Systematic Niche Design Approach in Developing Dancing Water Nozzle for Water Fountain

Sivaraos, Leon. S, Aidy Ali, M. F. Abdullah, Amarnath

Abstract:--- In the waterfountain branch exist a technology gap in the dancing waterfountain niche. To close this niche, a systematic niche design approach is needed to bring out a successful product in less time to close this gap efficiently. This paper shows a suggested systematic design approach on the example of a new dancing waternozzle with an easy control unit. The design methodology shows the product specification, conceptual design, detailed design and a validation using FEA tool and Rapid prototyping. The design approach uses different methods for a fast design generating. The design approach is explained in every step with an example of the dancing waterfountain. A dancing waternozzle without a complex control unit is developed. The detailed design of the dancing waternozzle is made successfully with this approach but to fulfil all requirements to this design further development on the design is needed.

Index Terms: Dancing waterfountain, niche product, product design, systematic design.

I. INTRODUCTION

The aim of this project is to identify the requirement of the new dancing waternozzle, to design a suitable design approach to close a technology gap in a niche and to generate an optimized design of the dancing waternozzle. Dancing waternozzles are related to the moving or dancing water fountain. These nozzles have angular or rotational movements to generate these effects [1]. Dancing waterfountains are a new way to entertain with a waterfountain which move synchronized to music or lighting to generate a dynamic show which is computer controlled [2].

For special or complex products, a new design approach needs to get develop because the related approaches could not be applied efficiently in some cases [3]. Some design methods are developed to bring out an optimized biometrician sustainable product with consideration of environmental friendly design [4]. Design methods are involving also decision-making approach.

Zerbes brings out a planning process in 2014 which provides the needed information's for a decision at the specific design stage. When it comes to choose a design approach to design a niche product researches shows that there is no suitable design approach for this problem. The need of a new design approach is to bring out a suitable design approach to design a niche product to close a technology gap in a specific sector. So, the paper also shows detailed the chosen design methods to design a product to close a niche in a technology gap in less time and how the chosen design methods flow. For the design methods CAD tool are used for the detailed design and FEA tool for the validation of the model. Some methods get used in a different way. The methodology focused on a good design in less time. A drop-down selection method is used in a morphological box to ensure that all concepts are on a high level to avoid rework between the conceptional design phase and the engineering phase. Also, the concept development step uses a kind of embodiment design to give every concept a structure of build. The design approach gets classified into concept generation, engineering and validation of the model.

II. METHODOLOGY

When setting out to design a new niche product, a literature review is essential for this project. The literature review should also show different methods and approaches of all design phases to have a big choice of different methods. This approach consists out of different design methods to generate an accurate product in less time.

The literature review shows that the sector of entertainment waterfountain is a branch full of innovative products. Most inventions made in this sector are develop throughout history. So, they innovate the technology into this branch [2]. Also, a look on existing design knowledge is important. Reusing design knowledge is important. Using this knowledge can help to enhance the efficiency of the product development [5]. However, the literature research shows that the entertaining waterfountain leave out an innovation in the dancing waternozzle sector. There is no dancing waternozzle which performs two independent movements without a complex computer control. This paper presents the work of the design step, the engineering step and a step to validate the performance of one product for closing the niche in the dancing waternozzles. The overall design flow is mentioned in Fig. 1.

Revised Manuscript Received on February 11, 2019.

Sivaraos, Advanced Manufacturing Centre, Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, Malaysia.

Leon. S, Faculty of Mechanical and Bio Process Engineering, Hochschule Hannover - University of Applied Sciences and Arts, Germany.

Aidy Ali, Department of Mechanical Engineering, Faculty of Engineering, Universiti Pertahanan Nasional Malaysia (UPNM), Sg. Besi Camp, Kuala Lumpur, Malaysia.

M. F. Abdullah, Department of Mechanical Engineering, Faculty of Engineering, Universiti Pertahanan Nasional Malaysia (UPNM), Sg. Besi Camp, Kuala Lumpur, Malaysia.

