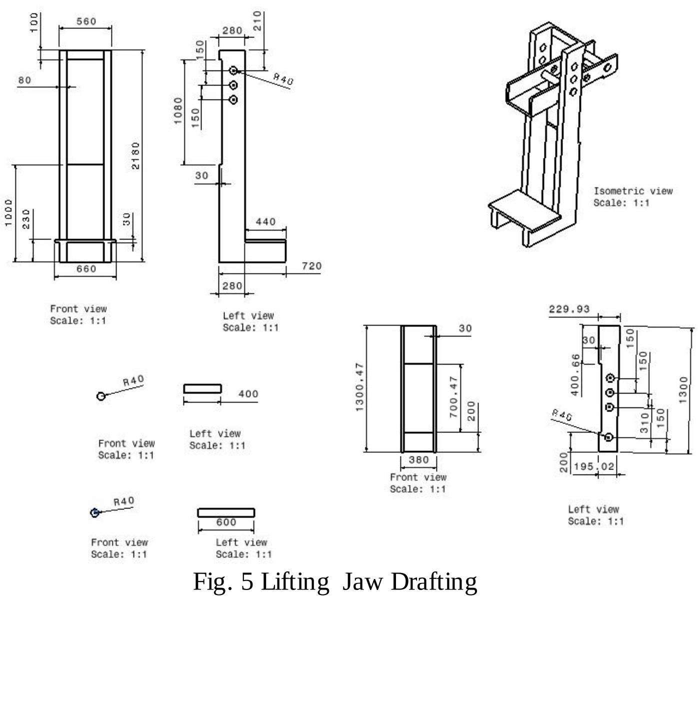


Fig. 5 Lifting Jaw Drafting

The assembly of proposed encompassing jaws CAD model of kiln tyre lifting system The design and analysis of kiln tyre lifting jaw system was carried out in a systematic way as described below. Initially CAD model for the lifting jaw was developed.

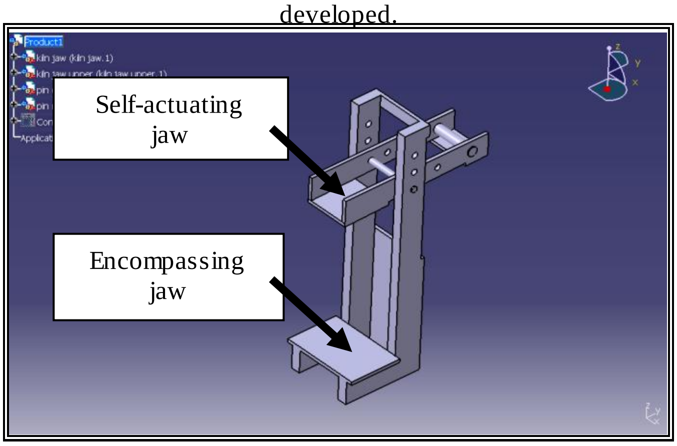


Fig. 6 CATIA model of Lifting Jaw

Further, meshing for the kiln tyre lifting jaw was done using HYPERMESH software as shown in Fig. 7. It having mesh size of 10mm, no of nodes 111436 and no of elements 475210.

