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DESIGN AND ANALYSIS OF FORKS FOR THE MANUFACTURING OF SPECIAL PURPOSE STACKER

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ABSTRACT
For a material handling system design, material handling equipment selection and its design is the first stage. This project is mainly concentrated on the design and analysis special purpose stacker and its forks, for lifting heavy load. The forks have to sustain the load without any failure up to four ton. By the Practical experimentation results for the deflection in the rare and the front end of the forks are should be acceptable. The result when compared to the calculated values before designing of forks and the model analysis using ANSYS should be less than plus or minus 4 mm, which is a standard variation acceptable by the customer. Hence all the customer requirements and conditions were successfully achieved.

INTRODUCTION

Introduction to material handling system:

Materials handling is loading, moving and unloading of materials. To do it safely and economically, different types of tackles, gadgets and equipment are used, when the materials handling is referred to as mechanical handling of materials.

- Materials handling is the movement and storage of materials at the lowest possible cost through the use of proper methods and equipment
- Materials handling is the moving of materials or product by any means, including storage, and all movements except processing operations and inspection.
- Materials handling is the art and science of conveying, elevating, positioning, transporting, Packaging and storing of materials

In earlier days movement of material from one place to another was a difficult and time consuming task inside the industry, mainly it was difficult due to the size, weight or the quantity of material to be moved. Therefore many different types of equipment were introduced for the easy and fast moment of the materials in the industry, those are known as material handling equipment.

Important requirement for better material handling system:

- Safe and fast movement of material to the desired destination
- Accurate and timely movement of material whenever needed
- Supply of exact quantity of material needed
- Minimum space utilization by storing of materials
- Cost effective with higher production rate.
- Size, weight or quantity is no more a barrier for material transport.

Application of material handling system:

- Static storage
- Dynamic storage
- Automated storage and retrieval system (ASRS)
- Buffer storage and work in progress (WIP)
- Order picking
- Ware house controlling
- Vehicle guided systems
- Assembly process
- Packing process

- Quality auditing or Quality assurance
- Stocking
- Automated guided vehicles (AVG's)
- Unit load conveyors

Introduction to company and Objective:

- The field of material handling systems is booming these days, with lots of new techniques and modern equipment are being designed and implemented to reduce the work load and to save time for the transport of materials in industry. Having interest in the same field, approached few material handling system manufacturing companies, so as to contribute my work in this field. BAKA LIFTEC Pvt. Lmt., a material handling system manufacturing company had a unique requirement to manufacture a customized stacker for a construction company, with the capacity to life the load of 4 ton.

OBJECTIVE AND METHODOLOGY

This was the first time for the company to manufacture a stacker sustaining to carry a load of four ton. As I had applied for a project work in BAKA LIFTECH, I was fortunate enough to get this project with a very unique customer requirement for a customized stacker. On discussion with the client we found out the following requirement.

Customer requirements (Project Objective):

- Requirement is for 2 stackers
- The toilet block is to be lifted from stored position on I beams, transported and to be loaded onto the rail trolleys
- The bottom of the toilet block is concrete slab
- The rail trolleys will be placed at both ends of the toilet block and there will be clear gap for forks entry between the two rail trolleys.
- Considering the variation in the size of the toilet block the customer is insisting on stacker with adjustable forks
- The wheels should be of bigger size as the equipment will have to cross the groove on the shop floor flat is made for rails. The width of the groove is 90mm
- The maximum lift high can be around 500mm and load 4000kg.
- Adjustable forks with length 3600mm and max width over forms at 2000mm
- Water protection for power pack, electrical and drive motor

