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Design and Development of Automatic Sieving Machine for Granular/Powder Materials

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ABSTRACT
The term 'Mechanical Handling of Materials' is important for loading-unloading and movement of materials. After discovering wheels and levers, materials have been moving via mechanical conveyors. In this article, a mechanical device will be introduced which can sieve and move granular and powder material at a same time. This device is recommended for construction sights. Sand can be sieved with this machine as sand is both known as powder and granular according to the diameter of sand particle. This device is normally designed for the building construction labors of Bangladesh with the construction theme of Screw Conveyor. The materials of this device have been selected under the consideration of monetary value. Design of this device has been completed with the help of Solid Works software. The manufacturing process and material selection process have also been described. The fabrication of the sieving machine is a prototype of actual product.

Keywords:-Material Handling, Conveyor, Prototype Fabrication, Cost Effective Design, Product Designing

INTRODUCTION

Sand is used mostly for any kind of construction. For the purpose building construction, pure and absolute sand should be needed. But almost all kinds of sand have some impurities. To solve this problem sand sieving machine is used. The working procedure and mechanism of a sand sieving machine are so easy and user friendly. Before the invention of this machine, people were sieving sand manually. It was too much time consuming that decreased productivity. But this machine does the same thing automatically that improves productivity as well as save time. Sands are put into this machine and this machine removes all kinds of impurities such as small rock, large-grained particles, coal, clay, and so many things, and finally, you will get the pure and fresh sand. To improve productivity, ensure the quality of construction, for saving time, this machine can solve many more such problems in an instant.

There are various types of sand sieving machine present at the market. They are too heavy as well as bulky. For this reason, those machines are not portable at all easily. But this machine is small in size as well as very light in weight but performs the same thing that other machines do. The attached wheels ensure the mobility of this machine easily. On the other hand, this machine can separate in part by part so easily that anyone can attach or detach any part easily when needed.

Objectives

The objective of this research is to design an automated sieving machine which can be used in the building construction sites for sieving the sands from different impurities.

LITERATURE REVIEW

Material handling methods are important in every sector of modern technology. Different authors studied different methods for establishing better material handling process in different time spans. Chakraborty & Banik (2006) showed the way to select the necessary material handling equipment by using multi-criteria decision making tools [1]. Decision making problems were broken down to reach in the conclusion by using AHP. Onut et al. (2009) discussed Multiple Criteria Decision Making for choosing the appropriate material handling equipment to explore the dueling factors [2]. In that research, FANP, MHE and TOPSIS were employed to determine the system characteristics and proper system alternatives.

Osman Kulak (2005) developed the factors for the selection of material handling equipments. He used FUMAHES, which is a multi-attribute decision making process [3]. Evaluation for complete and incomplete information has also done in his research in order to the selection process.

Product development for specific industry has been researched by Krishnan and Ulrich (2001). Variation in market opportunity is necessary. This is also important for the sale of the products. This work combined the operation management and product designing in a single phase [4].

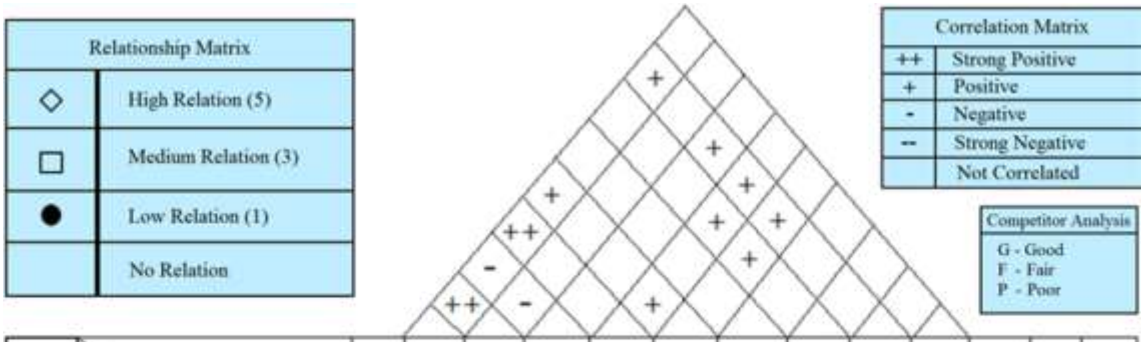
Brown and Eisenhardt (1995) organized the product development into a three steamed research. Research findings were synthesized into a successful product designing model [5].

