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Failure Mode and Effect Analysis (FMES) Approach For Design and Development of Barrel Lifting and Tilting Machine

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ABSTRACT:

Several industries deploy barrels that are too heavy and large making them unstable to lift the desired material. The load sustaining capacity of worker has certain limitations. Due to lack of power they cannot lift barrel by bare hands. Even if machines are used to do the work, two machines are required to perform lifting and tilting. With a view to resolve these problems and reduce cost as well as labor work, present system is designed with machine which can perform both lifting and tilting of barrel that can be handled by a single worker. Handling the loads manually amplify disorders owing to regular and accumulative worsening of the musculoskeletal system especially during lifting and handling tasks. Labour-intensive operations result in lower back pain and harms frequently seen in musculoskeletal disorder. The occurrence of injuries increase as a reason of quite heavy and large loads, difficulties in grasping or instabilities. The marginal load carrying capacity of employee also contributes to risk of accident. Now-a-days, the most available jacks are manually powered. The studies revealed that these manual hydraulic jacks were very difficult for operation by labors especially the females in terms of strength and energy needed during operation and are time consuming. Thus, to overcome this problem of musculoskeletal disorders and injuries with increase in efficiency in the industrial material handling, a new lifting and tilting system is proposed.

Keywords: Barrel, FMEA, Lifting and Tilting, Manual Handling, Musculoskeletal Disorder.

1. INTRODUCTION

In numerous industries one of the handling device for handling raw material and finish product are drums that manually handled. In workplace drums are traditionally conveyed, elevated, encumbered, slanted, etc. by workers. Handling heavy load manually is time consuming and could be hazardous and risky from worker point of view. The small sized pharmaceutical companies use different types of raw materials that are taken out from containers of different sizes. Industries avoid barrel pump usage as it requires maintaining multiple barrel pump which is expensive. In automobile workshop need multiple types of oils. Company require an apt material handling equipment for effective material handling. In small units or workshops, drum barrel is handled manually which consumes high time and manual intervention. A drum handling equipment is proposed for appropriate handling of drum. Such equipment could lessen worker fatigue and hazards during drum handling.

2. LITERATURE REVIEW

2.1. The paper presented the usage of devices for handling drums in the business units to lower down the number of workers in handling process. A study of material handling effects on human element was highlighted. The fatigue algorithm study of multiple devices handling materials in industries was conducted. In numerous industries considered here, raw material and finish product were manually handled typically in 210 litre drum. The manual handling of heavy loads consumed more time and presented risky environment for workers. Hence, an effective handling equipment is essential for material handling. Manual drum handling equipment can be used to do various function like conveyance, leaning, elating, loading and unloading.

2.2. The paper discussed the position control of a direct drive rope-based lift system with releasing of mechanical brake. The electrical equipment comprised of a high torque, low-speed permanent magnet synchronous motor with external rotor directly connected to the rope pulley. The drive used only stator current sensors for torque control and an incremental encoder on the motor shaft. A detailed model of the system, which encompassed rope elasticity was presented along with a load torque estimation algorithm and a feed forward action on the torque reference signal. Such orientation was used to reduce the cabin falling at brake releasing below a noticeable threshold. Final experimental results supported the mathematical theory defined in the paper, validating the proposed control strategy. The need of maintenance was greatly reduced with improvement in the system reliability.

2.3. This paper described hydraulically operated drum lifter and tilter which is mobile on three wheels, two of which are steering type. The drum lifter was comprised of hydraulic system, mainframe, drum holding device, gearbox and lifter. The drum lifter lifted drums with manual hydraulic jack and equipped with return valve and foot pedal to control drum carriage lowering rate and ensured accurate and reliable hydraulic action. This is the vital solution for rapid and harmless drum handling. It handled an assortment of drums by installing the exact accessories for the specific size and drum type. The system provided extra lift, easy reach and greater straddle width. The system raised and controlled dispensing as per need.

3. OBJECTIVES

After review of various research papers, and findings presented in such papers and also after study of need of such handling systems following objectives were identified -

1) Build a device for drum conveying, stacking, unloading, elating and tilting process.
2) Develop suitable handling equipment for handling drum with ergonomic considerations.
3) Fabricate prototype model through application of FMEA technique.
4) Testing and Validation.