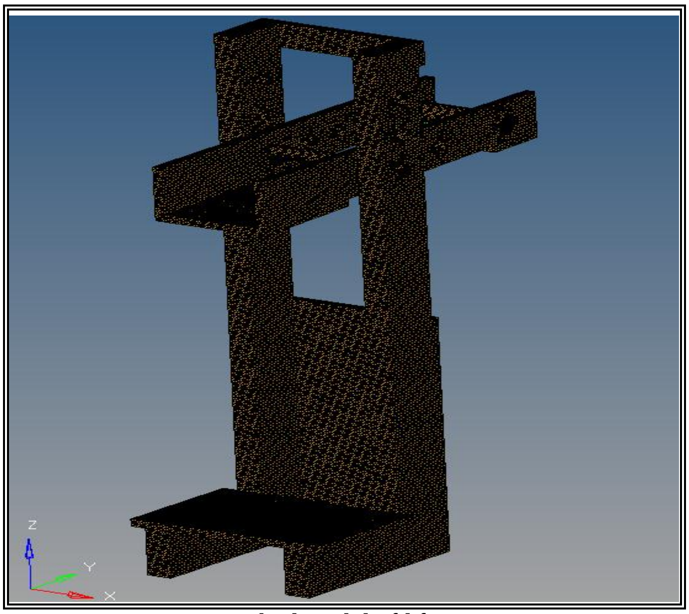


Fig.7 Meshed model of lifting jaw

Furthermost, analysis of kiln tyre jaw was carried out using ANSYS. The boundary conditions which were applied during analysis are described below The total weight of the Kiln tyre is 72149.1 kg. For this total weight considered first iteration the Kiln tyre will be lifted by four jaws, the force on each jaw will be 1/4th of the total weight. Therefore, we apply a force of 1.7e5 N. In the analysis area we are going to concentrating results are as follows, first is the deformation on the lifting jaw and next for the Von-mises stresses

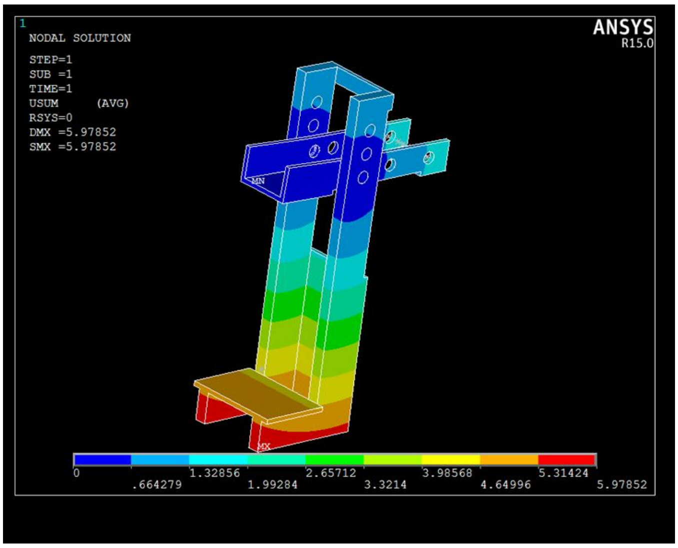


Fig.8 The deformation on the lifting jaw is found to be 5.9mm

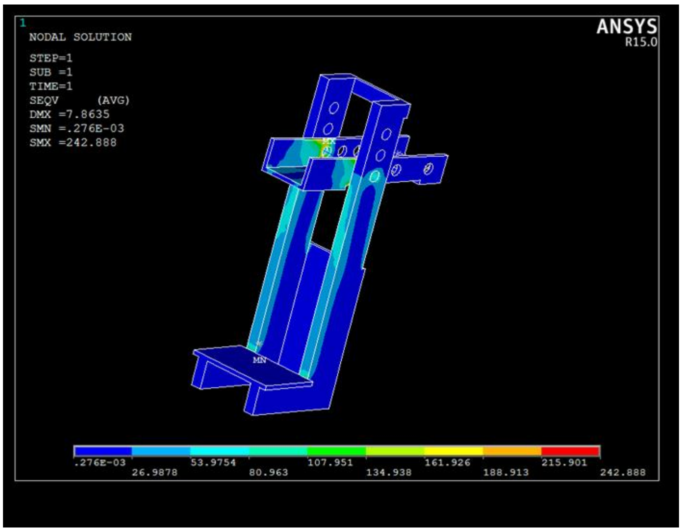


Fig.9 The Von-mises stresses are 242.88MPa

Stress value for Lifting jaw is 242.88 N/mm^2 which is well below the critical value 390MPa. Hence, design is safe.

