Bulletin of the JSME Vol.12, No.2, 2018
Journal of Advanced Mechanical Design, Systems, and Manufacturing

A practical application for machine design education

Hüseyin R. BÖRKLÜ*, Nurullah YÜKSEL*, Kadir ÇAVDAR** and H. Kürşad SEZER*
*Department of Industrial Design Engineering, Gazi University, 06500 Ankara, Turkey
**Department of Mechanical Engineering, Uludag University, 16059 Bursa, Turkey
E-mail: kursadsezer@gazi.edu.tr

Received: 10 January 2018; Revised: 5 March 2018; Accepted: 26 March 2018

Abstract
Machine design is perhaps the most important course for Mechanical Engineering students. There are many diverse approaches to the design education in universities worldwide. This paper outlines some collaborative experiences for methodical design education in mechanical/industrial design engineering context at Turkish Universities. For this purpose, a case study based on a student project titled "the conceptual design of a new meatball forming machine" is utilized and the experiences of the conceptual design works made with project groups are presented. The design process outlined in this paper is based on the systematic design approach of Pahl and Beitz. The method applied includes problem definition, formulating (function diagram), creating and selecting of best design variants. The positive feedbacks received from student practices show that this work can be useful for industry followers, design lecturers and young engineers.

Keywords : Design education, Engineering design, Mechanical design, Methodical design, Teamwork

1. Introduction

Systematic engineering design of the technical systems has been dealt with by quite a few researchers. Pahl and Beitz's (1997) well-accepted comprehensive work on the topic has been widely used as basic teaching book for many years. Several similar publications in the open literature on theoretical and systematical design approaches including the Pahl&Beitz have been examined (Rodenacker (1991); Koller (1985); Roth (2000); Meerkamm and Hochmuth, 1998; Franke, 1985). In these publications, depending on the author's approach, it is possible to find systematic design themes such as the flow of the design work during the planning and design process, the suitable methods for designers, design with catalogues, and design with physical effect catalogues and so on. Such systematic design methods emphasize that the systematic workflow ensures the success better and quickly depending on the designer's experience, knowledge and intuition. On the other hand, the design approaches have been less accepted and used in industry because they take a long time to achieve the design goal, and are not easily applicable and understandable (Badke-Schaub et al. (2011); Tomiyama et al., 2009; Mayda and Choi, 2017). To facilitate the applicability of these approaches so as to benefit from their superiorities, it is suggested to share carefully and explicitly conducted real-time design projects in detail, and experiences along with their feedbacks for the communities including R&D activities and others. To that end, in this paper, it is presented to examine the effects and results of such approaches used in the methodical design lectures. To find out the candidate engineer's knowledge and experiences, a case study based on a student project in the methodical design lecture has been developed. Creative ideas for new products facilitating of human life and more cost-effective, also friendlier for the customers are also within the scope this work. To demonstrate the steps in the design practice, the sample student project; "conceptual design of a meatball forming machine" with the main requirements of "ergonomic and cost effective design" is presented. This design assignment is a sample of the various projects of the lectures "methodical and systematical design" in the mechanical engineering department of Uludag University and the industrial design department of Gazi University in Turkey. Such project based learning and teaching, in principle, aims that the candidate engineers will learn the possibilities and also complications of the team work in a quasi-real design environment.

The paper is organized as follows: Section 2 briefly introduces the current design methodologies. Sect. 3 details the methodical design course in the mechanical engineering or industrial design departments of Uludag/Gazi Universities in Turkey, and a conceptual design application implemented are given. Sect. 4 and 5 presents conclusively the observed design experiences and feedbacks in the case study.

Paper No.18-00019
[DOI: 10.1299/jamdsm.2018jamdsm0036]
© 2018 The Japan Society of Mechanical Engineers

2. Design Methodologies

Design methodology is closely linked with design theory as the latter is about how to model and understand design, and the design methodology is about how to design or how design should be. Among the famous design methodology books, Table 1 compares Axiomatic Design of Suh, Total Design of Pugh, Mechanical Design Process of Ullman and Systematic Design of Pahl and Beitz by Tomiyama et al. (2009). Although it is not possible to indicate the best, the decision and choice depends on the application and designer's skill and experiences. Of the design approaches, we used systematic design of Pahl&Beitz as it is successfully used as teaching material and easy to learn and teach in undergraduate level courses.