4. METHODOLOGY

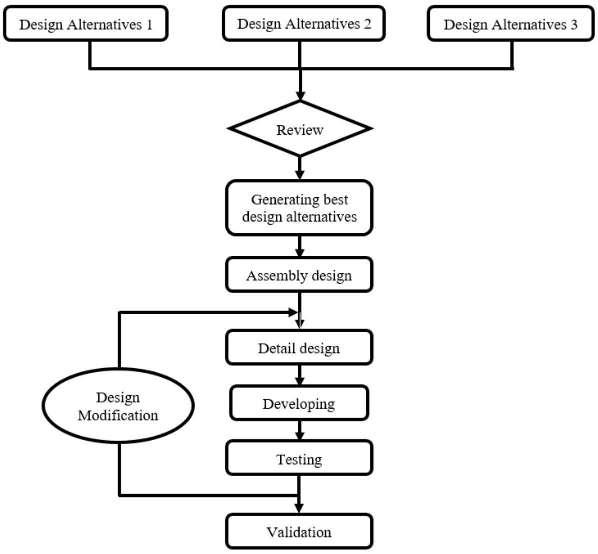

Fig. 1: Development Flow Chart

Figure 1 represents the development flow chart that briefs about the procedure followed in the development process. Handling practices in industries are governed by various power sources like electric, hydraulic, vehicle driven or manual. Obviously the cost involved in each case is different [1]. The weight of handling is significant when the quantity handled and distance of movement is large. Hence, it is necessary that the cost of handling should be as minimum as possible. It is desirable to have handling system which need very less power and thus cost of handling is reduced radically [2]. Hence, human powered mechanically driven liquid handling system/equipment has significant, importance. In most of the cases not only loading, unloading but also tilting / rolling liquid barrels, is also needed. Hence the equipment which has above capability need to be designed [3]. Various prevailing devices were studied to develop solution for typical problem. Since liquid handled was acid for batteries, which is toxic is nature, care is needed during loading, handling and unloading as per standard guidelines [4]. A standard operating method and checklist of minimal obligatory facilities for use of perilous chemicals are prevailing. Utilization of contaminated barrels / containers / drums with hazardous waste chemical, oil and lubricant was published in the 2021 and similar guidelines were studied before developing handling system [5].

5. CONCEPT DESIGN

5.1 Design A:

Fig. 2: Design A

This design as shown in Figure 2 can be specifically used for tilting operation of the barrel in material handling system. The caster wheels are provided for moving fully loaded/filled barrel while using this design in real-time industrial operations. This can be operated only by a single worker. The drawback of this design is the barrel can't be lifted.

5.2 Design B:

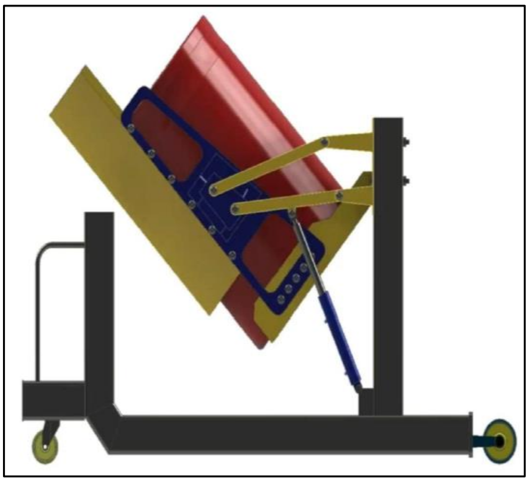

Fig. 3: Design B

This design as illustrated in Figure 3 can be used to carry heavily loaded/filled barrel and other heavy objects for industrial purposes as material handling system. This design is an example for comfortably and safely moving of heavy objects with least chances of damaging. This can perform the tilting operation only as lifting feature is not given in this design, which can be considered as a drawback.

5.3 Design C:

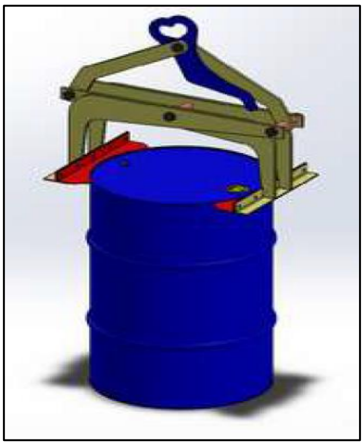

Fig. 4: Design C

This design as shown in Figure 4 is of a crane which is used to carry heavy barrels and other objects which are very difficult to handle by bare hands of industrial workers. This works on external electric power supply. The setup installation of this design demands a minimum specific roof height as per requirement. The tilting operation cannot be carried out by using this design.

