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Design and Development of Foam Shredder for the Furniture Industry

Melani B. Cabrera, Jaypee B. Pajarillaga, Wilfredo L. Infante, Hubert T. Dungao
Holy Angel University, Philippines
Faculty of Engineering and Architecture, Holy Angel University, Philippines

Abstract: Micro, Small and Medium Enterprises (MSMEs) dominates the manufacturing industry for which it comprises the 99.6% of the 946,988 establishments in the Philippines. Improving Micro, Small and Medium Enterprises (MSMEs) operations is inevitable in order to be competitive globally. Engineering technology intervention, therefore, is sought to speed up production and improve quality. Apparently, machines are available only abroad for which prices are too high. This situation paved the way for the collaboration between university-government and private industry to develop low cost equipment that can be utilized by the MSMEs in the country. This project is about the designing and developing a low cost foam waste crusher machine that is to be used by furniture industries to disintegrate foam scraps. Specifically, the machine will address the need of small and medium scale furniture industries in Central Luzon in terms of recycling foam wastes generated from production of upholstered furniture. The Solid Works software of the university's mechanical engineering department was used in the simulation and analysis of the design. Kinematic analysis of the designed equipment was conducted using the Cosmos Motion component of the software. Finite element method using the Cosmos Works was likewise used for the stress, strength and dynamic analysis of the designed machine elements. A prototype was constructed, tested and validated.

Keywords: *Furniture; Foam Waste;MSME*

I. INTRODUCTION

Manufacturing industries are growing in thePhilippines. The Philippines has 946,988 business establishments based on 2014 figures provided by the Philippine Statistics Authority (PSA). Of these, 99.6% (942,925) are micro, small, and medium enterprises (MSMEs) and the remaining 0.4% (4,063) are large enterprises. Of the total MSMES 12.47% or 117,462 establishments are in manufacturing industry. Region 3 is included on the top five (5) locations of these establishments together with National Capital Region, CALABARZON, Central and Western Visayas. (DTI, 2014).

With the surging growth of the furniture industry in the country, it is just imperative to improve their productivity and competitiveness by investing in technology to streamline their production and be environmentally and economically competitive.

Furniture makers in Central Luzon utilize scrap foams in making throw pillows and other furniture accessories. Foam wastes were generated from production of upholstered furniture. These furniture firms, at present, are cutting their scrap foam manually since they cannot afford the high price of foam crusher that is already available in the market. Prices range from two (2) thousand dollars to 40 thousand dollars (PhP 100,000.00 to PhP 2,000,000.00). Since there is no locally made foam shredding machine available at this time, this study aims to design and develop a foam waste shredder machine that will be used by furniture industries to disintegrate foam scraps.

By providing a snapshot of the opportunities for recycling in 1994, the demand for foam is high so polyurethane recycling has a future. Having the technology to recycle a material is of little value unless there is a viable market for the recycled material. The flexible polyurethane foam industry, fortunately, has developed an eager market for its recycled products. Today, bonded carpet underlay comprises the majority of all carpet cushion sales. Driven by bottom-line considerations, polyurethane foam recycling is gaining steam industry-wide. But it is good to keep in mind that recycling provides a significant environmental benefit. Long before the current recycling boom, the flexible polyurethane foam industry began working to create a market for recycled fabrication scrap. Only a small portion of polyurethane foam waste ends up in landfills (Environmental Sunshine, 1994).

Twelve (12) furniture companies were surveyed to determine the system design requirements for the machine and be the basis or criteria in designing the machine.

The Solid Works software of the university's mechanical engineering department was used in the simulation and analysis of the design. Kinematic analysis of the designed equipment was conducted using the CosmosMotion component of the software. Finite element method using the CosmosWorks will be used for the stress and strength analysis and dynamic analysis of the designed machine elements.

The machine is mostly made alloy steel to prevent kinds of degradation such as rusting. The machine is automated and a 3 horsepower 1 phase motor 110/220 volts with 3450 revolution per minute and a fabricated metal blade made of high grade alloy steel.

This study made used of the following definition of terms throughout the research process:

Foam Waste.

A foam waste is the excess foam generated during production of upholstered furniture. There are different types of foam used in furniture that generates waste which are polyurethane, high density foam, evlon, high resilience, latex rubber, supreem, rebond, memory, closed cell foam, and dry fast foam.

Crusher.

A crusher is a machine designed to disintegrate solid materials into particles ("Crusher", 2008). The crusher may be used to shrink the size, or change the form of the foam waste materials so they can be more easily recycled.

Crushing.