Amarnath, Department of Mechanical Engineering, Indian Institute of Information Technology, Design, and Manufacturing Jabalpur, India.

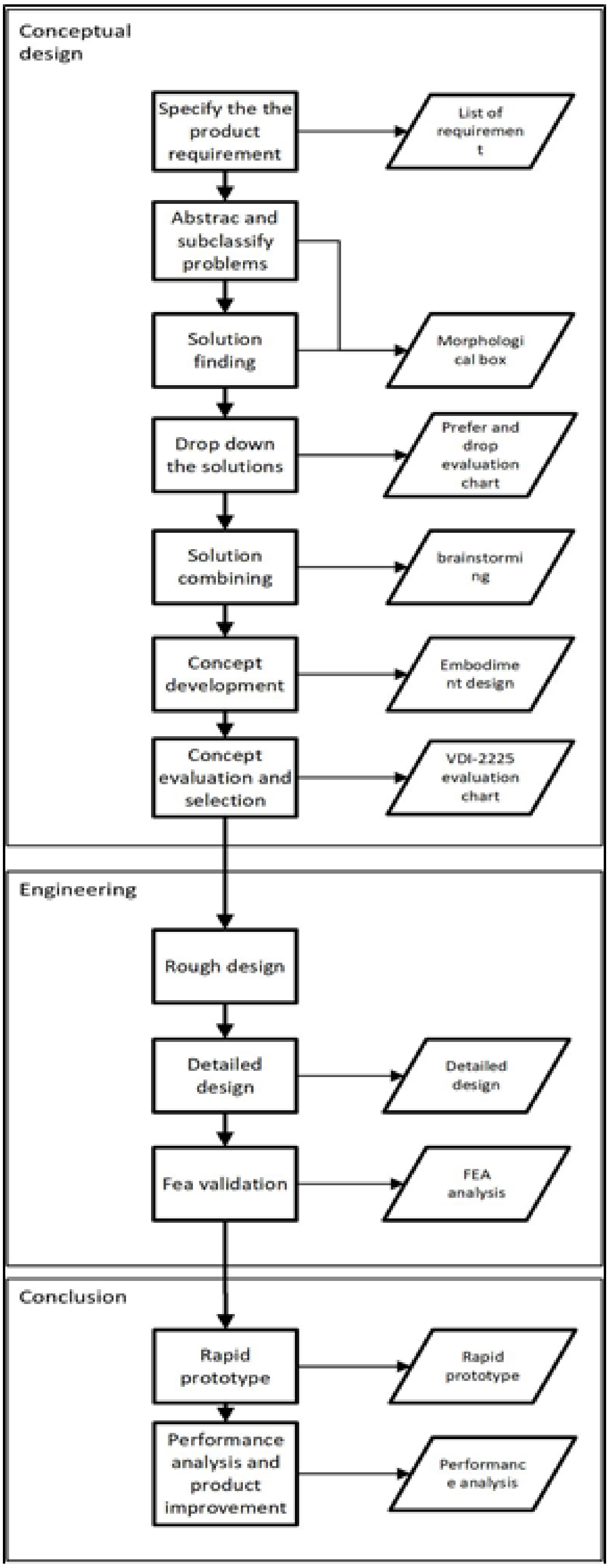

Fig. 1: Design flow chart

III. DESIGN OF THE DANCING WATERNOZZLE & RESULTS

A. Specify the Product Requirement

This step-by-step approach starts with the specifying of the product. The first step should show which purpose and which properties it should have or not have. This step uses the method of a list of requirements. The list is settled using a guideline of main property list which comes with a template of requirement category's like geometric, kinematic, force, energy, material, signal, safety, ergonomic, manufacturing, assembly, transport, usage, recycling cost and date [6]. The requirements are classified into "demanded" and "nice to have" or "wish". It is required that the product fulfill all demanded requirements to get an acceptable product. All requirement should be listed as a positive statement and should be as precise as possible. Qualitative and quantitative requirements need to get considered. Quantitative requirements should come with a specific value or a value range and a unit. Qualitative requirements need to be a clear statement like waterproof. The list of requirements should be as precise as possible. But, it is impossible to consider all requirement. So, the list of requirements is a concurrent ready method which will grow with the progress of the project [6]. The requirements consider the niche product of the dancing waternozzle. Most requirements are in the kinematic category to give a clear movement for the following steps. It should rotate and wobble the nozzle. The requirements are listed in Fig. 2.