Table 1 Comparison of design methodologies - adapted from (Tomiyama et al. 2009).

Design methods	Axiomatic design (Suh)	Total design (Pugh)	Mech. design process (Ullman)	Systematic design (Pahl and Beitz)
Advantages / Education	Theoretical and systematic good for graduate schools	Simple, no need for training	Used and tested in design courses	Successful teaching worldwide. Covers major topics in design
Advantages / Practice	Applicable for all designs. Design examples with analysis tools	Easy use and usefulness proven by practitioners	Tested for relatively simple designs	Tested for relatively simple designs
Disadvantages	Not widely used by academic world. Complex and difficult to learn.	Has not been updated and developed in the last decade.	Industrially not widely accepted	Can be misused. Requires long time to apply by new users.

The conceptual design stage of the design process is concerned with synthesis, which The Concise Oxford Dictionary defines as: "Combination, composition, putting together (opp. to analysis), building up of separate elements, especially of conception or propositions or facts, into a connected whole, especially a theory or system" by Pugh (1991). The flow of conceptual design phase suggested by Ullman (1991) is given in Figure 1. The generation of concepts is iterative with this evaluation. Here, there are two general approaches: functional decomposition and generating concepts from functions.

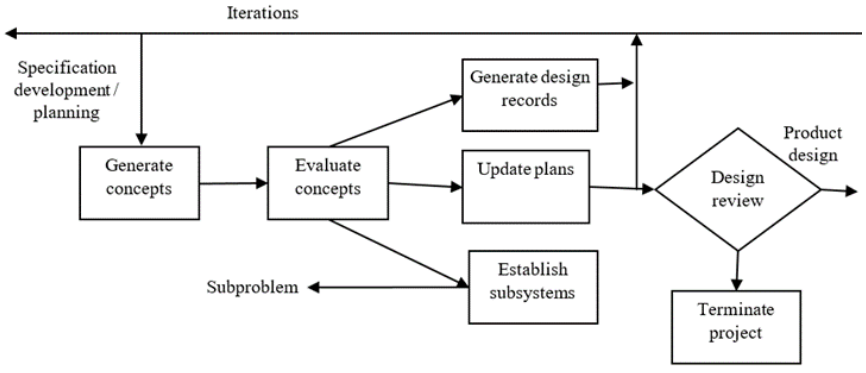


Fig. 1 The conceptual design phase of the design process by Ullman (1992)

French's ten design guidelines that are obtained from his extensive experience and study was given by Dieter (1991). Among the others, these guidelines include rules such as avoiding arbitrary decisions, searching for alternatives, applying abstraction, aiming for clarity of the functions etc. Another rule suggested is to complement: "Think always ergonomic and economic design rules in all steps". It is also relevant to mention here that all these design methodologies must be augmented with creativity that we believe is a crucial ability of the designer. According to Luppicini (2003), creativity in

[DOI: 10.1299/jamdsm.2018jamdsm0036]
© 2018 The Japan Society of Mechanical Engineers

design is also viewed in relation to the design knowledge and the challenge of articulating design knowledge and designers' judgment in procedural terms. From our observations throughout the project, generally, the students are not aware of their creativity. Hence, the lecturers involved in the design education projects had to give a trigger effect to the students.

3. The Case Study: Conceptual Design of Innovative Meatball Forming Machine

By using the techniques educated in "a methodical design course" in the mechanical engineering or industrial design departments of Uludag and Gazi Universities in Turkey, a total of 8 student groups each consisting of 4 or 5 of the candidate engineers carried out various design projects. Each group is given a separate project theme and they are asked to use principles of the methodic design teaching and formulate their designs by producing solution proposals. Comparative results evaluated by the experience of the teachers and the results are critically discussed. Also noted here that a further work is in progress with questionnaires and manufacturing the designs of each group, through which sizable statically information can be generated for more objective evaluations. Detailed market research and cost analyses have also been conducted by each group. The design processes featured ergonomic and cost effective aspects. Each project output has been presented and after all the presentations, a public survey is performed to select the best project which has been presented below.