Crushing is the procedure of conveying a force amplified by a mechanical device over a material made of molecules that bond together more strongly, and resist deformation more

("Crusher", 2008).

Ergonomics.

Ergonomics is an engineering concept that applies principles, data and methods to design in order to optimize human well-being and overall system performance (Adams, n.d.). It is used to prevent avariety of health problems and stillincrease efficiency by designing the machine to fit the operator instead of forcing the operator to conform to the machine.

II. PROBLEM IDENTIFICATION

With the surging growth of the furniture industry in the Philippines, it is just imperative to improve their productivity and competitiveness by investing in technology to streamline their production and be environmentally and economically competitive.

Furniture makers in Central Luzon utilize scrap foams in making throw pillows and other furniture accessories. Foam wastes were generated from production of upholstered furniture. These furniture firms, at present, are cutting their scrap foam manually since they cannot afford the high price of foam crusher that is already available in the market.

Generally, this study aims to provide a sustainable manufacturing for furniture industry in our country by improving their productivity and competitiveness through technology innovations.

Specifically, the objective of this project is to develop a foam shredder that will be utilized in crushing the scrap foams of the furniture manufacturers in Region III, that is

1. safe and efficient locally designed and fabricated semi-automated foam shredder equipment
2. reliable and maintainable
3. easy to use
4. effective design capacity is not less than 40 kgs. a day

Conceptual Framework

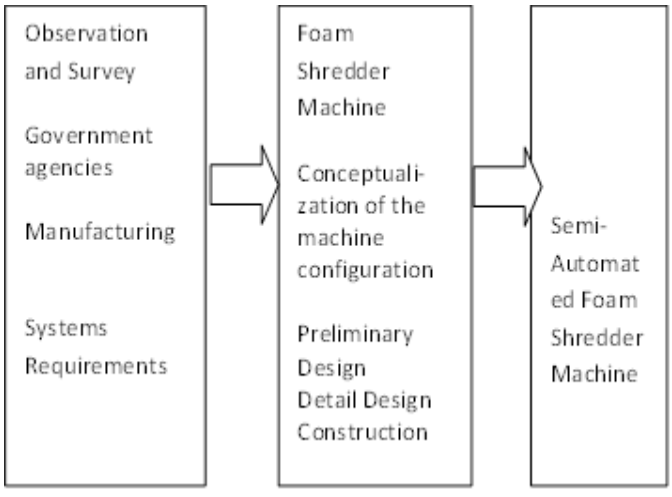

Figure 1. Research Operational framework

The main input in the process flow is the design and concept development of the Foam Waste Crusher which pertains on how the crusher was designed and formed. Survey will be conducted to manufacturing so as to determine problems in furniture operations regarding scrap foams. Systems approach is to be used in identifying and finding solutions to the problem. The survey will also be used in identifying the systems requirements. The new technology design will then be compared to the existing practice in shredding foams. Other input includes the fabrication of the machine which are as follows: man, material, method, machine and method. The said inputs are vital on the development of the foam waster crusher.

In the process phase, data collection was done, in which includes related literature for the study of the existing machines, classification and measurement of machine and fill out forms which comprise of the survey conducted on furniture industry in Pampanga. Data processing and analysis and machine design and construction were also part of the process phase of the framework.

The design and parameters of the foam waste shredder is the final output of the study which comprise of the geometric layout, final specifications, and quotations of the whole crushing machine.

III. METHODOLOGY

3.1 Research Design

The study about the Foam Waste Crusher is conducted in order to develop and produce a crushing machine that's ergonomically design and will meet the target markets budget and needs. The foam waste crusher's purpose is to disintegrate the foam scraps produced during the construction of the furniture so as to create a new raw material. In order to satisfy the research objectives, the researchers opted to obtain the view of the furniture manufacturers in line with the topic. Along with the primary data, the researchers also made use of secondary resources in the form of articles and related literatures to support the survey results as well as to compare findings and results.

3.1.1. Descriptive Design

The research used a descriptive design in which it describes the current situations such as the capacity requirements and design specifications wish list of the furniture industries for it to be both low cost and ergonomically designed so it can address the foam waste in small and medium furniture industries

3.1.2. Research Participants

The furniture manufacturing companies in Pampanga were asked to participate to get relevant information for the study. The researchers made use of a complete enumeration approach in which every member of the population is included. To achieve pertinent information, certain inclusion criteria was imposed. The participants qualified for sample selection must be furniture manufacturers who produce upholstered furniture. This qualification ensured that the participants understand the use of a foam waste crushing machine.