	Request List for the wobbling waterfountain		
need wish	requirements	value	unity
	Geometric		
w	small		
n	quadrat groundplate		
w	low balance point		
	Kinematic		
n	rotation of a nozzle	0-250	rpm
n	rotation axis tilt to center axis	15	degree
n	rotation of this tilted rotation axis around center axis	0-150	rpm
n	the tilting can get switch on and off		
n	both movements must are indipendent to each other		
	Force		
w	consider the force of water	0-1000	l/min
w	waterpressure	0,25	bar
	Energy		
w	no prefered source of energy		
	material		
w	resistable against Water		
w	Temperature	5-40	°celsius
w	Huminity	0-100	percent
	Manufracturing		
w	prefer standardpats		
	Usage		
w	Controllabe over two potentiometer (the controll is no		
	Date		
	last submission on 23.05.18		

Fig. 2: List of requirements

B. Abstract and Sub-Classify Problems

Step 2 is to abstract main problems out of the list of the requirements. This step focus on abstracting main problems which are obvious from the list of requirements. These main problems are now subclassify into sub-problems to become a clear function structure. At least, every requirement should be expose in one sub-problem [3].

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

C. Solution Finding

Step 3 is to generate a morphological box from out of the problems and sub problem. For generating solutions of every subproblem, brainstorm method was used to find solution based on designer's experience, knowledge and ability of iteration. Using brainstorm methodology will cause that some solutions does not make sense of are too complex or not compatible with other solution [7]. To avoid generating concepts which are not feasible or nonsense, a first drop-down selection of the solution is made. The morphological box is shown in Fig. 3.

row	Functions		alternative solutions						
	Main	Sub	1	2	3	4	5	6	7
A	Location of spinning		on top of joint	on joint	below of joint				
B	Spinning	drive	el. direct	el. w/ gear	combustion engine	waterstream turbine	water force nozzle	hydraulic/pneumatic engine	
C		bearing	Ball bearing	Slide bearing	el. Magnetic bearing				
D	Wobble	movement	orbital	hypozykloid					
E		movement tranlation	swashplate	incline/ramp	lever	other			
F		drive	lever	el. Solenoid	contollcylinder	el. Servo	water force nozzle	hydr. Drive	crankshaft
G		joint	ball joint	no rotation joint	universal joint				
H	Waternozzle		fingernozzle	fannozzle	waterjetnozzle				
I		mount	1 G	1 1/2 G	other				
J	Watersupply	pump	external pump	internal pump					
K		supplypipe	through system	external w/ rotational mount	hosepipe				

Fig. 3: Morphological box

D. Drop-Down Selection

Step 4 is drop-down selection. For this step, the prefer and drop method. This step will show that a drop-down solution right after the solution finding process makes it easier to generate concepts on a higher level. The prefer and drop method comes with a checklist where every sub solution gets evaluated. The order of the criteria of evaluation is compatibility, fulfill requirement, feasible, effort, safety and prefer because of knowledge. When a solution is not able to pass, one criteria of the method it will get dropped [6]. This method makes sure that only the best, feasible and compatible solution are in the concept generation, which will improve the goodness of the concepts. The safety will not be considered for the dancing warternozzle because this task is related to a risk assessment which can get done as further development of this model. The Prefer and Drop Table is shown in Fig. 4.

