

Evaluation in Conceptual Design of Human Powered Sand Sieving Machine

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Abstract. Sand sieving machine has the function to sieve sand and stone that mixed together. The sand and the stone cannot process further if they mix. Thus, this machine will help operator work which was doing sieve with no machine mechanism. With machine mechanism driven by human power will reduce the time to sieve. The objective of this paper is hopefully can make the best concept design in terms of production costs and production capacity. The stages of evaluation design begin with functional decomposition, concept making with morphology matrix and concept evaluations with feasibility judgment, go or no go screening and basic decision matrix. In evaluating the product, one or several of the best concepts are chosen to further developed into products, based on selection criteria. The results of this design obtained the best concept of sand sieving machine in terms of efficiency, energy, and flexibility. From this paper, it can be concluded that the design of this sand sieve will environmentally friendly and bring many benefits, is positive and very good to continued.

Keywords: Sieve; Sand; Design; Machine; Evaluation.

1. Introduction

In designing product concepts, it is sought as much as possible alternative product concepts that all meet the technical specifications of the product. In evaluating the product, one or several of the best concepts are chosen to further developed into products, based on selection criteria. Criteria for evaluating product concepts are not easy to compile. Nevertheless, the evaluation process to choose the best product concept must be done [1].

Liu A in his paper describes that conceptual design is recognized as the most essential and creativity-requiring phase that has a dominating influence on the product quality, especially for complex technical systems, such as the sophisticated machine tools. Increasing market competition keeps imposing higher requirements from the upstream and tighter constraints from the downstream. Unlike the innovative design of consumer products where the challenge lies in how to add new functions to satisfy emerging customer needs (CN) [2].

In the early 1960s, the lack of quality of products and projects become a motive for researchers and practitioners began to investigate new design methods as a way to improve the outcome of T design processes [3]. After that, the period of expansion has been occurring through the 1990s right up to the present day [4]. However, there is still no clear image of the fundamental of the design process [5,6]. Furthermore, at universities, many of the design methodologies were developed and in industrial applications are only rarely applied [7,8].

Fritz Zwicky developed general Morphological Analysis (GMA) as a method for structuring and investigating the total set of relationships contained in multi-dimensional, non-quantifiable, problem complexes.

The morphological approach called by Zwicky is “totality research” which, in an “unbiased way attempts to derive all the solutions of any given problem”. It may help us to discover new methods or configurations, which may imprecise way, or which we might have overlooked by another method with less systematic [9]. Ritchey in his paper describes that General morphological analysis is based on the fundamental scientific method of alternating between analysis and synthesis. This GMA is including the process of “cross-consistency assessment”. Because of this reason, it can trust as a useful, non-quantified method for investigating problem complexes, which cannot be treated by formal mathematical methods, causal modeling, and simulation [10].

Ya Zhang describes that in the traditional mechanical design process, the product not only has performance requirements but also has many financial needs such as manufacturing cost and sales profit. Many conditions also have great uncertainty. Besides, in design and evaluation, in addition to the existing theoretical analysis, in most cases, it is mainly judge based on the designer’s experience [11]. Design fixation could have negative impacts on design outcomes, especially when it occurs during the ideation stage, i.e., the conceptual phase of a design process [12]. Most people are likely to encounter obstacles during idea generation [13].

In this paper will describe a project that uses morphological analysis to evaluate the design of sand sieving machine. This sand sieving machine is another prototype of the other machine that was built. Sand sieving machine has the function to sieve sand and stone that mixed. The sand and the stone cannot process further if they mix [14]. Thus, this machine will help an operator

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work which before does the sieve with no machine mechanism. This machine also will reduce the time to sieve.

This design built the same as the other sand sieving machines, work with various mechanisms. This means that many examples can be used as a reference in designing. The machine varies according to the capacity, features, and advantages that designer wants. With these conditions, of course, the design of sand sieving machines is something that is not too difficult and possible to do. The objective of this paper is hopefully can make the best concept design in terms of production costs and production capacity. In terms of production cost because the machine does not use an electric motor, so the selling price becomes cheaper. In terms of production capacity, the method of sieving sand with sand sieving machines can increase the amount of sand filtered capacity.