3.1.3. Instrumentation

To collect data regarding the expected requirements of the foam shredder, a survey questionnaire was use to serve as the main data-gathering instrument for this study (See Appendix A). The researchers used open ended questions in which contains factual, opinion, and probe questions. The questionnaire prepared is divided into two main sections: a profile and the survey proper. The profile contains factual information such as the company name, name of the participant and his/her position in the company. The survey proper consists of questions regarding the kinds of upholstered furniture their company produce, knowledge about foam waste crusher, how they handle their foam waste, the need or their outlook regarding the Foam waste crusher in the furniture manufacturing industries, and their preferred design,

specifications, and price in a machine like the foam waste shredder.

3.2. Reliability

The foam waste crusher functionality is expected to last up to 5 years from its initial use; wear and tear becomes a vital point for the failure of the machine. There are certain parts of the machine that must be monitored and maintain to verify its function according to its desired or intended purpose. The gear lifespan last only from 5 years to 6 years based from daily usage. The conveyor belt that makes the two metal roller wheels must also be considered for possible failure because of its rubber composition.

3.3. Validation

Series of test starting from the conceptual design up to its development is to be done. Particularly, focus on the machine operations such as its speed, safety and production output.

Assembly and test process validations are an integral, process-driven requirement applied against all supplied equipment and are most specifically applied against the foam waste crushing machine and systems which produce safety related products. Validations of the machine are an integral procedure that is mandated to verify the machine fabrication procedure and functionality.

This also defines the expected performance of the material installed in and out of the machine; documentation on how the foam waste crushing machine will be built typically includes the mechanical and electrical drawing of the foam waste crusher. The machine's main critical function which is the crushing of waste foams into pieces must comply with its desired purpose based on specification of the machine.

3.4 Project Design

The machine is composed of (1) Drive Motor, as the main device that produces motion in order for the crusher rollers to move; (2) Belt Drive, the part attached to the motor and the crusher roller which is a transmission system that transfers power (3) Crusher Rollers, the main parts that rotate in opposite direction in a single phase which then produces motion that will enable shredding or cutting; (4) Belt cover, one part of the machine which acts as a cover or protection of the belt inside the crusher housing; (5) Motor Cover, part of the machine which acts as a cover or protection of the motor inside the crusher housing; (6) Crusher Housing, the main frame of the whole machine that is made up of stainless steel to prevent rusting. It contains the motor, belt and blades internally, and an external crusher opening or mouth; (7) Crusher Support, the bottom part which will support the crusher housing. It acts as the machine's base for easy access and reach of the machine and for faster transport; (8) Roller, the wheels of the crusher support for easy transport; (9) Catch box, this part is positioned directly below the crusher housing.It acts as the container of the shredded foams; (10) Electric push button box, the control device of the machine. It controls all the dynamic components of the machine.

The Solid Works software of the university's mechanical engineering department is used in the simulation and analysis of the design. Kinematic analysis of the designed equipment is conducted using the Cosmos Motion component of the software. Finite element method using the Cosmos Works will be used for the stress and strength analysis and dynamic analysis of the designed machine elements.

Once the equipment design and the fabrication methods have been finalized, the machine components will be machined and fabricated by accredited fabricators of DOST-3 with the supervision of the design engineers. Assembly and performance testing of the equipment will be done at the HAU Engineering Laboratory. Field testing will be conducted at one of the prominent furniture makers in Pampanga. Equipment operation and maintenance manual will be developed by the project staff. Personnel from the technology adaptor will be provided with training on the operation and maintenance of the developed equipment. The machine is expected to yield at least 30 to 40 kgs. per hour of operations.

IV. RESULTS AND DISCUSSIONS

A. Project Design and Description

Presently, furniture makers in Central Luzon utilize scrap foams in making throw pillows and other furniture accessories by manually cutting the foam into small pieces. Since there is no locally made foam shredding machine available at this time, the proponents of this study aims to design and develop a foam waste crusher machine that will be used by furniture industries to disintegrate foam scraps in order to create new raw materials. The machine will address the need of small and medium scale furniture industries in Central Luzon in terms of recycling foam wastes generated from production of upholstered furniture.

Based from the survey conducted to which the system requirements were obtained, from the 12 furniture companies in Pampanga are the following: 11 out of 12 were looking into the shredder design and cost, 10 out of 12 were maximizing the capacity or output, 9 out of 12 are concern on its safety and ease of use, 8 out of 12 on its reliability and 7 out of 12 is on maintainability.