Considering cost is an important factor for designing and development of new product. Marion and Meyer (2011) investigated in such a way that new entrepreneurial companies can yield a definitive fund flux [6]. Chen and Liu (1999) researched that 3 objectives can be achieved at a same time. They are identifying factors of product designing stage, cost effective design and design with computer software. They also cleared that, product life cycle is also important for the cost effective design [7].

According to the above research studies, the authors tried to incorporate the idea of material handling and product designing in a single skim. A new design has been proposed for the handling and sieving of sands in the mini construction sites in cost effective way.

QUALITY FUNCTION DEPLOYMENT

Quality function deployment (QFD) is an organized way to deal with characterized client needs or necessities and addressing them into explicit plans of the item, components, cycles, and creation plan, to such an extent that those requirements are made. A QFD has been prepared (Figure 1).



Valuation Scale	Customer Requirements \ Technical Requirements	Customer rating (5)	Capacity	Body Weight	Movement Mechanism	Extraction Mechanism	Rotating Mechanism	Lucrative Design	Waste Collection	Time Saving	Durability	Qixia Dali Mine Machinery Co. Ltd.	Xinxiang Dongzhen Machinery Co. Ltd.	Henan Remort I/E Co. Ltd.
High	Cost	5	◇	□	●			□			◇	P	P	P
	Easy to Use	5		□	◇	□			●	◇		G	F	F
	Portability	5		◇	◇					●		P	P	P
Medium	Machine Life	4	□								◇	G	F	G
	Reduction of Size	4	◇	◇	□	●			●	□		P	P	F
	Comfortability	4		◇	◇	□			●	□		P	G	F
Low	Aesthetic Look	3						◇				G	F	F
	Eco Friendly	3				●	◇					F	G	G
	Less Physical Labor	3	◇	□	●				●			G	G	G
Our Importance Rating			72	99	90	34	15	30	16	54	45	SUM= 455		
Percent Score (%)			15.8	21.7	19.8	7.5	3.3	6.6	3.5	11.9	9.9	Total= 100		

Figure 1: *House of Quality for Sand Sieving Machine*

This QFD helped for the planning of the design of the product. This also gave the idea about the competitors who also have the same kind of machine. Some major relationships between customer and technical requirements are given below:

- Relationship between capacity & physical labor is high because with increased capacity it takes less physical labor
- With the increase of body weight the capability of portability decreases
- By decreasing in body weight, the cost can be decreased, so they are highly related
- Portability saves time. That's why relation between portability and time saving is low
- Lucrative design and cost are highly related as to increase the aesthetic look of the machine, cost increases

There are some relations between different technical requirements. They are:

- Body weight and capacity have a positive relationship because with the increase of capacity body weight also increases.
- Capacity and extraction mechanism are

highly proportional, because with the increase of capacity the rate of extraction increases.

- Body weight and movement mechanism are negative related. It becomes difficult to move the machine if the machine weight increases.
- Rotation mechanism and waste collection are proportional because the waste is collected by rotation.
- The more the machine rotates, the more the time saved and so they are positively related.

- At the time and fabrication, these relations were kept under consideration.

FUNCTIONAL STRUCTURE DEVELOPMENT

To breakdown the overall process into less and plain section, functional structure should be decomposed. Normally engineers follow this process in order to understand the functions of the device in detail.