2. Methodology

In this stage, the author drafts a machine concept. This stage includes the project plan. The objective of this task is to make several machine concepts from a combination of function concepts using the morphology method, then do a concept evaluation to get a final machine concept.

A morphological chart is a matrix with columns and rows which contain the aspects and functions to be fulfilled and the possible solutions coupled to them. These functions and aspects are derived from a program of demands. In principle, overall solutions can create by combining various sub-solutions to form a complete system solution combination [15]. Morphological charts encourage to structure the solution and creativity space. The morphological chart is essential tool for information processing, and is not limited to purely technical problems but also can use in the development of management systems and other fields [16,17]. The morphological matrix is not only a very useful tool of the direct solution but also excellently fits with the initial phases of the problem-solving process since it may be aimed at finding the interesting problematic for processing and the same at the line of research and at the chances and the probabilities [18].

The evaluation consists of activities to compare product concepts and make decisions. In comparing two or more concepts, the two concepts should be stated in the same level of abstraction. Information to make these decisions is obtained by comparing the capabilities of the product concept to meet the requirements in product specifications. There are two kinds of ways to compare, namely absolute comparison and relative comparison. So each product concept is directly compared to several targets set in the criteria. In relative comparisons, the concept of alternative products is compared with each other using size measures specified in the criteria.

The research method can be seen in Figure 1. Initially, functional decomposition continued with the merging of concepts using the morphology matrix. After all the possible concepts are examined, the four best concepts for evaluation are selected. Concept evaluation consists of

feasibility judgment, go or no go screening, and basic decision matrix.

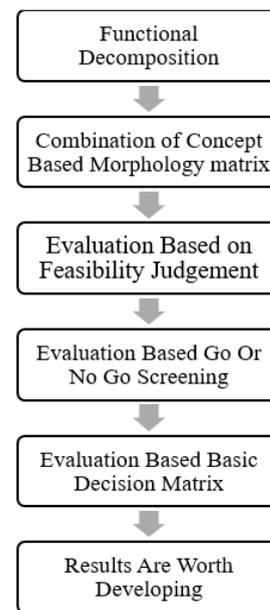


Fig. 1. Research method

2.1 Functional Decomposition

The product has two aspects, namely the physical structure of the product and the function of the product. The physical structure of the product can be broken down into several components. The function of the product is abstract. The function is the behavior of a product that is needed to meet the technical requirements.

Product functions describe what the product does, while the product structure describes how the product carries out the function. In other words, structure follows function. The Functional decomposition of sand sieving machines can be seen in Figure 2.

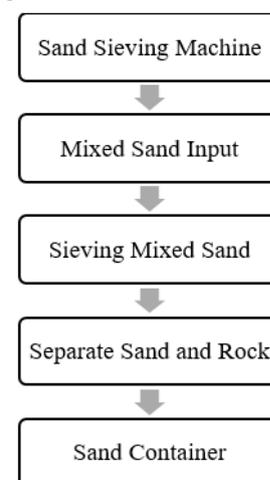


Fig. 2. Functional decomposition of sand sieves.

2.2 Morphology Matrix

Table 1 is the morphology of the sand sieving machine based on the functional decomposition.

Table 1. Matrix morphology sand sieving machine

NO	Concept Function	1	2	3
A	Power	Crank	DC Motor	AC Motor
B	Power Transmission	Chain	Gear	Belt
C	Mixed Sand Input	Open tub	Funnel	
D	Sand Sieve	Centrifuge	Vibration	
E	Separate Sand and Rock	Sieve	Sand Funnel	
F	Sand Container	Without container	With Container	

From the morphology Table 1 above, a combination of concepts is carried out by combining each function concept with other function concepts. In this way, of course, there will be a lot of machine concepts obtained. The results of many variations of the concept are not written entirely. Only certain concepts are written, with consideration may or may not be made.