In this section, the conceptual design of a new and innovative meatball forming machine, which the students involved in the project prepare using the general approach taught, will be introduced to illustrate the systematic design work steps with an example. Various other projects have also been carried out to see the implementation of design methods with different project groups. These projects include; motor scythe, olive harvesting machine, shaving machine, special service tool etc. As the goal here is to see the positive aspects as well as the deficits of the method through the application, rather than giving full details on other projects, emphasis was given to the experiences gained with one selected exemplary project. The study, which is carried out after defining the problem in detail, consists of eight steps as outlined by the authors previous work in Börklü (2010) and, Mayda and Börklü (2014):

1. Clarifying the task and defining the problem (state of the art)
2. Setting up a requirements list
3. Establishing the function structure
4. Searching for and combining working principles
5. Selecting suitable combinations (first evaluation)
6. Firming up into principle solution variants
7. Additional selection procedures (second and third evaluations)
8. Evaluation and final decision

Especially in big food industries, a variety of meatball making machines are used for fast production. These machines can make dumplings as desired according to their needs, and there are types with and without mixing reservoirs (materials ready area). In addition, care must be paid to the hygiene rules of these machines. The operations on these machines must be done manually or automatically.

This study covers the conceptual design of a new meatball forming machine to be used in industrial kitchens, and the methodical design philosophy shall be used in the study.

3.1 First step: Clarifying the task and defining the problem

The developments in the field of science and technology in the last century have continued at a dizzying pace. After the industrial revolution; there have been major developments in such fields as motor vehicles and transportation, electronics, nuclear, aerospace and aviation, information and communication, defense, manufacturing and materials, genetics, medicine, nanotechnology, 3D printer and so on (Bunch et al. 2004).

Meatballs of various kinds and specifications occupy a very important place in Turkish and World cuisines. There are many kinds of local dumplings such as Akcaabat, Inegol, Adana, Izmir, Sivas, Tekirdag, Kadinbudu, Balaban, Firinda,

[DOI: 10.1299/jamdsm.2018jamdsm0036]
© 2018 The Japan Society of Mechanical Engineers

Roast, Potato, Watery (Misket, Lump). These can be made with raw and stuffed meatballs. Some examples of meatballs from the world cuisine may include; Italian, Japanese (Tsukune), American sauce, Swedish, Spanish, Polish, Dutch, Bangladesh, etc. In fact, one of the most common/famous dishes of the whole Middle Eastern region is actually two other original examples of the world's meatballs: American Hamburgers and Indonesian Meatballs (Bakso). The main ingredient of the meatball is; red meat, chicken, vegetables, or a mixture of these (and even fish). The types of cooking are the barbecue, frying, boiling, and the like. Here we will focus on the meatballs, which are generally referred to as butcher or meat (or street) meatball.

Making traditional meatballs is a difficult and time-consuming process. It is usually done by ladies at home. As material; mince (from red meat), stale bread crumbs, onion, garlic, salt and various spices are used. The operations are mixing of these materials at certain rates, kneading until proper consistency, and small parting as balls, and shaping. In the case of production big party meatballs, many employees must work in restaurants. There may be some problems with the desired meat quality and hygiene conditions. In addition, the demanded or required amount of meatballs cannot be produced in time and there is a need for automation in the production of meatballs especially in large establishments where demand and consumption are high for all these and similar reasons. Some meatball forming machines and meatball preparation equipment can be found on the market. However, these machines are not original designs, they are adapted from hamburger making machines. Therefore, it is very important to make a meatball-making machine that can be designed in new, innovative, original, modular and various sizes/types. This new machine which will introduce conceptual design within the scope of this paper will not only make the meatballs (shaping) but also provide automation for the meatball preparation.

3.2 Setting up a requirements list

A sample requirements list (design specifications) prepared for the conceptual design of the meatball making machine is given in Table 2. The meatball forming machine to be designed according to this list which has many items such as geometric sizes, working speed, functioning properly, energy source, protection of the meatballs from adverse effects, hygiene, maintenance, and costs. There is often a need for the conceptual design process and, if necessary, these needs can be flexed/modified depending on the development of the design. The requirements in the need list are arranged as Demands and Wishes (W) as noted by Pahl and Beitz (1997). These needs must be met absolutely by the design solutions and the desires must also be met to the extent that technological and economic conditions permit.

Table 2 The requirements list for the sample design project (W: Wishes).