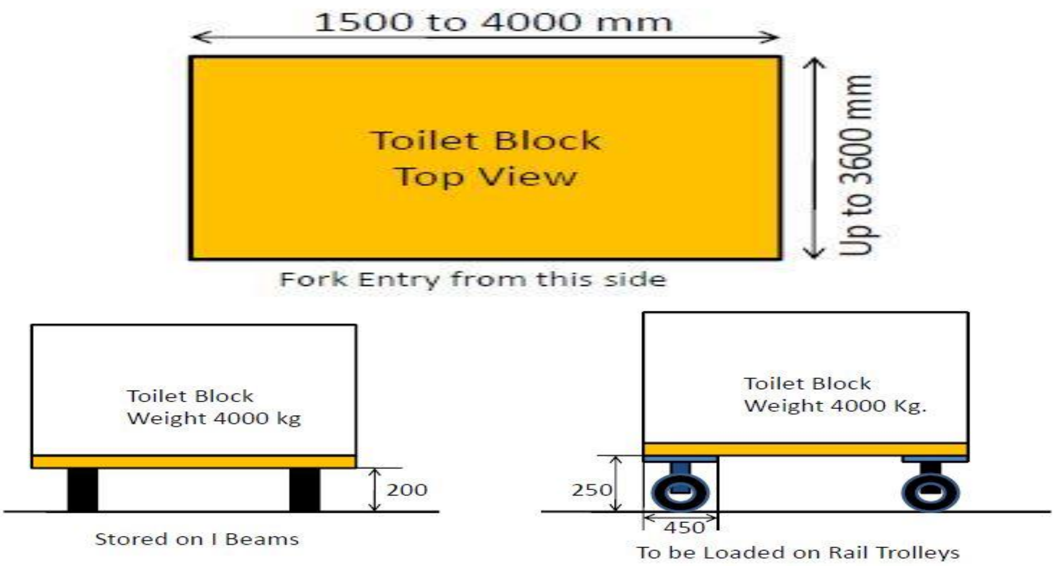

Fig1: Pictorial representation of customer requirement

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METHODOLOGY

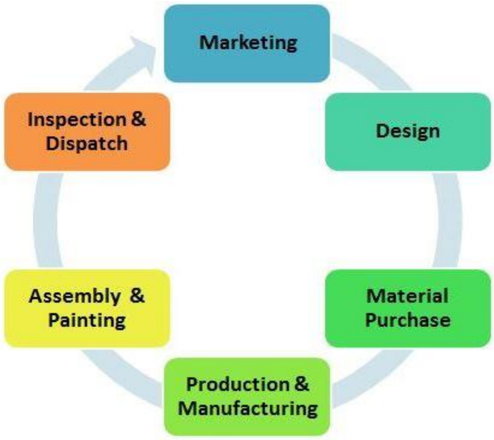

Fig2: Product Life Cycle

- **Design:-**
- No Analysis, Modification of the Existing Drawing
- Order by marketing team
- Preparation of the proposal drawings for approval
- Forward the designed drawings to customer for approval
- After getting approval from the customer, production drawings will be released
- **Procurement of the material:-**
- Standard materials will purchased
- Few materials will be manufactured
- In-house purchase department carries out this task
- **Machine Shop:-**
- Machining activities takes place according to the drawings given
- After machining fabrication work will be carried out
- **Painting:-**
- Spray painting is done in-house
- Powder coating painting is out sourced
- **Assembly:-**
- All different parts are collected at assembly point
- Assembly starts with the base part and later all other parts are assembled one by one
- There are many sub-assembly parts used for the assembly of main assembly
- **Testing and inspection :-**
- Hydraulic testing is done
- Functional and load criteria is checked by practically loading the stacker.
- Manual inspection will be done for the hydraulic fluid leakages and rectified if any.
- **Packing and Dispatching**

  Safe packing is done; dispatch is scheduled and delivered on time to the customer.

DESIGN CALCULATION AND DESIGNING

Keeping in mind the customer requirement and the design criteria, the load calculation will be done in the In-house software, which calculates the bending or deflection of the forks at front and rare end of the forks. To calculate the bending, precise input data is necessary such as the dimensional parameter and properties of the material which is used to manufacture forks. In this care material used is EN8 for the forks. This calculation is done to justify the design to be done.