2.3 Feasibility Judgement

This stage is the first stage of evaluating the concept. In the feasibility judgment, a product concept is formed by using absolute comparisons where each product compares to several targets set in the criteria. In general, experiencing one of the three reactions, the concept is not feasible, the concept may be developed further if something supports and the concept should be investigated further. As for the preparation of criteria in this stage, it is through brainstorming the designer by considering the user's feelings in using the product. This evaluation is carried out with the following considerations:

- Technological impossibility
- Inability to meet customer demand
- The concept made is considered unusual / out of the ordinary
- Concepts that are made are not original ideas
- There is no enthusiasm to choose the concept in question

2.4 Go or No Go Screening

If the technology used in a product concept is considered mature, then the evaluation of the next product concept is an assessment of the ability of the product concept to meet the desires of the user. In this case, the evaluation of the strength of the product concept to meet user desires is absolute, and each assessment must be answered with yes or no.

The consumer demand criteria are based on surveys that have been carried out for users, namely construction workers. They asked for sand sieving machines that were fast in sieving, large capacity, rigid, high durability, minimal vibration, simple construction, corrosion-resistant, easy to operate, minimal noise, high practicality, cheap, cheap and attractive spare parts.

In Table 2 all customer requests are addressed to the four selected concepts as a result of the first evaluation

phase above, namely (K1, K2, K3, and K4. Each concept will only have two answers, namely "yes" (Go) or "no" (no-Go) The concept that answers the most "yes" is the chosen concept.

Table 2. Go/no-go evaluation

NO	Costumer Demand	K1		K2		K3		K4	
		Go	No	Go	No	Go	no	Go	no
1	Fast in sieving	√		√		√		√	
2	Large capacity	√		√		√		√	
3	Rigid	√		√		√		√	
4	High durability	√		√		√		√	
5	Minimal vibration	√			√	√			√
6	Simple construction	√		√		√		√	
7	Corrosion resistant	√		√		√		√	
8	Easy to operate	√		√		√		√	
9	Minimal noise	√			√	√			√
10	High practicality	√		√		√		√	
11	Cheap machine	√		√		√		√	
12	Cheap spare parts	√		√		√		√	
13	Attractive machine	√		√		√		√	

2.5 Basic Decision Matrix

The basic decision matrix method or the Pugh method is a simple and proven method to compare alternative product concepts. In principle, this concept provides a way to assess (by giving numbers) each alternative to other alternatives in a relative capacity to meet the criteria made based on the wishes of the user. By comparing the values (numbers) obtained by each alternative, an overview or information about which alternative is better is obtained. The steps in this method consist of

- Develop criteria for comparing products
- Give weight to each standard
- Choosing alternative product concepts to be compared
- Choosing alternative product concepts
- Calculating the final grade

At this stage, each selected concept of the previous evaluation results is compared to the criteria. This criterion is a previous consumer request coupled with additional requests that are more specific nature. One of the selected concepts is used as a datum. The concept used as a datum is the most preferred concept and is considered the best compared to other concepts.

The concept of choosing the results of evaluation results in the basic decision matrix is a concept that has a plus value for the datum based on the criteria. Based on

the information about the datum, the designer determines the concept used as the datum is the first concept (K1). Table 3 is a basic decision matrix that helps to determine the final concept.

Table 3. Basic decision matrix

NO	CRITERIA	VALUE	ALTERNATIVE	
			K1	K3
1	Fast in sieving	10	DATUM	S
2	Large capacity	9		S
3	Rigid	3		S
4	High durability	10		S
5	Minimal vibration	5		S
6	Simple construction	3		S
7	Corrosion resistant	3		S
8	Easy to operate	8		S
9	Minimal noise	2		S
10	High practicality	8		+
11	Cheap machine	9		-
12	Cheap spare parts	4		S
13	Attractive machine	3		S
TOTAL +				1
TOTAL -				1
TOTAL				-1

3. Results and Discussion

From morphology matrix, 144 combinations of concepts were obtained. All concepts are then examined and evaluated. The possible design of sand sieving machine will evaluate later. The best concept will be chosen in the next stage.

From feasibility judgment, four concepts meet the desired standards. Four concepts are as follows.