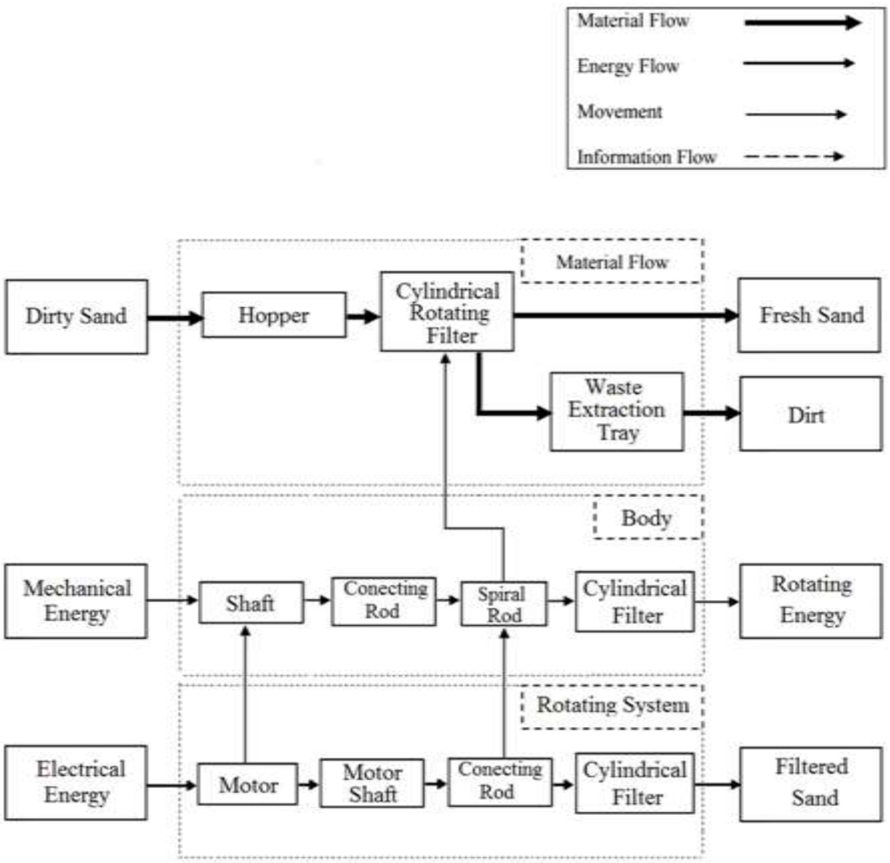


Figure 2: *Cluster Faction Structure*

For developing a product functional decomposition stage is very important. Cluster Function Structure shows how the function and process of this machine works. It also shows the conversion of energy and material. For easily design a product functional decomposition helped a lot. The typical cluster function structure is given in Figure 2.

DESIGN ANALYSIS

Design analysis is such an important step to design and develop a product. A perfect design of a product can ensure the perfection of a product. The outlook of the product, the strength and maximum capacity of the product, the working principle, and almost every requirement can be simulated through design. Different types of functions, their operating parts, and their behavior in the real field also can be simulated. During assembly of the product mismatch of different parts, size differences and their suitable place to fit is very much difficult to estimate. But through the design of the product, this difficult job can be done so easily.