			design of a moving waterfountain							
		alternative solution	compatibility						good	+
				fulfill demanded requirements					bad	-
					feasible				need info	?
						effort acceptable			proof	!
							safety			
								prefer		
Main function	sub function		A	B	C	D	E	F	notice	solution
Spinning	drive	1	+	+	+	+		+		+
		2	+	+	+	+				-
	bearing	1	+	+	+	+				+
		2	+	+	+	+				+
Wobble	movement	1	+	+	+	+				+
		2	+	+	+	-				-
	movement translation	1	+	+	+	+				+
		2	+	+	+	+				+
		3	+	+	+	+				+
	drive	1	+	+	-	-				-
		2	+	+	+	+				+
		3	+	+	+	+				+
		4	+	+	+	+				+
	joint	1	+	+	+	+				+
		2	+	+	+	+				+
Waternozzle	nozzle	1	+	+	+	+				-
		2	+	+	+	+		+		+
	mount	1	+	+	+	+		+		+
		2	+	+	+	+				-
Watersupply	supply	1	+	+	+	+				+
		2	+	+	+	-				-
		3	+	+	-					-

Fig. 2: Prefer and drop table

E. Solution Combining

Step 5 is to come out with concepts. For selecting solutions out of the, with prefer and drop method shortlisted, morphological box, brainstorming method is used. At least, all solution should choose once. Eight concepts should be designed. In some subproblems, only one solution is good enough to get through the prefer and drop evaluation. This solution is considered as best solution for this problem. So, all concepts will use this solution for the specific problem. The combining table only show the category's with more than one solution.

F. Concept Development

Step 6 is to turn the concept solutions structure into a visual concept using a CAD software. The CAD software is used to make the communication easier between designers or even different departments of a company. When it comes to understanding, a complex dancing mechanism CAD is a powerful tool to make communication easier for all involved people. In this step, the first part of embodiment design gets done on an easy level for these early design step. The structure of building gets develop using knowledge and experience of the designer. The concepts shown in Fig. 5.

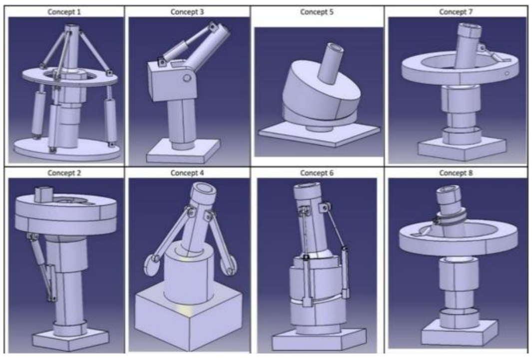

Fig. 5: Concept development

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

G. Concept Evaluation and Selection

Step 7 is to evaluate the different concepts using the VDI-2225 method. This method comes with an evaluation table shown in Fig. 6 and a validation table. The evaluation considers technical and economic aspects. For the niche products, the technical aspects are more important. When the evaluation is done, the method comes with an s diagram shown in Fig. 7, which shows the economical rating over the technical rating to show how balanced the concepts are developed. Just the best concept out of the evaluation table with a balanced development between technical and economic aspects can be chosen for the detailed design. Concept 8 is considered as the best concept with over 80% of all ratings. Also, the s value with 1.05 is close to 1 which validate this concept balanced development.