2. Design of Spreader Beam

The loads over a component can be decomposed into those are axial in nature, those that exert bending forces and those that creates torques. One of these normally dominates to such an extent that structural elements are specially designed to carry it, and these names are common. Thus ties carry tensile loads; beams carry bending moments; shafts carry torques; columns carry compressive axial loads. Figure 10 shows these loading on to shapes that resist them well. [10]

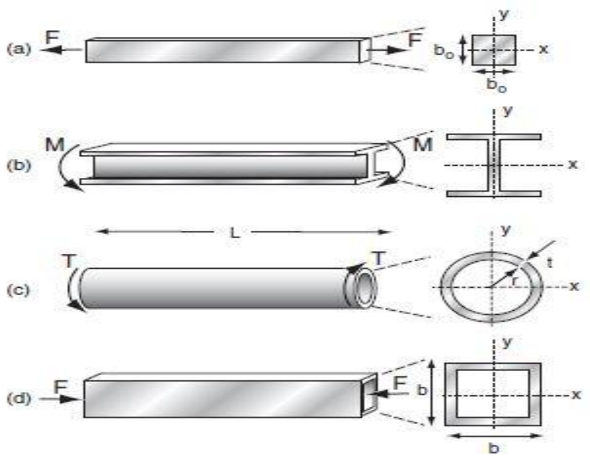


Fig.10 Loading on different shapes

Shape factor can be written as,

$$\text{Ø}^{e}B = \frac{S}{So} = \frac{EI}{EIo} = \frac{12I}{A^2}$$

Where, Bending stiffness= S α EI

E =Young's modulus

I = Moment of inertia

Shape factor for Different section is compared.

1) I - section

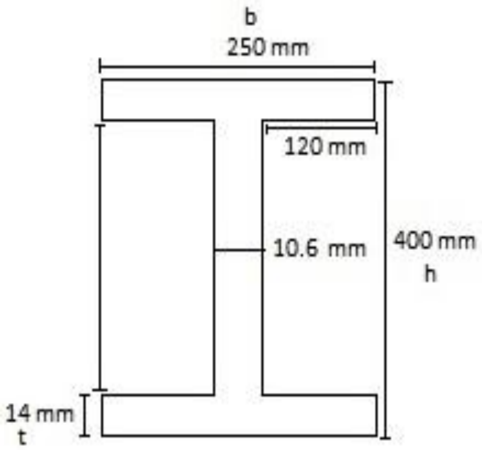


Fig-10a I – section (t=10.6mm, b=250mm, h=400mm)

$$\text{Ø}^{e}B = \frac{\sqrt{2\pi}}{3}\left(\frac{h}{t}\right)^{1/2}\frac{(1+3b/h)}{(1+b/h)^{3/2}}$$

$$\text{Ø}^{e}B = 10.95$$

2) Hollow rectangular section

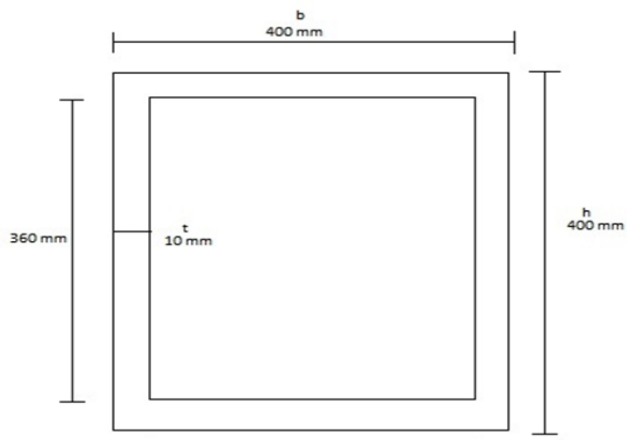


Fig-10b Hollow rectangular section (t=10mm, b=400mm)