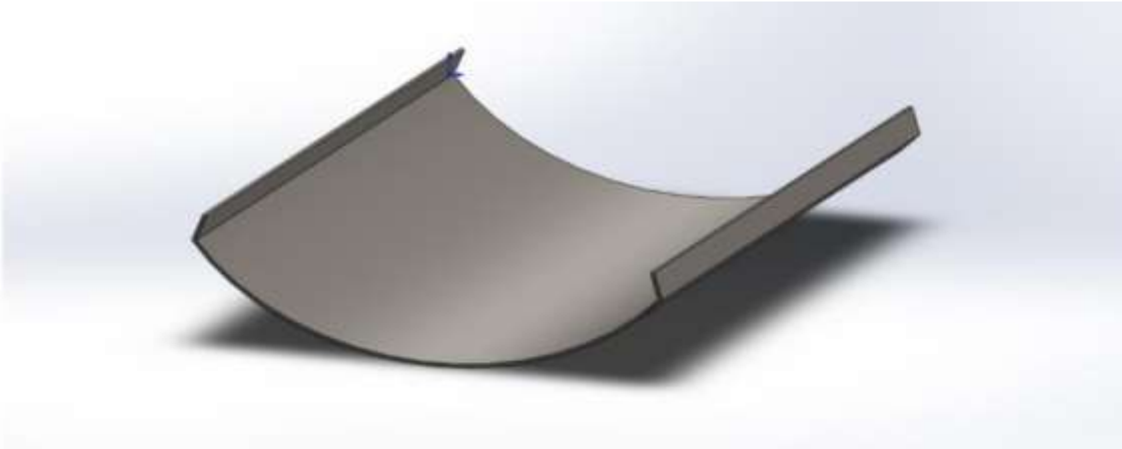


Figure 3: *Hopper*

All of the significant parts/sub-assemblies were designed and assembled to create the main machine. The whole process was designed in Solid Works 2018. The final design is given in Figure 3. The important parts of this machine are:

- Hopper
- Net
- Net Holder
- Main Shaft
- Motor
- Pedestal Bearing
- Rear Axle
- Rear Wheels
- Caster Wheels
- Main Frame

A rotary gear motor is used in this machine to drive the main shaft that is attached to the net. As this design is a prototype design, that's why 0.5HP gear motor is used to drive the shaft at a constant speed so that the sand does not spread out.