5.4 Design D:

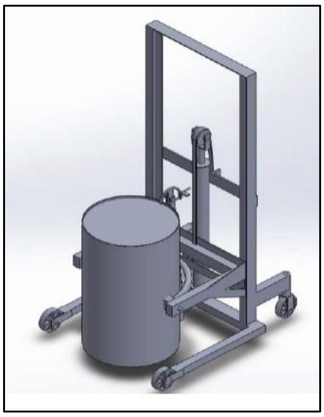

Fig. 5: Design D

This[6] design as demonstrated in Figure 5 can be used to perform lifting as well as tilting operation of the heavily filled barrel in industrial applications. This design requires no external power source except human efforts. The lifting operation can be done by using hydraulic actuator mechanism to a certain height. In this design there is a provision of gearbox and a handle to carry out tilting of the barrel with comfort and safety [7].

6. PERFORMANCE EVALUATION OF DESIGNS (Based on 40 points)

Evaluation system was developed to assess the design alternatives developed on 40 point rating with each parameter having (5) points each.

Table 1: Performance evaluation of designs

Sr. No.	Selection criteria	Design A (5)	Design B (5)	Design C (5)	Design D (5)
1	Ease of handling	**3**	**2**	**5**	**5**
2	Ease of use	**2**	**1**	**4**	**5**
3	Aesthetic	**2**	**3**	**3**	**5**
4	Ergonomic	**3**	**4**	**5**	**4**
5	Lifting	**0**	**0**	**5**	**5**
6	Tilting	**4**	**4**	**0**	**5**
7	Initial cost	**5**	**4**	**1**	**4**
8	Maintenance cost	**5**	**5**	**2**	**4**
9	**Total (40)**	**24**	**23**	**25**	**37**

As shown in Table 1, design alternative (D) emerge to be most suitable alternative out of the final alternatives evaluated based on parameters as mentioned [8].

7. Failure Mode Effect Analysis (Fmea)

FMEA approach was used for identifying potential modes of failure for final design alternatives and improvise this design accordingly [9]. The activity from design for the same is as shown in Figure 6.

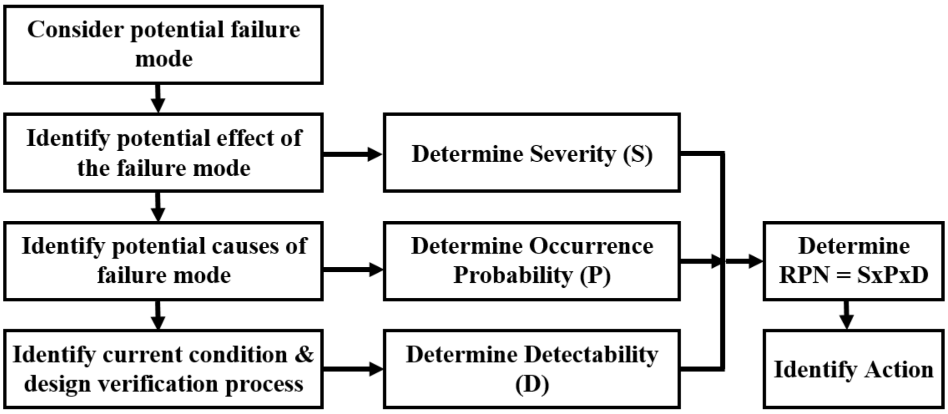

Fig. 6: FMEA Activity Cycle

Table 2: Design FMEA Table

Function	Potential failure mode	Potential effect of failure	S	Potential causes of failure	P	Current ability to detect	D	RPN= SxPxD	Action priority
Lifting of load	Improper movement of actuator	Customer unhappy	8	Poor product performance	6	High	4	8x6x4 = 192	A
		Incorrect movement of drum	6	Problem with actuator less fluid power	4	High	4	6x6x4 = 96	
	Non appropriate gripping of drum	Risk of accident	9	Poor gripper operation	4	High	4	9x4x4 = 144	B
	Improper tilting action	Customer unhappy	8	Poor product performance	4	Moderate	6	8x4x6 = 192	A
		Liquid dispensing not possible	6	Jamming of mechanism/ mechanical malfunction	4	Moderate	6	6x4x6 = 144	
	Bonding of lifting bracket or breakage during loading of drum	Rise of accident	9	Mfg. defect	2	Moderate	6	9x2x6 = 108	
				Material defect	2	Low	8	9x2x8 = 144	B

Based on the findings of FMEA as shown in Table 2, it can be concluded that improper moment of the actuator and improper tilting action are on high priority followed by bracket breakage, non-appropriate gripping of the drum[10]. After critical design review and analysis[11][12] of the frame structure safety of the structure was ensured. This was done using FEA Analysis of the frame structure [13].