In order to design a machine that is of lower price, it was use raw materials that are relatively cheap but efficient and have high durability. The machine is mostly made of AISI 4140 alloy steel to prevent kinds of degradation such as rusting. Its identified parts are categorized as static and dynamic components. The static components are parts that are stable and the dynamic components are moving parts that will accomplish the crushing feature of the machine.

The machine components and functions are given as follows:

1) Drive motor. A standard 3 Hp, 220 Volts, single-phase electric motor running at 1700 rpm clockwise is being used to rotate the shredder shafts accompanied by the shredder blades and spur gear to produce the necessary means to tear the rubber foam.

2) Belt Drive. Standardized V-type rubber belt of length 1296.5 mm and belt width of ½" is being used to transmit power from the electric motor to the shredder shafts.

3) Shredder Shafts. Two shredder shafts made of □75 AISI 3130 hold the shredder blades and spur gears rotating in opposite direction to enable shredding or tearing. One length is 870 mm and the other is 725 mm.

4) Belt Cover. Belts covers made of 1/8" thickness MS serve as machine guards to protect the operator from the running belt, pulleys and spur gears. One belt cover measures 85 mm x 245 mm x 632 mm and the other belt cover measures 110 mm x 214 mm x 377 mm.

5) Shredder Blades. The shredder blades made of 16

pieces of 4140 steel with measurement of ⌀150 mm and thicknesses of 25 mm shred or tear the foam into pieces.

6) Shredder Housing. Two rectangular boxes and a hopper made of mild steel serve as main frame of the whole machine. One of the rectangular boxes measures 100 mm x 316 mm x 430 mm and the other rectangular box measures 120 mm x 316 mm x 430 mm. The dimension of the hopper is 316 mm x 430 mm x 385 mm.

7) Shredder Support. The shredder support is made up of several pieces of ¼" x 2" x 2" angle bars welded together and serves as the base support for the shredder housing for easy access and reach of the machine and for faster transport. Plates necessary for the attachment of caster wheels are also welded in the shredder support. The total dimension of shredder support is 610 mm x 650 mm x 750 mm.

8) Roller. Four standard caster wheels serve as rollers for the machine for easy transport. The casters are smooth-swiveling, perfectly aligned, structurally stronger. Welding the top plate to a retaining plate allows the fork assembly to swivel between the two plates on a single row of hardened steel ball bearings. Wheels have smooth-operating ball bearings. Medium duty up to 750-lb. capacity.

9) Feeder Plate. The feeder plate made of 1/8" thickness MS plate with measurement of 70 mm x 275 mm x 436 mm can be tilted at 90o angle so foam can be fed to be shredded by the shredder blades.

10) Electric Push Button Box. A standard electric push button box serves as the control device of the machine for controlling the dynamic components of the machine. This single-speed, push-button control station provides one-hand operation for the machine. Molded rubber enclosure insulates against electrical shock. Station is sealed against moisture and dust. Switch is activated by pressure on raised rubber portion of enclosure face.

B. Machine Design and Effective Capacity

The maximum capacity of the machine is 100 kgs. per hour. Its effective capacity ranges from 30 to 40 kgs. per hour. Table below explains the number of trials time and motion conducted in order to determine the effective capacity.

Table 1. Time and Motion Analysis Sheet

Trial No.	Weight (kg) Before	After	Time (min)
1	3.20	3.00	20
2	4.10	3.00	24
3	4.00	3.80	24
4	2.00	2.00	13
5	3.80	3.10	16
6	3.60	3.50	16
7	4.80	4.60	23
8	6.20	6.00	33
9	3.80	3.60	15
	35.50	32.60	184.00

Capacity = 35.50kg/184 min x 60 min/hr =

12 kg./hr or 90kg/8-hr a day

C. Product Cost

Below table shows the detail material and labor costing of the machine. The total cost of the machine is Php 108,454.98.

