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Strength Analysis of Leveling Pipe Lifter Design through FEA/FEM

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Abstract:
In this paper, design and analysis of a Pipe lifter for leveling & lifting has been presented. The design is limited having lifting capacity of 4000kg and up to 2.5metrer. Unlike many other operations, material handling adds to the cost of the product and not to its value. It is therefore important first to eliminate or at least minimize the need for material handling and second to minimize the cost of handling. Presently the concrete pipes are handled manually by use of crowbar and human worker which is time consuming, damages the pipes while transportation, unsafe work practice hence there is a need of concrete pipe suspender for fast and safe handling of concrete pipes. It is important to lift and keep the pipes properly. If the tool is prepared incorrectly, it may cause partial or total damage of the pipes. Worker safety conditions highlight the use of concrete pipe suspender, concrete pipe holder. Lifting and placement of the concrete pipes can be managed safely by the concrete pipe lifter equipped by jaws. Light weight, structure is simple, so the usage of it is very favorable. The concrete pipe can be kept lifted by turning the hanging force into clamping force. Here we are conducting a non-linear analysis of a pipe lifter and finding out the equivalent stress and deformation in static analysis carried out. The final design is selected based on design as well as FEA results. The parameters considered for selecting the design are maximum equivalent stress value, ease of fabrication, material saving and factor of safety.

Keywords: Pipe lifter, FEA model, stress analysis. Static & strength analysis, Hypermesh, Femap, Internet

Approach:
This paper is based on the concept of analysis based on software and results are interpreted and concluded for further design purpose. So many sources available for the conceptualization and used of the software for static and strength analysis like internet, previous paper published on static analysis, books.

Finding:
Various software is available for the analysis like Hypermesh. Hyper works, Ansys, Femap etc. Hypermesh software is used for the static analysis of pipe lifter in this and results are given by it. Stress, displacement of the structure of pipe lifter is analyzed in static analysis by Hypermesh software. Software results are more practical and very close to the experimental results.

Scope and limitation:
Software analysis now played a vital role for the development and analysis for the product development. Now almost every industry used this software analysis for their product development. In future its uses will increase very rapidly in engineering industries. This paper shows the importance of software analysis because this is the non-destructive method for analysis and obtained results which are very close to experimental results. But it has some limitation also by which it can be used with some care. It depends upon the CAE engineer to use effectively under some precautions and also results interpreted depend on CAE engineer for further used of it.

Originality:
Model of pipe lifter design as per the requirement of lifting capacity of 4000kg and up to 2.5meter length. All dimensions are also obtained through theoretical calculation & after the FEM results.

1. Introduction:

Lifting and handling of concrete pipe is a main task in most of the industrial and commercial purpose. Concrete pipes are commonly used for rainwater drainage and sewerage in most civil works. There are various techniques available for concrete pipe handling.

Conventional Method of Concrete Pipe Handling:
Presently the concrete pipes are handled manually by use of crowbar and human labour as shown in fig.1&2. This technique requires 4-5 human labours for whole process of installation of pipe in the field. This is so time consuming process and it may cause damages to the pipes while transportation. It is found to be quite unsafe for the workers.

The conventional concrete pipe laying work involve following process: -

1. Moving a crane to the site concrete pipe storage yard.
2. Fastening a concrete pipe to a crane using a wire rope or chain choker and lifting up the pipe.
3. Moving the pipe to a trench for installation.
4. Placing the pipe and calibrating its position to be connected through the repetitive trial and error.
5. Connecting and aligning the pipe and adjusting the slope, if necessary.

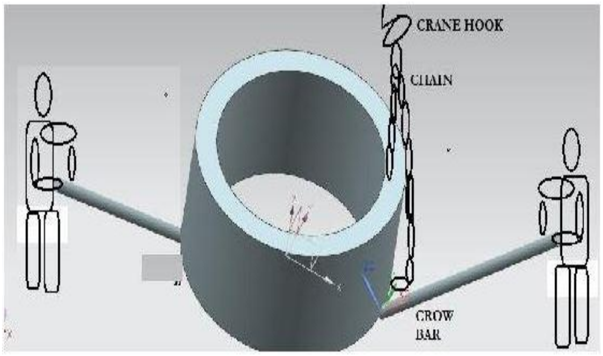

Fig. 1. Concrete pipe handling using crowbar

Fig. 2. Concrete pipe handling using crowbar

During concrete pipe installing work, labors are exposed to the risk of accidents when they enter the trench to install pipes. Safety concerns also arise when workers need to handle heavy weight concrete pipes.