$$\text{Ø}^{e}B = \frac{2\sqrt{\pi}}{3}\left(\frac{b}{t}\right)^{1/2}$$

$$\text{Ø}^{e}B = 7.4$$

3)Hollow Cylinder

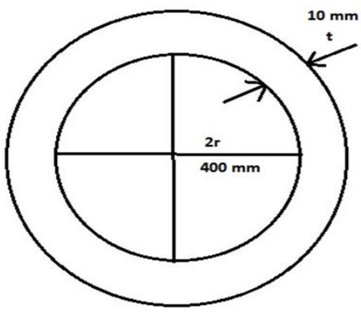
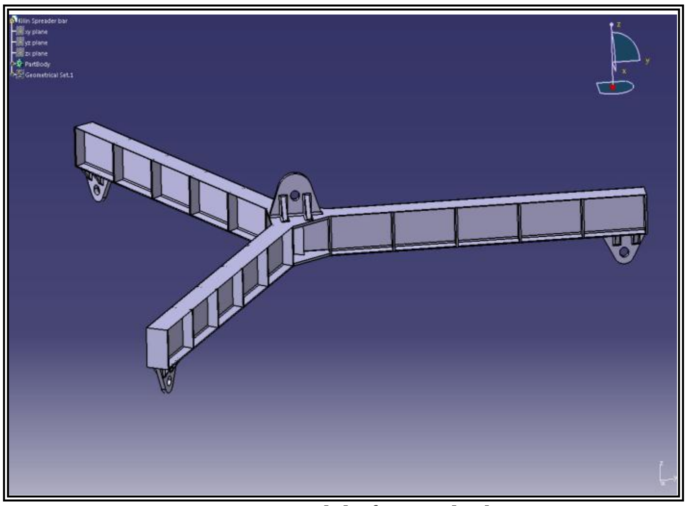


Fig-10c Hollow rectangular section (r=200mm, t=10mm)

$$\text{Ø}^{e}B = (2r/t)1/2$$

$$\text{Ø}^{e}B = 6.3$$

So from the above comparison the Strength of the I section is found to be more and which resist the bending moment very well. Therefore, the purpose of beam is fulfilled by using the I section beam for our application. The design and analysis of Spreader Beam was carried out in a systematic way as described below. Initially, CAD model for Spreader Beam was developed using CATIA software. First we had design model of three clamping spreader beam as iteration method.



Fig,11 CATIA Model of Spreader beam.

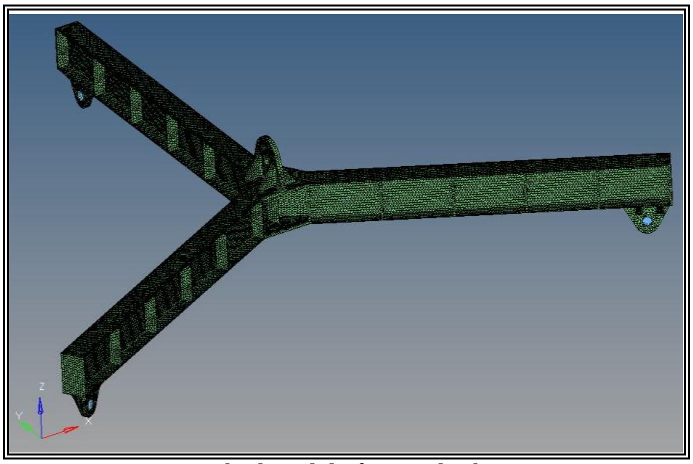


Fig.12 Meshed model of Spreader beam.

Further, meshing for the spreader beam was done using HYPERMESH software as shown in Fig.11.The Nature of type of mesh is tetrahedral. It having no of nodes 45355 and no of elements 137887.