Concept 1 (K1) has a sequence of A1-B1-C1-D1-E1-F2. This concept consists of: powered by a crank, power transmission with chain, mixed sand input use open tub, sand sieve use centrifuge concept, separate sand, and stone with a sieve and use the sand container. The machine will be used in a small village with no electricity so the crank is chosen. The transmission with chain has an advantage less power loss between 5-10%. The reason input with an open tub because hopefully, the input can contain sand as much as possible. The sieve has tube shape so if the sieve rotates sand will be sieved with a centrifuge concept. The sieve uses standard sieve that can separate small rock and sand. The output of the machine will have a box container that can contain sand.

Concept 2 (K2) has a sequence of A1-B2-C2-D2-E1-F2. This concept consists of: powered by a crank, power transmission with gear, mixed sand input use funnel, sand sieve use vibration concept, separate sand, and stone with a sieve and use the sand container. As state before crank is chosen because the machine will be used

in a village with no electricity. The transmission with chain has an advantage high efficiency and long life so it is not easily damaged. And also the gear must be free of fatigue loads and free from high loading. The reason input with funnel because the mixed sand will not be scattered. The sieve has plat shape so if the sieve vibrates the sand will down to container. The sieve uses standard sieve that can separate small stone and sand. The output of the machine will have a box container that can contain sand.

Concept 3 (K3) has a sequence of A1-B3-C2-D1-E1-F2. This concept consists of: powered by crank, power transmission with belt, mixed sand input use funnel, sand sieve use centrifuge concept, separate sand, and stone with a sieve and use the sand container. As state before crank is chosen because the machine will be used in a village with no electricity. The transmission with a belt has an advantage does not cause noise, maintenance costs are relatively cheaper compared to the drivers that use the gear. The reason input with funnel because the mixed sand will not be scattered. The sieve has tube shape so if the sieve rotates sand will be sieved with a centrifuge concept. The sieve uses standard sieve that can separate small stone and sand. The output of the machine will have a box container that can contain sand.

Concept 4 (K4) has a sequence of A1-B1-C2-D2-E1-F2. This concept consists of: powered by a crank, power transmission with chain, mixed sand input use funnel, sand sieve use vibration concept, separate sand, and stone with a sieve and use the sand container. The machine will be used in a small village with no electricity so the crank is chosen. The transmission with chain has an advantage less power loss between 5-10%. The reason input with funnel because the mixed sand will not be scattered. The sieve has plat shape so if the sieve vibrates the sand will down to container. The sieve uses standard sieve that can separate small stone and sand. The output of the machine will have a box container that can contain sand

From go or no go screening, two concepts were chosen that met the criteria. The two final concepts are the first (K1) and third (K3) concepts. Where both concepts have advantages, namely minimal vibration and minimal noise. Furthermore, the two concepts will be further evaluated with the basic decision matrix method.

From basic decision matrix by paying attention to the total weighting of the basic decision matrix table which is the final stage in the evaluation, the first concept (K1) is a final selected machine concept. The sketch of the final concept K1 we can see in Figure 3.

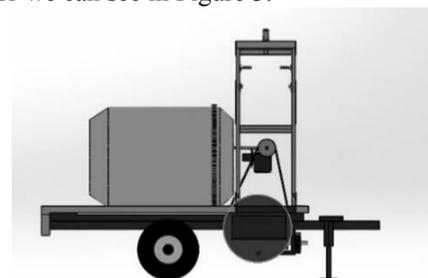


Fig. 3. Final Concept

4. Conclusion

The functional decomposition is helpful to breakdown what machine does begin with input, process, and output. Morphological methods are methods that produce the highest number of alternative product concepts. The go or no go screening method helps choose product concepts that fit the criteria. And the basic decision matrix method is very suitable for determining the best concept by giving a value weight for each criterion.

The sand sieving machine chosen based on the selection of the concept that has been carried out is a sand sieving machine with powered by a crank, power transmission with chain, mixed sand input use open tub, sand sieve use centrifuge concept, separate sand, and stone with a sieve and use the sand container.

From the whole description above, regarding the definition of this project, it can be concluded that the design of this sand sieve will environmentally friendly and bring many benefits, it is positive and very good to undergo further development.

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