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Vorhandenes Biegemoment	[Mb(max)= F*L]			
Tragkraft	F(L)	4000	[kg]	load in kgs
Tragkraft	F(L)	39240	[N]	load in newtons
Abstand	L	1600	[mm]	load center distance
Max Biegemoment (Gesamt)	Mb max(ges)	62784	[Nm]	bending moment
Anzahl Gabelzinken	ANZ(ZINK)	2	[/]	no of forks
Tragkraft pro Zinken	F (Zink)	19620	[N]	load on each fork
Max Biegemoment (Zinken)	Mb max(Zink)	31392	[Nm]	bending moment of each forl
Elastizitätsmodul	E	210000	[N/mm²]	youngs modulus
Erfordl. Widerstandsmoment	[W(erf.)= Mb(max)/Sigma(zul)			
Max. Biegezugspannung St 37	SIGMA zul. (St 37)	160	[N/mm²]	yield strength
Max. Biegezugspannung St 52	SIGMA zul. (St 52)	240	[N/mm²]	yield strength
Erf. Widerstandsmoment St 37	W erf. (St 37)	196200	[mm³]	
Erf. Widerstandsmoment St 52	W erf. (St 52)	130800	[mm³]	
Vorh.Biegegezugspannung	SIGMA vorh.	111	[N/mm²]	
Fall 2: Querschnittswert Breite (B) gegeben				cross section value
Erf. Widerstandsmoment **Stahlqualität beachten !**	W(erf.)	x	[mm³]	
Breite d. Gabelzinken	B	x	[mm]	
Erforderliche Höhe Gabelzinken	H(erf)	#VALUE!	[mm]	
Gewählte Höhe Gabelzinken	H(gew)	x	[mm]	
Vorh.Biegegezugspannung	SIGMA vorh.	#VALUE!	[N/mm²]	
Fall 3: Kein Querschnittswert gegeben				no cross section value
Breite d. Gabelzinken	B	x	[mm]	
Höhe d. Gabelzinken	H	x	[mm]	
Vorh. Widerstandsmoment	W(vorh.)	#VALUE!	[mm³]	
Vorh.Biegegezugspannung	SIGMA vorh.	#VALUE!	[N/mm²]	
Bestimmung der Durchbiegung (Kein Querschnittswert gegeben)				if no cross sec to determine c
Gewählte Breite d. Traggabel	B(gew)	25	[mm]	
Gewählte Höhe d. Traggabel	H(gew)	60	[mm]	
Vorh. Trägheitsmoment	I(vorh.)	450000	[mm² x mm²]	
Duchbiegung b. Krafteinleitung	f	283.47	[mm]	force
Gesamtlänge der Gabel		1600	[mm]	fork length
Durchbiegung an Gabelspitze		283.47	[mm]	deflection
Bestimmung der Durchbiegung (Trägheitsmoment gegeben)				given moment of inertia to find deflection
Verwendetes Profil				
Vorh. Trägheitsmoment	I(vorh.)	18646000	[mm² x mm²]	
Duchbiegung b. Krafteinleitung	f	6.32	[mm]	deflection
Gesamtlänge der Gabel		3200	[mm]	total length of fork
Durchbiegung an Gabelspitze		68.64	[mm]	deflection at tip

Fig3: Calculation for the deflection of fork

After the calculation we got the flowing results, which is also shown in the below figures:

i) Deflection at the rare end : 6.32 mm
ii) Deflection at the front end (tip) : 68.64 m

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Designing is done keeping in mind the customer requirements, as this is a whole new customized product, designing is done from the scratch. The designing is done in the design software called INENTOR-13 owned by the company, which is similar to AUTOCAD.