No	Requirements list for a meatball forming machine (as Demands or Wishes)
1	The machine's weight ≤ 30 kg, height ≤ 1 m and floor area ≤ 0.8 m^2
2	The machine must be easy to set up and fix.
3	The machine must produce at least 90 meatballs per minute.
4	(W) Must have adjustable speed and with a 3-speed system.
5	(W) The machine should work with minimum energy requirement.
6	(W) An emergency button should stop the system.
7	The system must work with electrical energy.
8	Body aluminum, carrier system should be made from composite material.
9	(W) System can be stopped with an emergency button.
10	The parts that come in contact with the meatball must be covered with a protective material against possible harmful effects.
11	(W) The machine can be easily cleaned and its parts are not affected by water.
12	(W) The temperature of meatball, etc. could be measured.
13	(W) The machine must be easy to use and must be controlled by a computer.
14	It should contain standard parts and be easy to produce.
15	(W) Mixing wings must be changed every 2 years.
16	The production cost should be ≤ $5000/machine for 100 machine/month.
17	……

[DOI: 10.1299/jamdsm.2018jamdsm0036]
© 2018 The Japan Society of Mechanical Engineers

3.3 Establishing the function structure

In technical systems, function is a relation between input(s) and output(s) according to Pahl and Beitz (1997). Throughout the system (system-wide) the system components (sub-systems) can be divided into functions. The overall function of this process is to bring the meatballs to the desired shape and size. To fulfil this overall function, sub-functions like “turn on energy, check the system, mix/knead meatballs, filler shape, cut the meatballs, pack, and store, separate the faulty products” are needed. A sample function structure for the meatball forming machine according to the requirements list given in Table 2 is shown in Figure 2.

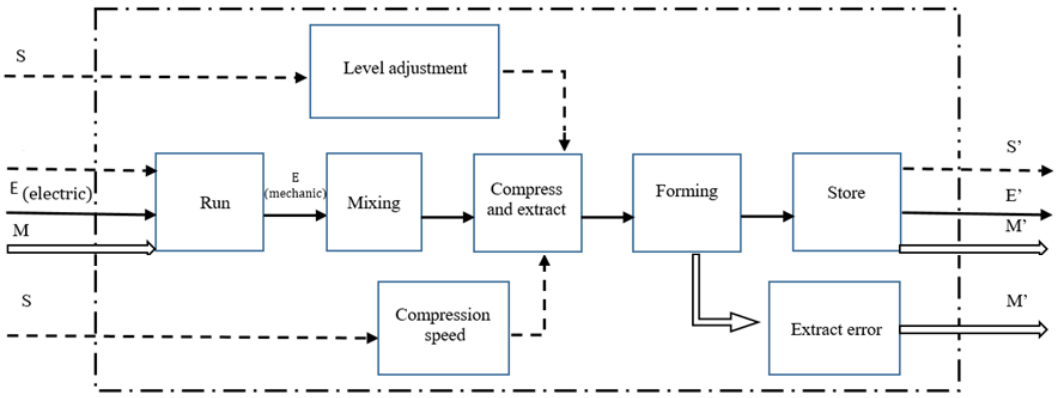


Fig. 2 Function structure for meatball forming machine (E: Energy, S: Signal, M: Material)

3.4 Searching for and combining the working principles

In this stage, the important sub-functions in the function structure shown in Figure 2 are selected and placed in the first column of a matrix. Sub-designs are obtained according to their possible solutions (with morphological matrix). In other words, the problem is first divided into sub-functions (small functional blocks), solutions are searched for, and alternative solutions of the whole system (variants) are obtained with various combinations of sub solutions as in Pahl and Beitz (1997). At this process, the adaptation of the sub-solutions and the flow of E, S, M must also be observed.

The energy required for the meatball forming machine has been determined as muscle strength along with the mechanical energy derived from electrical energy, but these options can be further increased. The control unit, wired remote control, and manual control options are also selected for system control. Preparation of meat mixture is also a very important step in making meatballs. In this study, it was assumed that the mix was ready before the process of shaping the meatballs in the machine. On the other hand, making mince with industrial machines saves time and energy. In this process, a mixer or a rammer is used. There are also another options for shaping meatballs. Of these methods, the ones most suitable for preparing food were selected in the project. Once the mince is packed in a closed container, they can be removed in a suitable manner and shaped to the desired shape. In addition, with the modular output forms, meatball shapes and sizes can be changed. The unwanted forms should be sorted out, and the appropriate ones should be packaged and continued to the production process. This can be done by the machine operator. If automation is desired, robotic arms, guides and special conveyors can also be used. The design variants obtained by the appropriate / harmonized combination of the sub-solutions in the morphological matrix in Table 3 are shown in Table 4.