- **Automated system in Pipe Installation (Vacuum Pipe Hoist)**

Vacuum Pipe Hoist as shown in fig 3 & fig4 is convenient pipe handling can be based on a crane or excavator. Vacuum systems eliminate the need for traditional handling equipment, such as towels, slings, chains, harness hooks, belts etc. In this system hoists represent a complete system. Onboard power is supplied by a small diesel engine mounted on a hoist boom with a vacuum pump and transmission.

The system is operated by a wireless remote-control unit.

In most cases, the hoists are mounted on hydraulic excavators. Thus, the kit includes an adaptor and a hydraulic rotation mechanism. With this set of equipment, the majority of pipe-handling work can be performed by one operator.

Contrary to widespread belief, failure of the vacuum pump or transmission does not cause the pipe to drop suddenly.

Fig. 3. Vacuum pipe Hoist

Fig. 4. lifting pipe

When the vacuum in the reservoir of the boom falls below a set level, a visual and aural warning is sounded. However, the lift continues to support the pipe reliably, as there is enough reserve built into the lifting strength to complete a guided lowering of the load.

Pipe-handling work is carried out more quickly and with fewer people, reducing the likelihood of accidents. The lifting effect is spread over the surface of the suction cups so there is no spot burden. This is especially important for the prevention of damage to pipe with internal concrete coating. But cost of this equipment is very high & with high maintenance.

- **Scissor Grab Pipe Lifter**

Scissor Grab Pipe Lifters as shown in fig 5 automatically clamp or grab, lift, and move pipe without assistance. The scissor grab is ideal for handling round materials such as steel bars, tubes and pipes.

Faster, smarter, efficient, flexible and fully automatic, Aardwolf bar and pipe lifters are designed to safely lift steel bars and tubes. No hydraulic power supply and no slings or chains are required. The operator is able to use the Scissor Grab Lifter to grab, lift and move pipe without assistance. The scissor grab is ideal for handling round materials such as steel bars, tubes and pipes.

- **Leveling Pipe Lifter**

Leveling pipe lifter as shown in Fig 6 & Fig 7 is robust in design. Leveling Pipe Lifter allow the user to place and position concrete pipe in one operation. And feature a cylinder built-in that automatically balances the pipe.

Lifting and placement of the concrete pipes can be managed safely by the concrete pipe handling system equipped by leveling pipe.