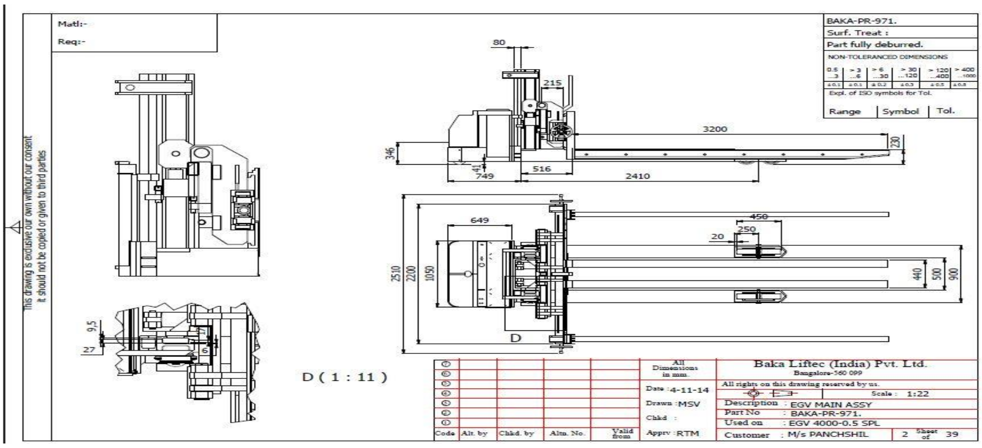

Fig4: Orthography projection of main assembly

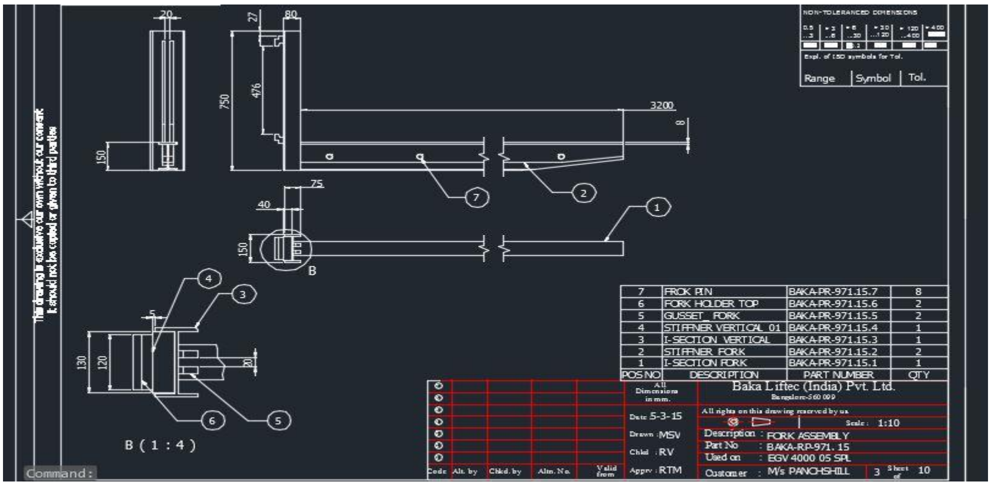

Fig5: Fork assembly

Fi6: Fork assembly in practical application

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MODEL ANALYSIS USING ANSYS

The utilization of FEA (finite element analysis) as design tool has made a remarkable growth in the recent past. ANSYS is a powerful and user friendly finite element program. [2]

ANSYS helps to perform the following task

i) Transfer CAD model of different structures, or components or construct the computer models
ii) Study physical response such as distribution of the temperature, levels of stresses or Electromagnetic filed.
iii) Applying the operating loads, either point load or UDL or different design performance conditions
iv) Optimization of the designs during development process, so that the production cost get reduced.

Material used for the forks is EN8; following is the composition for EN8 material:

Carbon	0.35-0.45%	Phosphorous	0.06% max
Manganese	0.60-1.00%	Sulphur	0.06% max
Silicon	0.05-0.35%		

Modeling procedure:

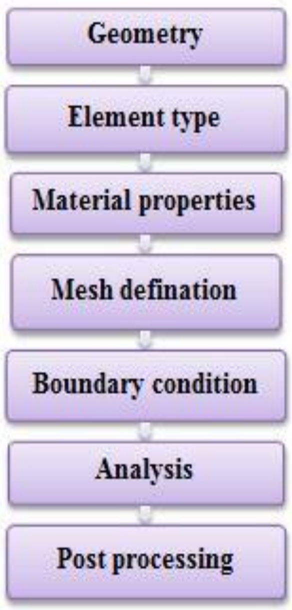

Fig7: Steps followed during the Model analysis in ANSYS

Advantages of EN8 material:

i) EN8 is a harder material when compared to other materials such as mild steel which is most commonly used in the field of manufacturing.
ii) It has more hardness due to the percentage of carbon present in it.
iii) It has 30-40 HRC in hardness and tensile strength is 600-700MPa.
iv) It can be further surface hardened to nearby 50-55 HRC by induction process method, hence resistance to wear.
v) As EN8 material has good homogenous metallurgical structure, due to this machining properties are consistent.
vi) It has very good resistance to bending.
vii) EN8 materials have increased straightness and cleaner surface.
viii) EN8 material can be brought very close to finished machine size and has increased physical strength over hot rolled bars having the same section.

Hence due to these very important and effective advantages EN8 material has been chosen over other materials such as mild steel for the manufacturing of the forks.

Table 1: Mechanical properties of the EN8 material

Condition	Yield stress (10^6 Pa)	Tensile stress (MPa)	Elongation (%)
normalised	280	550	16
Cold drawn (thin)	530	660	7

Dimensional parameter of the Fork:
Height of the fork: 0.145 m
Width of the fork: 0.075 m
Length of the fork: 3.2 m

Calculated values for the Analysis in ANSYS:
Young's modulus: 210 x 10^9 N/m^2
Poison's ratio: 0.30
Area of inertia: 1.90 x 10^5 m^4
Cross sectional area: 0.010875 m^2

Description:
We consider a model to be a cantilever beam, this is because the forks is similar to a cantilever beam whose one end is fixed and the other is free the load applied is distributed uniformly all over the cantilever beam (UDL). When it comes to the boundary conditions, the fixed end which is the rare end of the fork is constrained completely with zero degree of freedom.