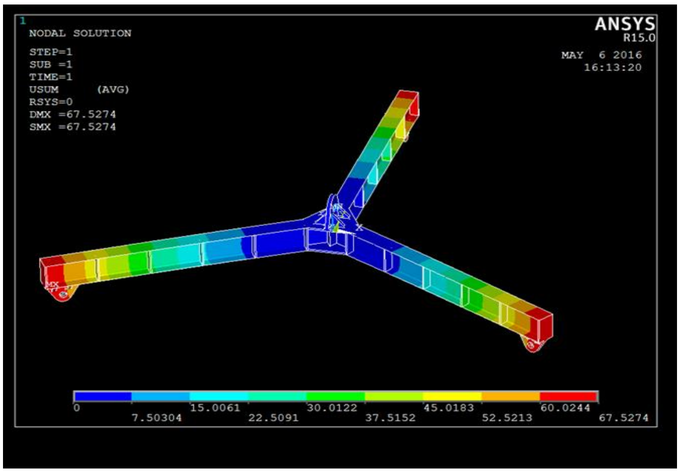


Fig.13 The deformation on the lifting jaw is found 67.52 mm

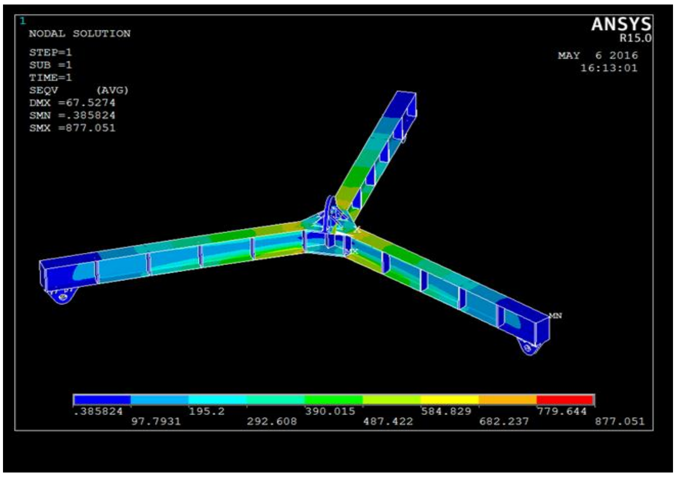
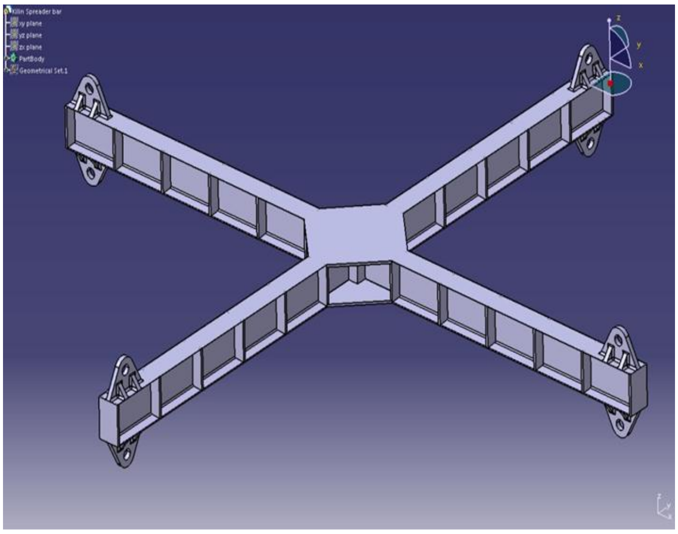


Fig.14 The Von-mises stresses are 877.05 MPa

Stress value for spreader beam is 877.05 MPa which is above the critical value 390MPa, and deflection is also 67.52mm. Hence, design is not safe Three clamping spreader. Hence we have to take further design with four clamping spreader beam.



Fig,15 CATIA Model of Spreader beam,

Further, meshing for the spreader beam was done using HYPERMESH software as shown in Fig.11. It having no of nodes 79448 and no of elements 285009.