Fig. 5. Scissor Grab Pipe Lifter

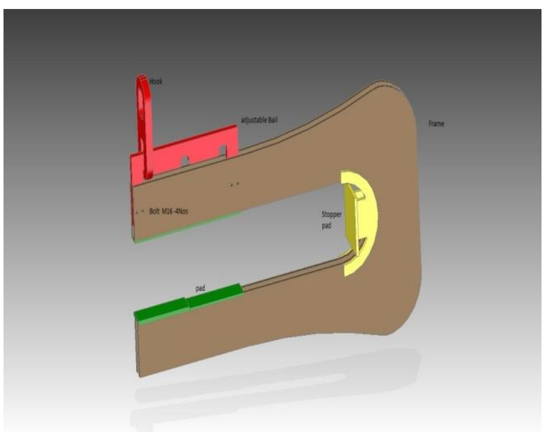

Fig. 6. Leveling Pipe Lifter

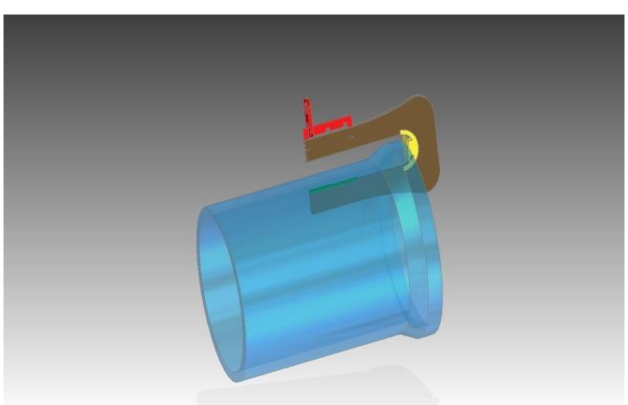

Fig. 7. Leveling Pipe

Pipe hooks can be used with any shape or type of pipe, including RCP, ductile iron, steel, or PVC.

Lifter. Light weight, structure is simple, so the usage of it is very favorable The Leveling pipe lifter consists of following parts:

1. U-Plate / Frame
2. Hook
3. Carrier / Adjustable Bail
4. Pad
5. Stopper pad/ supporting pad
6. M16 Bolts

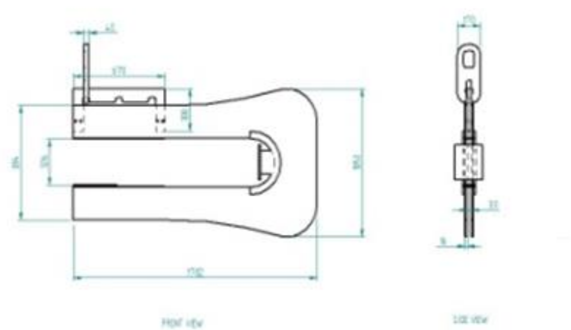

Fig. 8. 2D Drawing of Leveling Pipe Lifter

Features of Leveling Pipe Lifter

- Stand-up leveling bail adjusts for varying pipe lengths.
- Adjustable bail stop makes repetitive lifts easy to handle.
- Pipe stop helps drive the pipe into position.
- Built-in laser target holder allows operator to set & laser position at the same time.
- Positioning handle.

Advantages Leveling Pipe Lifter

- Weight and size are less than that of fully automated system.
- It requires less time to attach the whole system to the crane. So, it is quite convenient for frequent assemble and dismantle.
- It's initial and maintenance cost is less as compared to fully automated system. So, it is less costly than automated system.
- A labor does not need to enter into the trench, hence reducing possibility of accident.
- It is requiring only 1 labor and 1 operator, hence reduces the labor cost.

Finite element analysis (FEA) has become more important in recent years. Numerical solutions even for a very complicated stress problem can be obtained using this method. The model of a design or material can be computerized for a FEA system to analyze for specific stress related results. The suggested design can be verified using

FEA, to determine whether it can perform under the required specifications prior to construction or manufacturing. The solid under the required specifications prior to construction or manufacturing. The solid the finite elements, where elasticity principles can be easily applied. Its procedure requires a pre-processing operation that converts a computer aided design (CAD) model into a discredited form of mesh. A solver, containing various equations, then evaluates the mesh. Finally, a post-processing module interprets the results obtained from the solver.

This paper provides a case study of a structural behavior of the leveling Pipe lifter having lifting capacity of 4000kg and up to 2.5meter pipe using FEA. The objectives to conduct this investigation are:

a) To determine the maximum forces that can be applied to the Leveling pipe lifter;
b) To analyze the behavior of the leveling pipe lifter structure towards each loading conditions.

2. Literature Review

In field of Industrial Robotics and lifter design and analysis, many research works have been done by many researchers. Some of the distinguished ones which are relevant and carry basic information for this paper have been highlighted briefly.