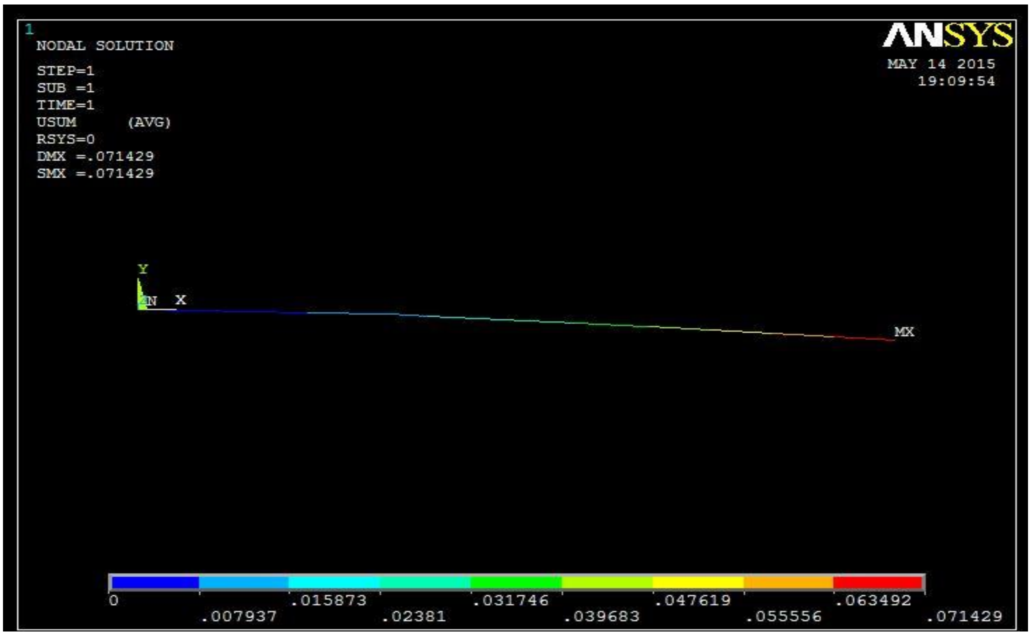

Fig8: Result for the deflection of the cantilever beam in ANSYS

After the analysis in ANSYS we got the following result:

i) Deflection at the rare end : 7.93 mm
ii) Deflection at the front end (tip) : 71.43 mm

FABRICATION

After the calculation and design was done successfully according to the customer requirement and there approval for the same, the production drawings were released accordingly .production drawings of each and every part was made in detail and according to which the fabrication and manufacturing of those parts took place.

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EXPERIMENTAL DETAILS

Load test was carried out after the assembly, 4 ton of load was practically loaded on the forks of the stacker and the bending or deflection was recorded.

Table2: Tabulation for the deflection of forks recoded with and without load

	1(in mm)	2 (in mm)	3 (in mm)	4 (in mm)
Without load	280	260	280	260
With load	210	253	207.5	250
Difference	70	07	72.5	10

The forks were lifted to a certain height and the distance between the floor surface and fork was measured and noted down, this was before applying the load. Now the weight of 4 ton was loaded on the forks of the stacker without any changes. Due to the load, there was a deflection in the forks, which is again measured and the values were recorded. Now the difference between the height of the fork before and after loading of weights is calculated and compared with that of initially calculated values before design and with that of the result obtain by Analysis in ANSYS.

Fig9: Experimental load testing

Fig10: Finished stacker with complete assembly and painting

RESULTS AND DISCUSSION

At the end to validate the project it is necessary to compare the results obtained for the deflection of the fork. Hence we will tabulate the results obtained for the deflection of fork by:

i) Calculation done before the designing of stacker and forks
ii) Model analysis for deflection using ANYSY
iii) Experimentally recorded values for deflection of forks

Table3: Comparison of the results

	Rare end (Max. value) in mm	Front end (Max. value) in mm
Fork deflection calculated before Design	6.32	68.64
Fork deflection analyzed using ANSYS	7.93	71.42
Fork deflection obtained by Experimental observations	9.7	72.5

DISCUSSION

- The deflection in the fork obtained by Practical experimentation for the rare end of the fork is 9.7 mm, whereas for that of calculated before designing is 6.32 mm and the model analysis using ANSYS is 7.93 mm.

- The deflection in the fork obtained by Practical experimentation for the front end (tip) of the fork is 68.64 mm, whereas for that of calculated before designing is 71.42 mm and the model analysis using ANSYS is 72.5 mm.

- The Practical experimentation results for the deflection in the rare and the front end of the forks are acceptable. The result when compared was found out to be less than plus or minus 4 mm, which is a standard variation acceptable by the customer.

CONCLUSION

- We can conclude that the design for the forks of the stacker was successful, as it could lift the weight of four ton as per the customer requirement.
- The EN8 material which was chosen for the fabrication of forks was appropriate for the task.
- The experimental values almost match with the calculated results before design and also with the Analysis result of ANSYS, with a variation in the permissible limits.
- The Practical experimentation results for the deflection in the rare and the front end of the forks are acceptable. The result when compared was found out to be less than plus or minus 4 mm, which is a standard variation acceptable by the customer.
- The working for the stacker is absolutely perfect and is manufactured and tested exactly as per the customer requirement.

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