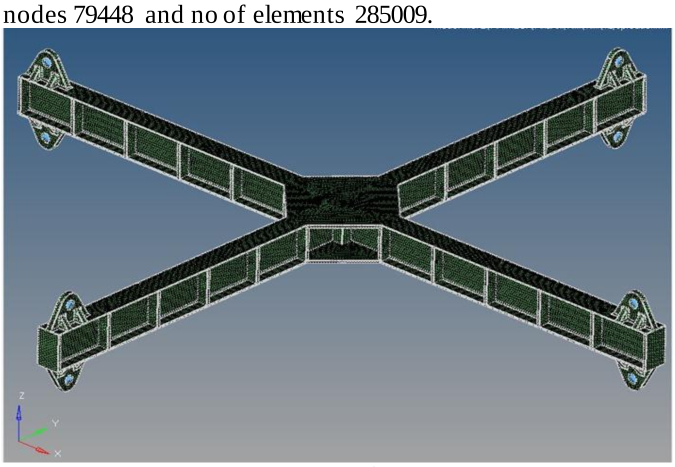


Fig.16 Meshed model of Spreader beam.

Further, analysis of kiln tyre jaw was carried out using ANSYS shown in fig 17 and 18.

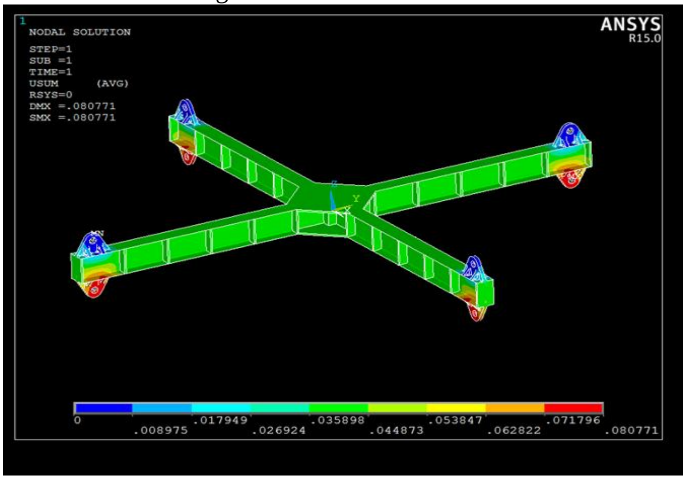


Fig.17 The deformation on lifting jaw is found to be 0.08 mm

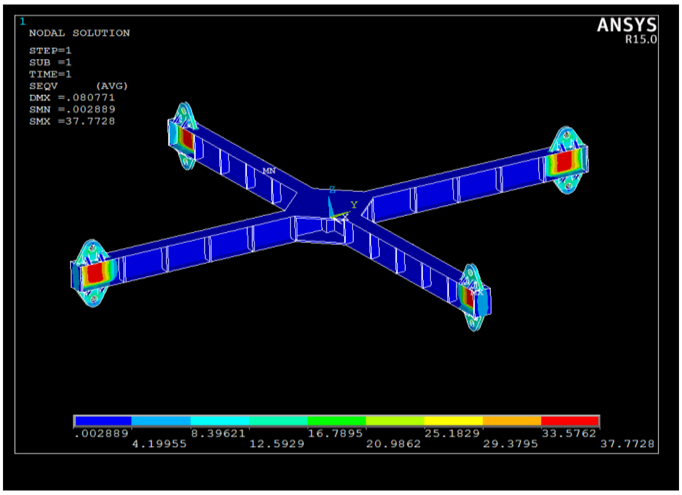


Fig.18 The Von-mises stresses are 37.77 MPa

Stress value for spreader beam is 37.77 N/mm^2 which is well below the critical value 390MPa. Hence, design is safe.

III. EXPERIMENTAL RESULTS & VALIDATION

Furthermost part So we want to validate the FEA analysis with the Experimental analysis. So constructed prototype scale down model of 1:5 model of lifting jaw and I section spreader beam shown in fig 19 and they tested were on UTM for experimental results.

Fig 19 Fabricated Prototype Models

Fig: 20 Experimental testing for lifting jaw

Fig: 21 Experimental testing for Spreader beam

Here are experimental results are shown in graph fig.21 and fig.22 which are load vs deformation.