Kim and Bernold [2009] compared the two innovative technologies for safe pipe installation. In that authors discussed about the conventional method of pipe installing and Stewart Platform based Pipe Manipulator (SPPM). The Stewart Platform, which provides 6-DOF and it, was directly connected to the boom instead of the bucket. The SPPM was built with sufficient DOF to manipulate a pipe accurately but its motion control interface is hard for operators to learn. The conventional pipe-laying method consists of a set of repetitive tasks which requires 4-5 workers. The quality of the finished work is influenced by the experience and skill of the operator of the backhoe excavator, pipe installers and helpers. Recently, increasing labor costs have contributed to the increase in the cost of pipe installation. Authors compared the two approaches and technical solutions. It highlights some of the lessons learned during the field tests, which considered the different pipe installation methods commonly used. Kim et al. [2010] carried out work on a performance evaluation of a Stewart platform-based Hume concrete pipe manipulator (HCPM). Authors identified the problems in conventional process of Hume concrete pipe laying work. HCPM was developed to improve the safety, quality, and productivity of conventional Hume concrete pipe laying work. Authors developed a model for performance evaluation of the HCPM, and then utilize the model to analyze the HCPM's overall work performance. It was found that the productivity of the HCPM method compared to that of the conventional method is found to be 165%. This means that the automated method provides a 65% improvement in productivity. It was also anticipated that this productivity improvement will be greater if it used the skilled operator or the HCPM upgraded as a commercial unit. The economic feasibility of the HCPM method was evaluated by using benefit/cost ratio, rate of return (ROR), and breakeven point analysis methods. The economic analysis results of the HCPM method showed that construction cost savings of 33%. Rad and Kalivitis [2011] described various stages of design and development of a low-cost sensor-based gripper. Grippers are useful for applying right gripping forces to different objects. The gripper was also equipped with range sensors in order to avoid collisions of the gripper with objects. It was a fully functional automated pick and place gripper which can be used in many industrial applications. Yet it can also be altered or further developed in order to suit a larger number of industrial activities. François et al. [1999] designed a simple three-finger gripper. The gripper was designed to realize a good compromise between limited workspace and robust grasping. Authors carried out a complete analysis of the stability of a grasp for this gripper including an analysis of the deformation of the fingers at the points of contact. Presented results on three-dimensional representations of objects computed from range data. Deaconescu and Deaconescu [2011] carried out work on Pneumatic Muscle Actuated Gripper. Presented a application of pneumatic muscles for concrete objects and developed two gripping systems with two jaws and integrated control system. Authors developed optimum solution in dimensions and performance. Modeling and simulation of the dynamic behavior of the pneumatic muscle are presented in this. Lanni and Ceccarelli [2009], [2002] proposed an optimum design of two-finger robot gripper mechanism using multi-objective formulation, considering the efficiency, dimension, acceleration and velocity of the grasping mechanisms and Presented a case study in the form of designing a gripper mechanism by using an 8R2P linkage. Numerical results have been reported to show the new proposed optimum design. Cuadrado et al. [2000] carried out a dimensional synthesis of gripper mechanisms using Cartesian coordinates. The formulation was based on practical design requirements and the aim was to derive an analytical formulation using an index of performance to describe both kinematic and static characteristics. The authors proposed an optimum design for gripping mechanisms of two-finger grippers in the form of a suitable optimization problem. Datta and Deb [2011] proposed determination of optimum forces to be extracted on robot grippers on the surface of a grasped rigid object a matter to guarantee the stability of the grip without causing defect or damage to the grasped object. Authors proposed solving a multi criteria optimization of robot gripper design problem with two different configurations involving two conflicting objectives and a number of constraints. Osyczka [2004] carried out a study on the choice, model and design of grasp and developed an expert system to resolve grasping issues. Also proposed a multi-objective optimization-based robot gripper design and solved the gripping problem with different configurations. Lalibert et al. [2002] presented different prototypes of under actuated mechanical hands. Authors proposed the development of self-adaptive and reconfigurable robotic grasping hands. It has three fingers and each of the fingers has three end actuators. The authors explained design of 3 degree of freedom under actuated fingers. Also explained A firsthand, which has 12 dofs and 6 motors. Finally concluded that under actuated hands can effectively perform a variety of grasps with very simple control algorithms. Alexander et al. [2003] invented concrete pipe lifting jaw. Authors proposed design of jaw system for multiple size pipes. The main objective of this research was to provide pipe lifting apparatus and method suitable for use on various ranges of concrete pipe sizes.