		Concepts							
Category	Parameter	C1	C2	C3	C4	C5	C6	C7	C8
technical	ease of design parts	2	3	4	2	1	1	4	3
	small size	2	2	4	1	3	1	2	3
	low balance point	2	1	2	3	4	2	3	3
	less parts	1	3	4	2	3	2	4	3
	less mass in movement	2	3	3	2	3	3	3	3
	rotation of a nozzle	1	2	2	4	2	4	2	4
	rotation axis tilt to center axis	4	3	2	3	3	3	3	3
	wobble movement	4	1	3	3	2	3	3	3
	the tilting can get switch on and off	4	3	3	1	2	1	3	3
	indipendency of both movements	4	4	1	4	2	4	2	4
	can handle load	4	4	3	4	3	4	3	3
economical	less actuators	1	4	3	3	3	3	3	3
	durability	3	3	4	2	2	1	2	3
	manufractable	3	4	4	3	3	3	4	4
results	technical average	2,73	2,64	2,82	2,64	2,55	2,55	2,91	3,18
	economical average	2,33	3,67	3,67	2,67	2,67	2,33	3,00	3,33
	average	2,64	2,86	3,00	2,64	2,57	2,50	2,93	3,21
	standard deviation of several ratings	1,17	0,99	0,93	0,97	0,73	1,12	0,70	0,41
	percentage	66,1	71,4	75,0	66,1	64,3	62,5	73,2	80,4
	rank	6	4	2	5	7	8	3	1

Fig. 6: Evaluation table

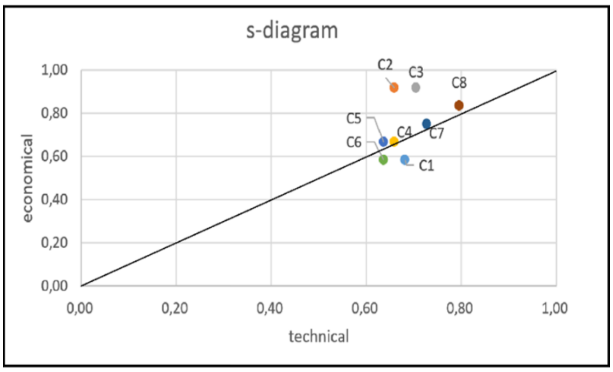

Fig. 7: S-diagram

H. Rough Design

Step 8 is rough sizing. Before it comes to the detailed design, the concept needs a rough sizing the proportions between several parts are quite easy to determine. But, for the rough size of the model, one significant part or link should be determined. This part a come from the morphological box or out of the list of requirements. This part will be the standard of the sizing of all parts of the model. The significant part of the dancing waternozzle is the fan, which is fully defined in the shortlisted morphological box. The type should be a Fan nozzle with a mount of G1.

I. Detailed Design

Step 9 is detailed design. This step is special because it has a loop until the model is considered as good. This step combines the structure of the concept with the rough sizing. The detailed design is based on a CAD tool. The aim of this step is to come out with a worked-out model which is complete defined in measurements and parts used. The detailed design phase is a multidisciplinary task which need good skills in iteration because some parts can affect each other. When a detailed design for a sub function is done, this maybe effect another sub function where some adjustments are needed now. The detailed design is shown in Fig. 8. When all sub functions are detailed and all needed adjustments are made, this model can get validated.

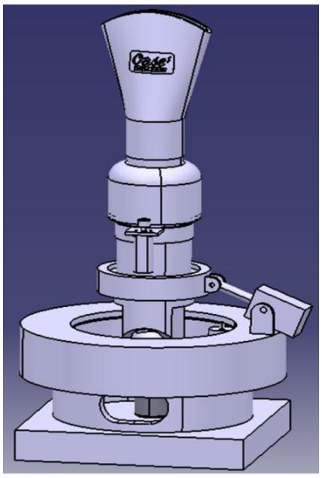

Fig. 8: Detailed model

J. FEA Validation

Step 10 is validation. For the validation, a FEA tool is used to validate the loads on the model. The loads are cause of the several movements and of forces of usage of the model. The FEA analysis should validate all critical sections of the model like joints and weak structures. When the validation is not successful the design focus is back on the detailed design to remove this failure. First, when the model passes the validation step it comes to the conclusion phase. The joint between the upper rotation plate and the rod of the solenoid is considered as critical. So, the FEA analysis of the dancing waternozzle is validating this section. The loads are from initiating the wobble dancing and the centrifugal force when the wobble speed is close to maximum. A momentum of 0.11Nm and a centrifugal force of max 15.8N is caused with considering water in the system. The FEA analysis shown in Fig. 9 that a change in material is need to make sure the rod will handle the loads. A maximum stress of 315N/mm2 can be critical when the material of that bought in parts not determined. Considering a safety value of 1.4, the material X20Cr13 (1.4021) because of its ability to withstand water without corrosion. It can handle a load of max. 460N/mm2 in the elastic limit.