For kiln lifting jaw

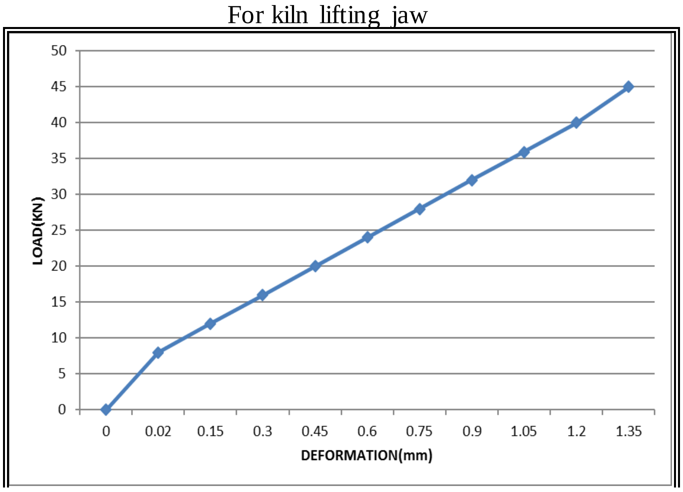


Fig:22 Graph of Load Vs Deformation for Kiln lifting jaw

The experimental result is 1.10 mm for 35.3 KN but we have the FEA results and compare with experimental result. Therefore, Deformation of jaw=5.9mm (FEA)

As the model is scaled to 5 times= 5.9/5

Deformation of jaw =1.19 mm

Percentage Error = (1.19-1.10)/ 1.19

=0.075

Percentage Error =7.5%

For Spreader Beam

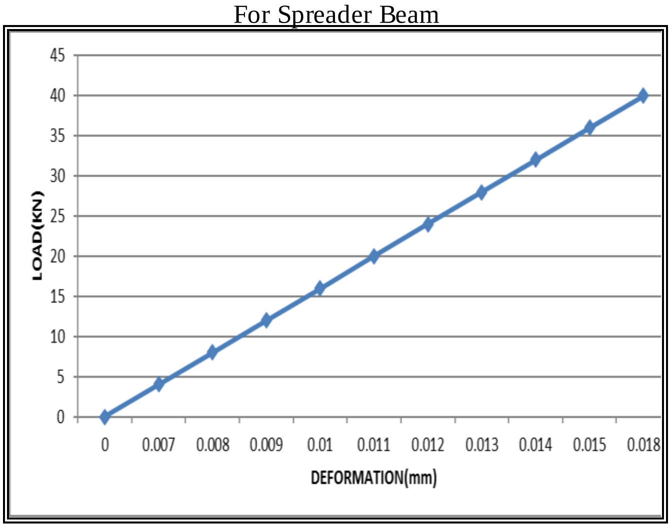


Fig:23 Graph of Load Vs Deformation for Spreader Beam

The experimental result is 0.015mm for 35.9 KN, but we have the FEA results and compare with experimental result.
Therefore, Deformation Spreader Beam =0.080mm

As the model is scaled to 5 times= 0.080/5

Deformation Spreader Beam = 0.016mm

Percentage Error = (0.016-0.015)/0.016

=0.062

Percentage Error =6.2 %

TABLE II

Comparison between Experimental and FEA results

	Deformation (in mm)	
	Lifting Jaw	*Spreader Beam*
FEA Results	1.10	0.015
Experimental Results	1.19	0.016

IV. CONCLUSION

1. Designing of the lifting jaw for kiln has been done using standards.
2. The designed model is checked for feasibility using software.
3. The Model is redesigned considering the software results and analyzing the assembly components.
4. The main components of kiln tyre rigging system are fabricated and are experimentally tested.
5. FEM results and the results from the experimentation has been validated. The values of both the results show close resemblance shown in Table II.
6. The design and analysis is carried out and it is tested for feasibility by analytical and experimental means.
7. Hence the objective of the project is achieved.

V. ACKNOWLEDGMENT

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