By all this literature survey I concluded that, there are two basic systems available for concrete pipe handling i.e. with the use of crowbar and human worker and second is fully automated system. In US and Korea, availability of worker is less; hence they are using fully automated gripping system. But in our country India, workers are easily available. Hence it needs to concentrate on cost and worker's safety. Therefore, it needs to be design semi-automated system which reduces the cost of equipment and improves the worker safety

3. Objective

Finite element analysis technique is used for the static analysis of pipe lifter through software called Hypermesh/Femap. Through this analysis Stress and displacement of the pipe lifter structure is obtained. In this analysis some assumption is made. This assumption is due to limitation in software analysis as well as theoretical method. Stress is measured in MPa and displacement in mm. Through this analysis we are actually find stress and displacement in every part of the pipe lifter that is study of behaviour of structure under loading condition.

4. Methodology

Steps that are involved during the analysis of levelling pipe lifter through Hypermesh/Femap software is given below:

1. First Cad model is made through Cad software such as Solidedge/Solidworks/ Catia.
2. This Cad model is transformed into step or parasolid format.
3. This file is imported into Hypermesh/Femap software to get the model in it.
4. Again, model is exported through hm file format to save it in Hypermesh format.
5. After the above step followed geometry cleanup has been done i.e. made connectivity of joints through different method of joint connection such as rod, spider, revolute, prismatic and others joint specification.
6. Next step is to find middle surface on which analysis has been done.
7. Meshing is done on middle surface i.e. surface is breakdown in small element. The smaller element break, the more accurate results are obtained. So many element types available such as triangular, rectangular and mixed type. Mixed type is more frequently used in Hypermesh for better results.
8. Load collector, Structure properties, Material properties are given through tool used in software.
9. Optistrut solver is used for the static and strength analysis for this paper to obtained results.
10. Stress and displacement have been obtained through analysis of levelling pipe lifter structure.

Static Strength analysis of levelling Pipe lifter

For the FE Analysis, it is necessary to create a solid model of pipe lifter in order to create a FE model. In present work, load is distributed to all members uniformly under gravity loading. Loads are applied at their position under loading boundary condition to study the impact of loading in form of stress and displacement.

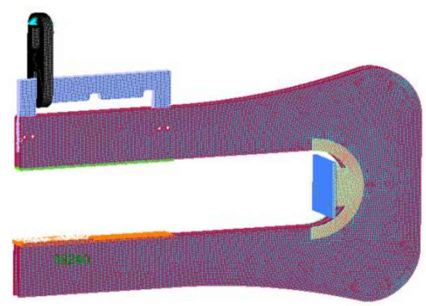

Fig. 9. FE Mesh Model of Levelling Pipe lifter (Weight: 328 kg)

The material of Levelling Pipe Lifter is steel (IS 2062: FE 410) with yield strength 250MPa and tensile strength of 410MPa. The properties of levelling pipe lifter are listed in below table.

Table: Properties of Levelling Pipe Lifter material

Modulus of Elasticity E(Pa)	$210x10^9$
Density(kg/m^3)	7800
Poisson ratio	0.3
Yield strength (MPa)	250
Ultimate\tensile strength (MPa)	410

In elasto-static problem, each element forms a stiffness matrix, [K], relating forces [F] and displacements[u] at nodes. The size of the stiffness matrix is equal to the number of nodes per element multiplies by the number of freedoms per nodes, as in the following.

$$[F] = [K]\ [U]$$

In eigen value problem, the characteristic matrix is formed as

$$\{[K] - \omega^2\ [M]\}\ [U] = 0$$

Where M is the mass matrix, ω^2 are eigen values, and u is the eigenvectors. In structural dynamics, the values are the natural frequencies and the vectors are mode shapes.

Loads and Boundary Conditions:

1. Leveling Pipe lifter's mass is inclusive of all equipment.
2. Constrains all the 6 degrees of freedom.
3. 1g vertically downward acceleration is applied

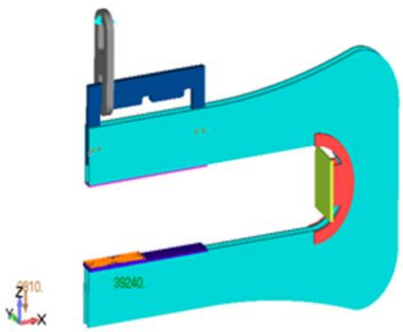

Fig. 10. Boundary Condition (Constraints in all 6 DOF)

Assumption made

- Rigid are used to connect hook with carriage.
- Rigid are used in place of bolts.
- Connection were made by keeping all the weld connection in mind.