Table 2. Machine Cost

Material Cost						
Material	Unit	Length	Width	Consumption	Unit Cost	Total Consumption
Gear, Pulley, Cutter Blade	set			1.00	80,000.00	80,000.00
Caster Wheels	pc			4.00	603.00	2,412.00
Belt	pc			1.00	180.00	180.00
Motor 3HP	pc			1.00	6,200.00	6,200.00
Push Button	pc			1.00	380.00	380.00
Flat Cord	m			4.00	70.00	280.00
Plug	pc			1.00	64.00	64.00
Chronic Chain	pc			2.00	27.00	54.00
Rubber Sheet	pc			4.00	30.00	120.00
Angle Bar - 20 ft/pc (s/5)	pc	30"		0.13	2,093.00	261.63
Angle Bar - 20 ft/pc (s/5)		33"		0.14	2,093.00	287.79
Angle Bar - 20 ft/pc (s/11)		20"		0.08	2,093.00	174.42
Cylindrical hinges - 4 x 1/2	pc			4.00	90.00	360.00
B.I. sheet - 4mm - 4 x 8	sheet	17.2"	9.3"	0.04	2,850.00	114.00
B.I. sheet - 4mm - 4 x 8	sheet	14"	13"	0.05	2,850.00	142.50
B.I. sheet - 4mm - 4 x 8	sheet	10.5"	13"	0.04	2,850.00	114.00
B.I. sheet - 6mm - 4 x 8	sheet	12.3"	17"	0.04	4,250.00	170.00
B.I. sheet - 6mm - 4 x 8	sheet	15"	12.3"	0.05	4,250.00	212.50
B.I. sheet - 6 mm - 4 x 8	sheet	4"	17"	0.02	4,250.00	85.00
B.I. sheet - 6mm - 4 x 8	sheet	5"	17"	0.03	4,250.00	127.50
G.I. sheet - 4 x 8	sheet	30.5"	14.8"	0.11	1,665.00	183.15
G.I. sheet - 4 x 8	sheet	15"	13.5"	0.50	1,665.00	832.50
Expanded Wire (4x8)	pc			1.00	500.00	500.00
Paint	pc			4.00	100.00	400.00
Paint	can			2.00	175.00	350.00
Total Direct Material Cost						**94,004.98**
Labor Cost						
Estimated Direct Labor Cost	3 persons x 7 days x 450					9,450.00
Total Product Cost				**Php**		**103,454.98**

D. Machine Validation

Previous technical problems presented namely, sound level during operation goes beyond the standard level; one set of cutters was loosened on the shaft; shredded foam was stacking in the chute; size of foam cannot be fixed to one size only; one gear is moving off from its position causing breakage of key; feeding of foam is inconvenient and the color of the machine is not attractive enough. All these problems were addressed when they revised the machine The cause of high sound volume was due to the vibration cause by GI sheet and frame attachment. Thus, the G.I. sheet was removed. GI sheet was placed to only cover the frames. Another cause of noise is the shaft is tightly assembled, thus when it rotates it contradicts with the driving mechanism of the machine. Metal gears also produce unnecessary noise when the machine is in operation. Thus, gears were replace into a plastic.

Table 4. Summary of the test conducted, their causes and action taken for each three (3) trials.

RESULTS / ISSUES	CAUSE/S	ACTION TAKEN
Sound level during operation is still not acceptable.	Probable cause of noise is the meshing of the gears	Replace one gear with different material (fabricate two gears:
Machine guard does not cover all the parts.	Set screws are not enough to hold the gear onto the shaft.	industrial plastic and aluminum alloy) meshing with the metal gear.
There is still significant amount of foam present on the chute.	The inclination of the chute is still not enough for the foam to slide	Fabricate gear caps to hold the gear onto its position on the shaft.
One gear is still moving off the shaft.		Redesign the chute. (No more inclination, allows free fall of shredded foam
Shredded foam is less than half inch in size		Extend machine guard to cover all rotating parts

CONCLUSIONS

The foam shredder machine is yielding a capacity 10 times more than the manual operation at a cost of Php 95,000.00.

Based from the case company, they are only gathering 30 kilos of scrap foams a day. Thus, the group proponents are recommending to offer the machine in varied sizes. Estimated price for varied sizes are given on the following table.

Table 1.Varied Sizes with Estimated Price of the machine

ITEM	DESCRIPTION	LARGE	MEDIUM	SMALL
1	CAPACITY, KG / MIN	5 – 10	3 -5	1 – 3
2	NO. OF BLADES	16	10	6
3	BLADES (SHAFTS, SPACERS, CUTTERS)	Php 80,000.00	Php 60,000.00	Php 40,000.00
4	MOTOR (PULLEYS, MOTOR, BELTS)	8,000.00	7,000.00	6,000.00
5	FRAME (BODY, ROLLERS, HINGES)	5,000.00	4,000.00	3,000.00
6	ELECTRICAL ACCESSORIES (SWITCHES, WIRES	2,000.00	2,000.00	2,000.00
TOTAL		PHP 95,000.00	PHP 73,000.00	PHP 51,000.00

The large to maximize its production output can be likewise utilized in shredding paper cups, paper plates, polystyrene, pet bottles etc. Thus, this machine can be offered to restaurants and fastfoods, schools and malls. The machine can still be further improved in order to make it more efficient, safe and adaptable to users or workers.

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