3.5 Selecting suitable combinations (first evaluation)

Up to this stage in the conceptual design project of the meatball forming machine, the requirements list (problem definition), function diagram (design form and small sub-functional parts), morphological matrix (sub component solutions and combination variants) have been prepared. Thus, five different alternative design solutions (variants) for the whole system are presented in Table 4. These alternative solutions are the most suitable design variants for the meatball machine. But among these, it is necessary to evaluate these solutions according to some criteria to find the

[DOI: 10.1299/jamdsm.2018jamdsm0036]
© 2018 The Japan Society of Mechanical Engineers

optimum design as noted by Pahl and Beitz (1997). For this purpose, the selection chart method was used and three design variants were chosen which were the most suitable for the optimal solution and the other two variants were eliminated. The use of selection chart for the sample design is shown in Figure 3.

Table 3 The morphological matrix of the meatball forming machine (sub-design solutions).

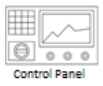
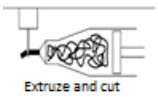
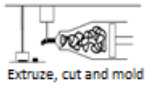
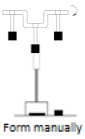
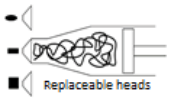
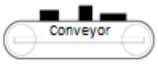
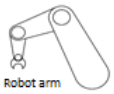
No	FUNCTIONS ↓ SOLUTIONS →	1	2	3	4
1	Energy conversion	Ω Electric Motor			
2	System control	 Control Panel	 Manually	Control	
3	Mixture the meatball mice		 BLENDER	Knobbing	
4	Forming and cutting of the meatballs	 Extruze and cut	 Extruze, cut and mold	 Form manually	 Replaceable heads
5	Package and storage	 Conveyor	 Manually set	 Robot arm	
6	Debug of the mistakes	OPERATOR DEBUG	MACHINE DEBUG		

Table 4 The design variants obtained by the appropriate / harmonized combination of the sub-solutions.

Variant 1	Variant 2	Variant 3	Variant 4	Variant 5
1.2 - 2.2 - 3.2 - 4.3 - 5.2 - 6.1	1.1 - 2.3 - 3.1 - 4.4 - 5.1 - 6.1	1.1 - 2.1 - 3.2 - 4.1 - 5.3 - 6.2	1.1 - 2.1 - 3.3 - 4.4 - 5.1 - 6.2	1.1 - 2.1 - 3.2 - 4.2 - 5.1 - 6.2

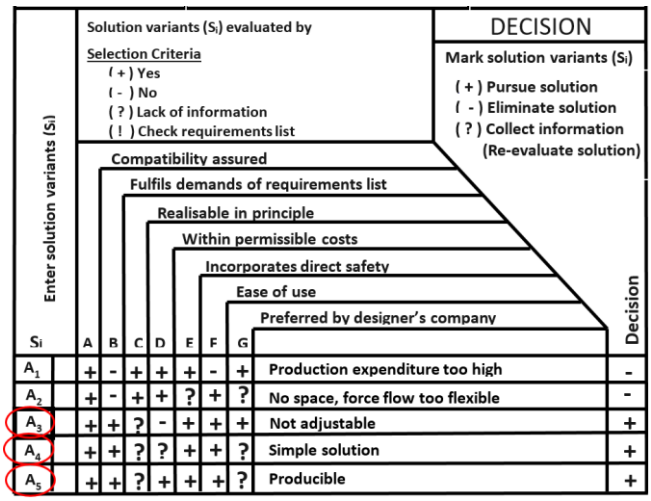


Fig. 3 The use of selection chart for the pre-evaluation of meatball forming machine

[DOI: 10.1299/jamdsm.2018jamdsm0036]
© 2018 The Japan Society of Mechanical Engineers

3.6 Firming up into principle solution variants

The five conceptual design variants were replaced to three relatively good and promising concepts with the preliminary evaluation process seen in Figure 3, and the rough schematic representations of these design variants were presented in Figure 4. The solution shown in Figure 4.a (Variant 3) had important feature distinguishing from the others is the use of a robot arm for packaging and storage. This robot arm can also be used here for the separation of faulty products. In the alternative design shown in Figure 4.b (Variant 4), the system uses the rams connected to the eccentric shaft to mix of the mince. The desired form can also be given to the meatballs with the changeable extruder heads.