Figure 4: *Net*

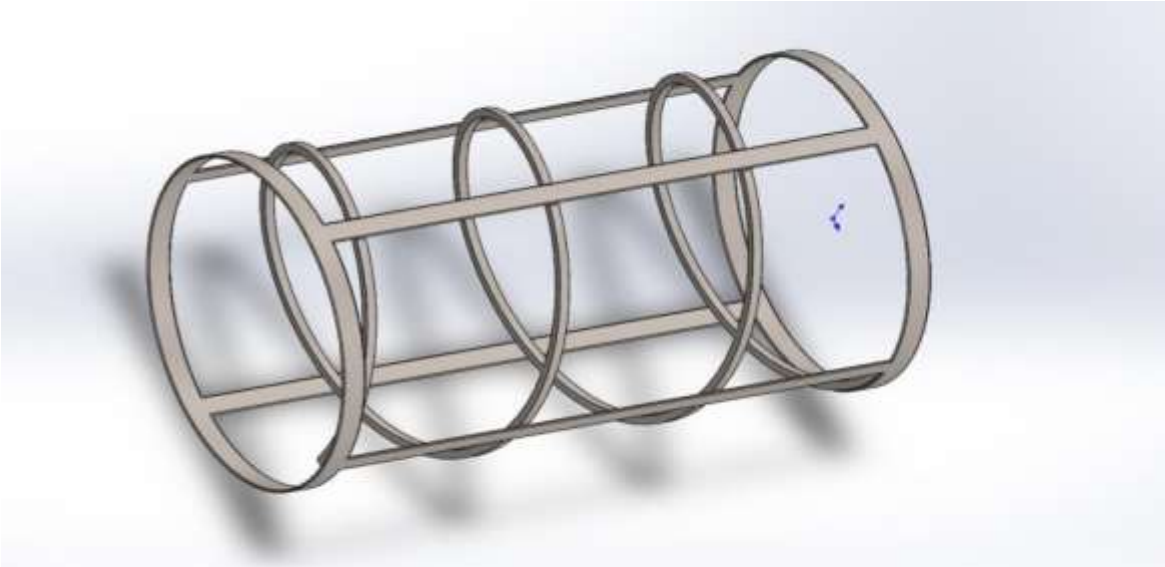


Figure 5: *Net Holder*

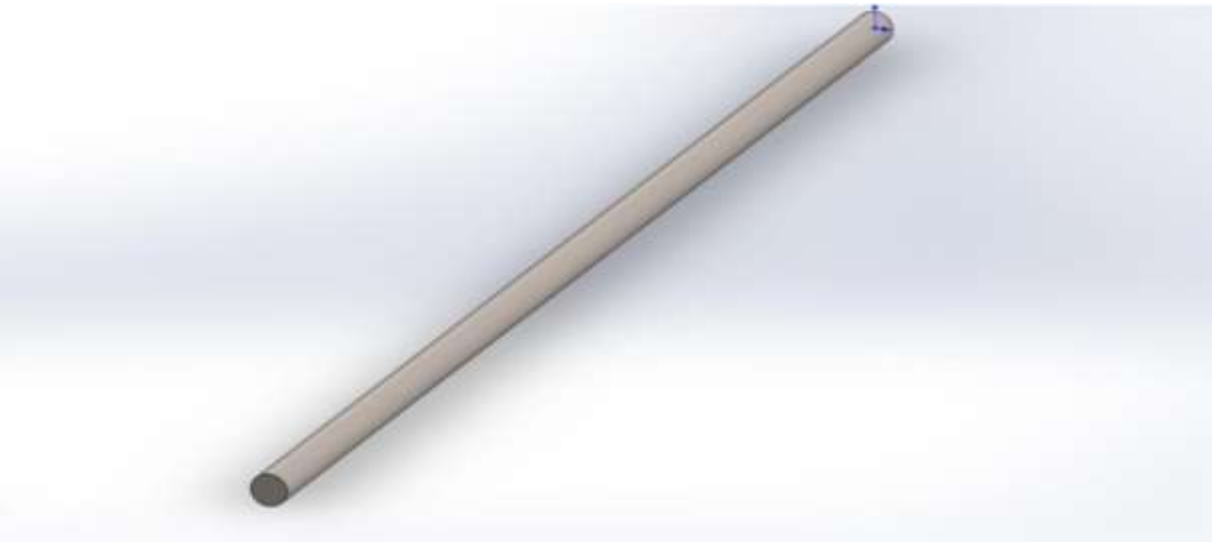


Figure 6: *Main Shaft*

Figure 7: *Motor*

Hopper: There are two hoppers in this sand sieving machine (Figure 3). One of them is used for inlet the sand and another for the extract the dust and impurities from the sand. Both are situated on the opposite side of the machine. Both are attached with a strong base with the machine so that they can carry enough loads. Both of them made with light and strong sheet metal.

Net: The net is the main element of this machine (Figure 4). Net is used as a sieve in this machine. This is a stainless Still net that is very strong. The total net is attached with a strong frame inside it. The small holes of the net ensure fresh sand for construction and remove the impurities.

Net Holder: This part holds the net very strongly so that the net can sieve the sand perfectly (Figure 5). This part of this machine also extracts the dust and impurities from the sand through a spiral inside it. The total part is made with mild still bar.

Main Shaft: A strong Stainless Still shaft is situated in the middle of the net and attached to the motor shaft so that it can transmit the power from the motor and can rotate the net so that the net can do the job properly (Figure 6).