Static Analysis

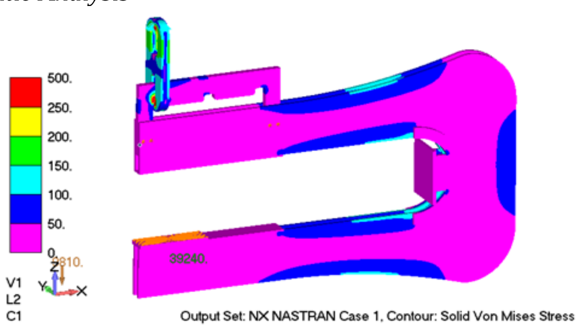

Fig. 11. All stresses are coming below 150Mpa

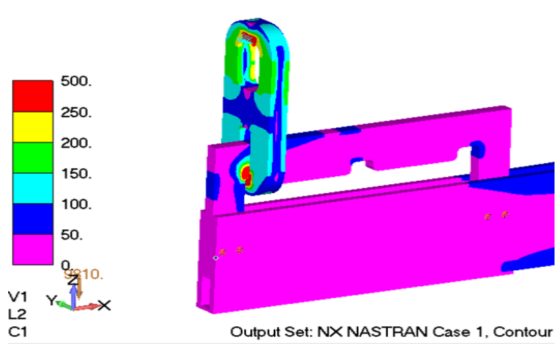

Fig. 12. All stresses are coming below 150Mpa

STRESS CONTOURS WITH HOOK ONLY

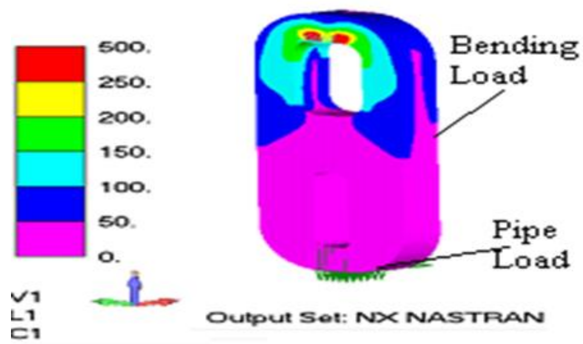

Fig. 13. Maximum Stress are coming < 200Mpa

Stress Contours With U-Plate/Frame Only

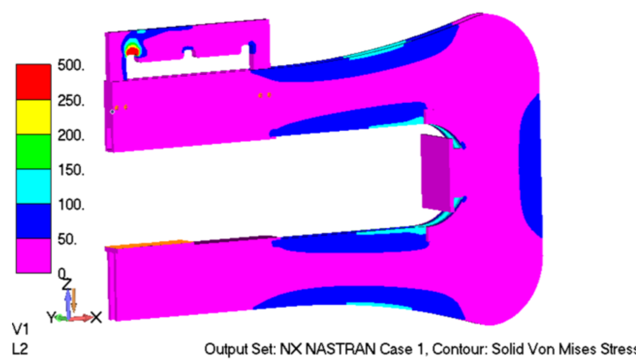

Fig. 12. Maximum Stress are coming < 150Mpa

Stress Contours with Carriage/ Adjustable Bail Only

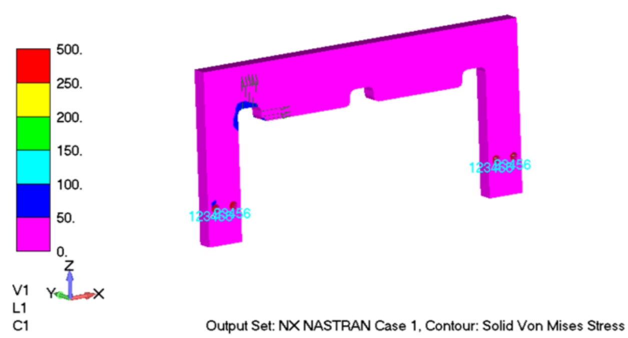

Fig. 13. Maximum Stress are coming < 150Mpa

Bolt Stress Calculation

Diameter of Bolt = 16mm (4 bolts)
Max Reaction force on bolt =41000N & 10000N
Resultant = 42201N.
Cross section of bolt = (3.14x16x16)/4 = 201mmsquare
Stress on bolt = 42201/cross section area of bolt= 209N/mm2