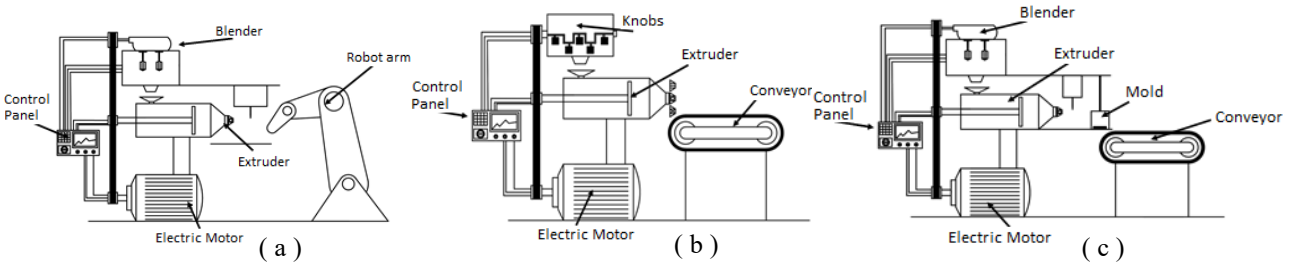


Fig. 4 Conceptual design variants obtained: (a) Variant 3 with a robotic arm and a blender, (b) Variant 4 uses knobs and a conveyor belt, (c) Variant 5 uses a mould and a conveyor belt

Finally, the system connected to the control unit shown in Figure 4.c (Variant 5) uses a blender to mix the ingredients. The product from the extruder is compacted in suitable moulds and brought to the desired form.

3.7 Additional selection procedures

In the “preliminary evaluation” section, five different design variants were created and then reduced to three. However, the number of design variants presented for the designer to continue designing is still too high, the designer must reduce the number of alternative designs to one, namely the better/optimal design should be select between these design variants. The method called additional selection operations is used for this purpose. The additional selection operations include two sub-methods:

1. Objectives tree (designing/implementing the criteria and significance of the design)
2. Value profile diagram (provision of criteria with a balanced distribution)

With these selection operations, the three available design variants are first reduced to two, and next, that is, the best design is determined. The objectives shown in Figure 5 are to arrange the criteria weight for evaluating the design of the meatball forming machine more precisely and to determine their significance level. Each objective in the tree has a weight value (percentage). These weight values are determined by considering the hierarchical structure. At the top, the full value (1 or 100) is taken for the whole system. In a sub-step, this whole value is shared among the other criteria and this process continues until the lowest step. At the lowest level, the sum of the criterion values should be equal to1 (or 100).

After the process of setting and weighing the criteria to be used in evaluating the design with the objectives tree, they are transformed into some parameters (that is, expressed in technical terms). Also, if possible, the units associated with parameters should be specified. After that, a scoring and evaluation should be done for the last three design variants according to these parameters (Table 5). Finally, the design with the least points from these three variants (Variant 3) is eliminated and the other 2 (Design Variants 4 and 5) are transferred to the next stage.

[DOI: 10.1299/jamdsm.2018jamdsm0036]
© 2018 The Japan Society of Mechanical Engineers