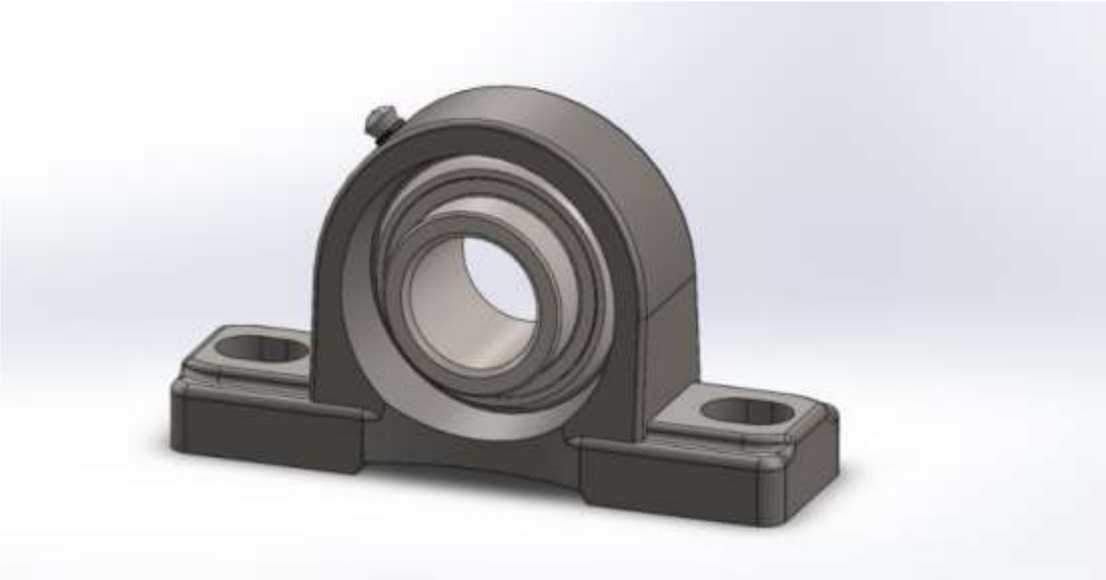


Figure 8: *Pedestal Bearing*

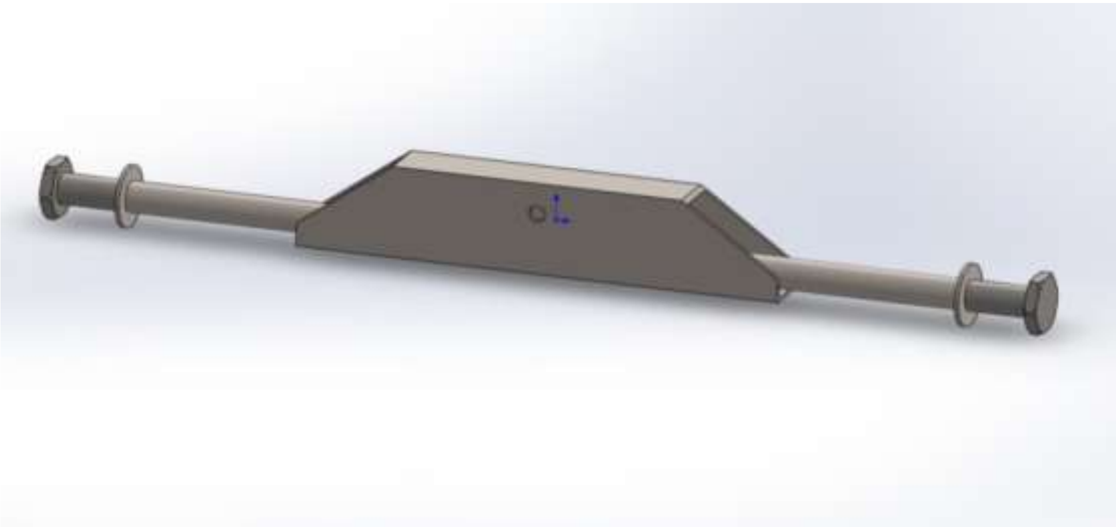


Figure 9: *Rear Axle*

Figure 10: *Rear Wheel*

Figure 11: *Caster Wheel*

Motor: A rotary gear motor is used in this machine to drive the main shaft that is attached to the net (Figure 7). Here 0.5HP gear motor is used to drive the shaft at a constant speed so that the sand does not spread out.

Pedestal Bearing: There are two pedestal bearings situated on the opposite sides of the shaft and attached with the mainframe of the machine (Figure 8). These bearings help to rotate the main shaft easily and smoothly.

Rear Axle: This axel is situated at the rear portion of the machine and holds the rear wheels (Figure 9). It has also a tilted feature so that the machine can tilt on a rough surface.

Rear Wheels: Two big and strong plastic wheels help to move the machine easily (Figure 10). Plastic wheels are used because of the lightweight of plastic.

Figure 12: *Main Frame*

Figure 13: *Proposed Design of the Sand Sieving Machine*

Caster Wheels: A pair of lock caster wheels is situated at the front of this machine (Figure 11). Lock caster wheels are used in this machine because this wheel can lock during the operation of the machine so that the machine cannot move during operation.

Main Frame: This strong mainframe holds all the different parts together and keeps them in their appropriate position. This frame is made with Mild Steel Angle Bar that makes it so rigid and strong (Figure 12).

Final Assembly: The finished and final look of this sand sieving machine after designed and assembles all the different parts together (Figure 13).