8. FRAME ANALYSIS

Figure 7, 8 and 9 represent the frame analysis and the results obtained.

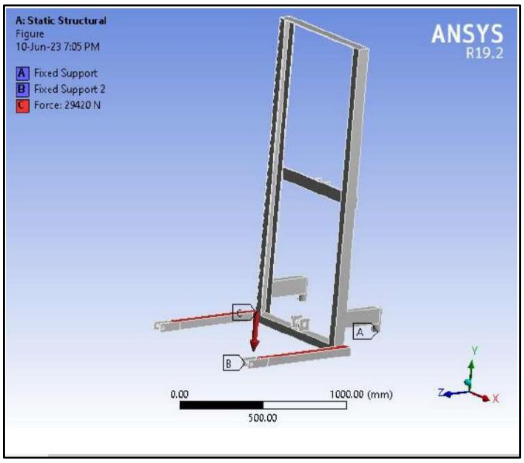

Fig. 7: Load applied.

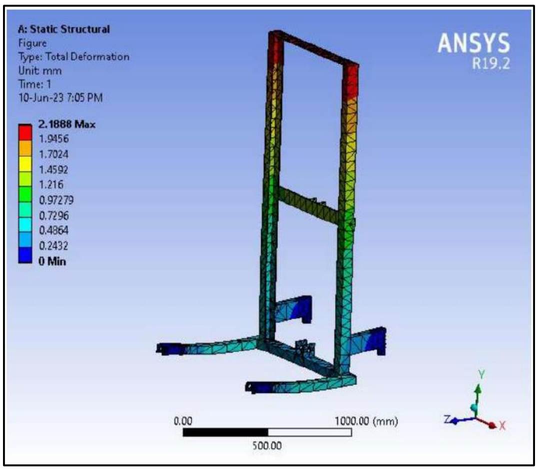

Fig. 8: Total deformation

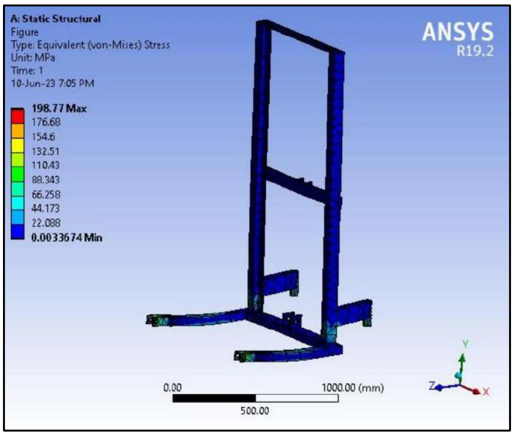

Fig. 9: Equivalent stress

Mild steel > Tensile Yield Strength

Tensile Yield Strength MPa
285

Mild steel > Tensile Ultimate Strength

Tensile Ultimate Strength MPa
340

9. TESTING OF MACHNE

The testing and authorization of the working of developed mechanism, trials were conducted at industry [14]. Feedback for performance improvements were also gathered [15].

Observation Table

Table 3 represents the results of liquid level amount in the drum and the time required for its lifting. These trials were conducted on Design D that was opted out from other designs considered.

Table 3: Results of liquid level in barrel and time consumed

Sr. No.	Liquid level in barrel	Time consumed
1	Empty barrel (0%)	40 sec.
2	25% filled	57 sec.
3	50% filled	1 min. 13 sec.
4	75% filled	1 min. 38 sec.
5	100% filled	2 min. 5 sec.

10. RESULTS AND DISCUSSION

1. A systematic approach for product development was ensured for design and development of drum handling device.
2. Design alternatives were developed and reviewed by following scientific methodology with pros and cons associated with design.
3. For the final design FEMA approach was effected to understand and analyze various failure modes and their associated risk priority numbers. (RPN)
4. With the high RPN, related failures design review was carried out and FEM approach was used to ensure safety and prevent failure. The maximum stress induced was 175 N/mm^2 at the weakest section which is ensuring design safety under various loading and tilting conditions.
5. Trials were conducted with the prototype and performance & safe working was monitored.

11. CONCLUSION

Systematic approach for product development was followed for development of drum (barrel) handling and tilting machine. Performance of the product was monitored for satisfactory working, which proved to offer best results.

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