K. Rapid Prototype

Step 11 is to produce a rapid prototype. The purpose of a rapid prototype was to shorten the time to market, but nowadays it becomes more a tool to generate small batches of a product [8]. The prototype has several purposes. It is an important role to find costumers or makes the communication easier between the different designers for

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

further development. The prototype is produced using Fused Deposition Modelling method. The design is slightly changed for that model with a scale of 1:2. The electrical motors and their mount are removed.

L. Performance Aanalysis and Product Improvement

Step 12 is the performance analysis. Here, the performance requirements of the list of requirements are checked and an improvement report is written. The model shows a successful combination of a rotation and a wobble movement which are independent from each other. But, the model is not able to fulfill all demanded. Speed of rotation of the nozzle is able to speed up to 228 rpm limited by the gear ration and the maximum speed of the motor. 250 rpm are required for the required demand.

IV. CONCLUSION

A gap has been identified in the niche of dancing waternozzles in the entertaining waterfountain sector. There is also no suitable design approach to generate a niche product in less time. This paper shows a systematic design approach on the example of the dancing waternozzle. Some design methods are used in that paper in a new way and it proves that it makes sense to give some methods a purpose in a design step where it is not been made for. The product of the dancing waternozzle was first specified before concept were developed in concept development phase. These steps were executed without spending much time into a survey. Eight concepts were generated to find the best matching the vdi 2225 evaluation table. It is evaluated by an expert and the best concept is chosen for detailed design. The detailed design was validated with FEA tools and a rapid prototype were produced.

This design approach shows how to close a gap in a niche in less time. This can be important to be the first company who have a niche product in their portfolio. This paper has proven that this systematic design approach works for closing a technology gap in a niche. This method is easy to apply without the need of a big knowledge in that specific niche. The approach is well structured and it is easy controllable in a design area.

REFERENCES

1. M. J. Yoo, and I. K. Lee, "Creating musical-fountain shows," IEEE Computer Graphics and Applications, 29(5), 2009, pp. 6-13.
2. S. Shakerin, "Water fountains blend art and engineering: A resource for engineering education," American Society for Engineering Education Annual Conference and Education, 2004, pp. 1-16.
3. N. Geren, Ç. Sarıgül, and M. Bayramoğlu, "Systematic mechanical design approach for a flexible printed circuit board assemblies (PCBA) rework cell: Part II–conceptual design of soldering and desoldering system," Soldering and Surface Mount Technology, 24(3), 2012, pp. 151-166.
4. G. Alexandridis, I. Symeonidou, D. Tzetzis, K. Kakoulis, and P. Kyratisis, "An integrated workflow of biomimetric design, material selection and computer aided engineering," Academic Journal of Manufacturing Engineering, 144(4), 2016, pp. 12-18.
5. Q. Ma, L. Meng, L. Song, P. Xue, M. Zhou, and Y. Wang, "A reuse method of mechanical product development knowledge based on CAD model semantic markup and retrieval," Academic Journal of Manufacturing Engineering, 16(1), 2018, pp. 11-18.
6. G. Pahl, and W. Beitz, Engineering design: A systematic approach. Berlin: Springer Science and Business Media, 2013.
7. J. D. Booker, R. Lock, S. Williamson, and J. F. Gómez, "Effective practices for the concept design of electromechanical systems," Journal of Engineering, Design and Technology, 14(3), 2016, pp. 489-506.
8. S. Graham, "Rapid prototyping: A key to fast tracking design to manufacture," Assembly Automation, 20(4), 2000, pp. 291-294.