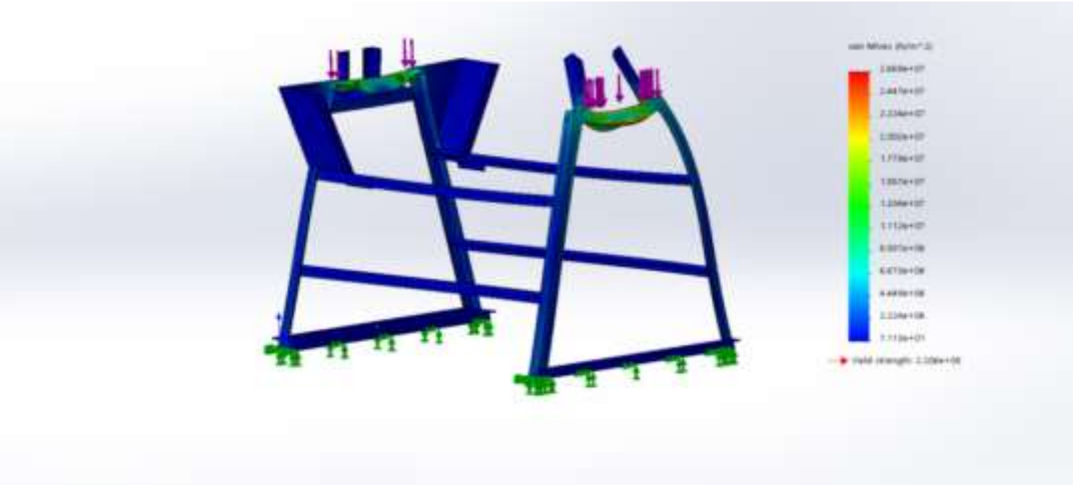


Figure 14: *Stress Analysis for Main Frame*

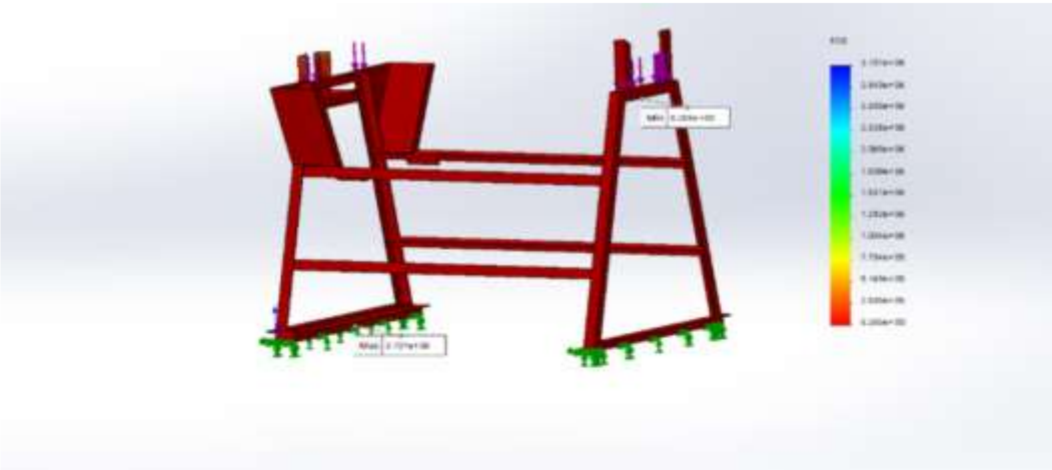


Figure 15: *Factor of Safety Analysis for Main Frame*

Stress analysis was performed on different parts. As the overall failure is dependent on the body part, the stress analysis result is given here in Figure 14. Factor of safety has been calculated in Figure 15. The purple arrows indicate external loads (force) and the green arrows show the fixtures. Force applied 300N. The material used is Plain Carbon Steel, which has yield strength of 2.206e+08 N/m2 and it is being seen that the highest yield strength that could be applied is 2.669e+07 N/m2. Therefore the part will not survive. We need to use Factor of Safety to prevent the part from failing.

MATERIAL SELECTION PROCESS

If anyone one to unsuitable materials from the manufacturing process, material selection is very much important.