Nominal Tensile strength of bolt = 600-1000N/mm^2(for carbon steel)
Tensile strength =300-400N/mm2
From above calculation Bolt with 16mm diameter is safe.

Displacement Contours

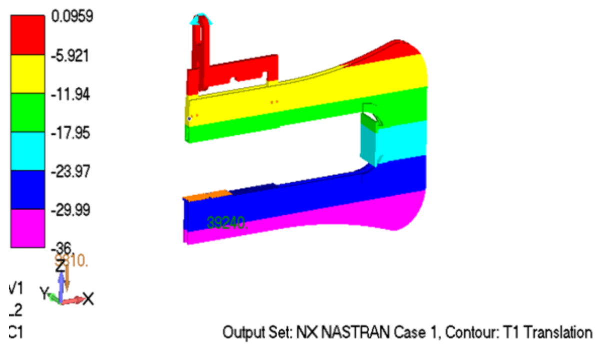

Fig. 14. Maximum Translation in X direction is 36mm

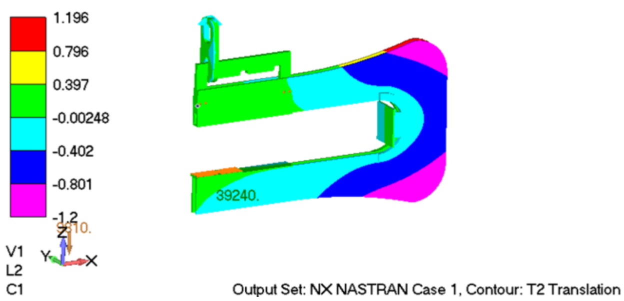

Fig. 15. Maximum Translation in Y direction is 1.2mm

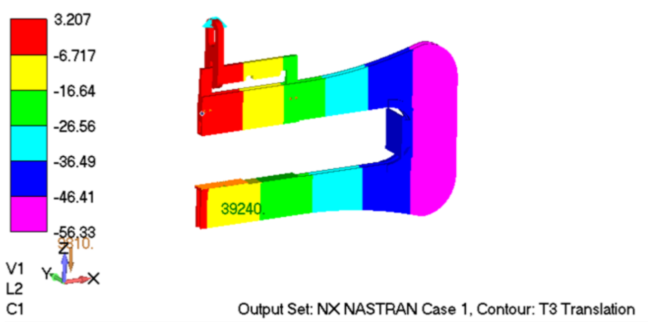

Fig. 16. Maximum Translation in Z direction is 56.33mm

5. Result

It is shown clearly by the analysis the maximum Von mises stress developed in the structure is less than 150Mpa, some area stress is less than 200Mpa which is safe, and the maximum displacement is within the limit in all direction (X, Y, Z).

6. Conclusions

I have studied various types of concrete pipe installation methods i.e. conventional and automatic. I compared the various advantages and disadvantages of all types of pipe handling methods. From that it is concluded that, both the systems i.e. conventional and automated, have some advantages as well as disadvantages.

Lifting and placement of the concrete pipes can be managed safely by the levelling pipe lifter with adjustable bail. Light weight, structure is simple, so the usage of it is very favourable**.**

Here I do strength analysis (Static& Bending) for levelling pipe lifter having lifting capacity of 4000kg and up to 2.5meter pipe. By the above analysis We find that the stress and displacement are safe for lifting 4000kg and up to 2.5meter of pipes.

7. Future Scope

1. To decrease the manufacturing cost by the use of FEM/FEA.
2. Analysis method is the non-destructive method for the design of structure over another method so can be used widely by the designer.

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