Table 1: *Qualitative Analysis for Material Selection*

Parts	Selection Criteria	Available Material	Selected Material
- Body Frame - Spiral Rod - Hopper	- Cost - Tensile Strength - Density - Ductility - Availability - Hardness	- Aluminum - Mild Steel	- Mild Steel
- Main Shaft	- Torsional Strength	- Mild Steel	- Stainless Steel

- Net	- Corrosion Resistance - Tensile Strength - Ductility - Hardness	- Stainless Steel	
- Wheel	- Tensile Strength - Resistance to Decay - Toughness - Availably	- Plastic - Mild Steel	- Plastic

In case of a new or development or upgrade of existing product, it is very much needed. The target is to meet the customer demand as well as the cost effectiveness. Qualitative and quantitative are the ways to select the material for any parts of the design. As example, the material selection process for body frame is given in Table 1, 2 and 3.

Assembling Process choice alludes to choosing the sort of creative interaction to have in an assembling plant. The choice of an appropriate assembling measure regularly includes thinking about the unpredictable coupling between the plan's qualities, the material, and the cycle. The interaction picked relies upon the customization of the item and the volume needed on the lookout. The connection between the cycle designs and volume prerequisites is portrayed on an item interaction lattice.

From the material selection process, we realize that, the best material for body frame, spiral rod and hopper is mild steel. Because mild steel can absorb more load. For the main shaft we use stainless steel because the corrosion resistance of stainless steel is higher. Plastic is used for wheel because it can carry the load and it is light in weight. For our product, the manufacturing process is cutting and welding. Disk cutter is used here because its cost is low, needs less time and quality is good. We use Arc Welding because the cost is low and the quality is good.

Table 2: *Material Selection for Body Frame Using Digital Logic Method*

Selection Criteria	**Goals, N=6 Number of Positive Decisions=N(N-1)/2=6(6-1)/2=15**															**Positive Decisions**	**Relative Emphasis Coefficient (α)**
Cost	1	0	0	1	1											3	0.2
Density						0	0	1	0							1	0.067
Tensile Strength		1				1				1	1	1				5	0.33
Ductility			1				1			0			1	1		4	0.267
Availability				0				0			0		0		1	1	0.067
Hardness					0				1			0		0	0	1	0.067
Total Number of positive Decision=15																	$\sum\alpha = 1$

Table 3: *Calculation of Performance Index for Body Frame*

Selection Criteria	**Weight Factor α**	**Mild Steel**		**Aluminum**	
		Selected Property β	**Weighted Score αβ**	**Selected Property β**	**Weighted Score αβ**
Cost	0.2	100	20	75	15
Density	0.067	34.39	2.3	100	6.7
Tensile Strength	0.33	100	33	72.5	23.9
Ductility	0.267	75	20	100	26.7
Availability	0.067	75	5	100	6.7
Hardness	0.067	100	6.7	50	3.4
Performance Index (γ)			$\sum\alpha\beta$=87		$\sum\alpha\beta$=82.4

Material selection & Manufacturing process selection is very important for product design and development. By material selection process we can understand which material is best for our product. It also helps us to know the property of the selected material. By manufacturing process we know how raw material transfers into the final product. It also ensures the quality of the product. For example, the strength of arc welding is higher than gas welding.

CONCLUSION

This sand sieving machine was developed, which filters sand with the help of a motor. The market analysis was done, and a house of quality was formed based on customer needs. Then functional decomposition, design and stress analysis, material and manufacturing process selection, and cost analysis of the machine were done. Knowledge acquired from these steps was used to develop the machine physically. This machine is simply operated by a switch, which makes it very easy to use, and no skilled labor is needed. A motor is used to rotate the cylindrical sand filter, increasing the sand filtering rate compared to human filtering sand with a hand tool. The machine is eco-friendly and makes very less noise which makes it free from sound pollution. It is not too heavy and the wheels make it easier to move from one place to another. It needs less maintenance. This machine can be used in construction sites where sand needs to be filtered. As this machine has higher efficiency than manual tools and the price is reasonable this can be a good option for construction sites. It can also be used in foundry shops where sand needs to be separated from pollutants to produce a mold from the filtered sand.

ACKNOWLEDGEMENTS

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