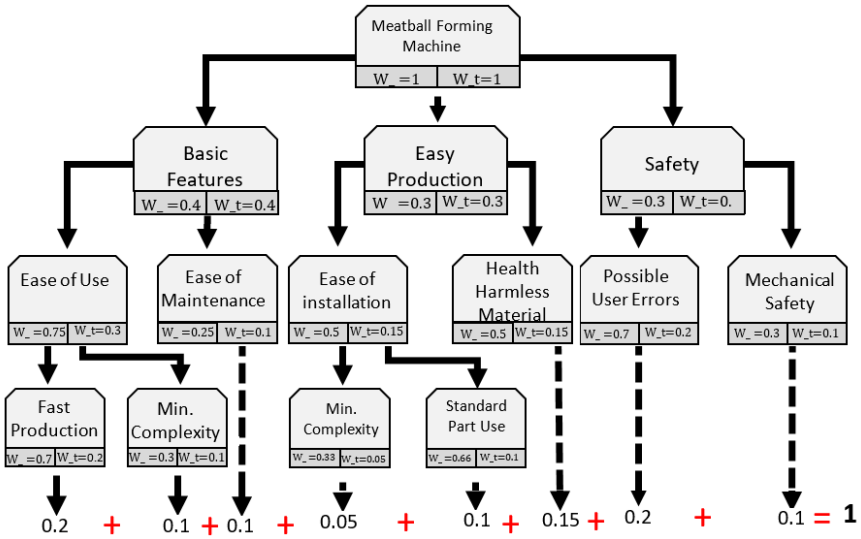


Fig. 5 Objectives tree for the meatball forming machine (W_: Weight value, W_t: Evaluation criteria numbers)

Table 5 Evaluation of the three principle solution variants for the meatball forming machine.

Evaluation chart				Variant 3			Variant 4			Variant 5		
	Evaluation criteria	W	Parameters	Objective level	Rate	W	Objective level	Rate	W	Objective level	Rate	W
1	Fast production	0.2	Produced meatballs	average	5	1.0	average	6	1.2	average	7	1.4
2	Ease of control	0.1	Complexity	more	8	0.8	average	7	0.7	more	8	0.8
3	Ease of maintenance	0.1	System regulation	average	7	0.7	average	5	0.5	average	7	0.7
4	Minimum complexity	0.05	System complexity	few	5	0.25	average	6	0.3	more	8	0.4
5	Standard part use	0.1	Standard parts	average	7	0.7	average	7	0.7	average	7	0.7
6	Health harmless material	0.15	Ease of production	average	6	0.9	average	7	1.05	average	5	0.75
7	Possible user error	0.2	Potential errors	more	8	1.6	average	7	1.6	more	8	1.6
8	Mechanical safety	0.1	Safety	average	6	0.6	average	6	0.6	average	6	0.6
		∑Wt=1			∑d3=52	∑Ad3=6.55		∑d4=51	∑Ad4=6.65		∑d5=56	∑Ad5=6.95

The best design should be chosen from between the last 2 design variants. While making this selection, the methods "objectives tree" and the "evaluation chart" are used. In all of the previous evaluation and selection processes, the variants 4 and 5, which receive the best scores, are now investigated to balance the design criteria. For this purpose, a graph called value profile diagram (see Figure 6) is used. Here, the rectangle thicknesses generated for both variants indicate the weight of the criterion (percent ratio) and the length of each variant from this criterion. The areas with visible angled lines are poorly handled, and those with too many fields (Variant 4) are eliminated. As a result of all these processes, the best/optimum conceptual design of the meatball forming machine is defined an alternative design (5). This selected conceptual design (Variant 5) will be used in the next detail design phase.

[DOI: 10.1299/jamdsm.2018jamdsm0036]
© 2018 The Japan Society of Mechanical Engineers

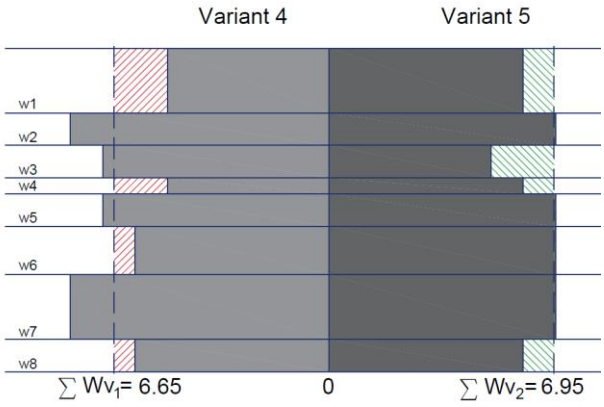


Fig. 6 Value profile diagram for the detection of weak spots

3.8 Evaluation and final decision

As a result of the evaluation and selection process, the design variant 5 was chosen as the best meatball forming machine design (Fig. 7). Since this is an exemplary design and the objective and focus here is to give the experience gained in the practice of the method, and then to present various proposals for improvement, other alternative designs (variants) are not given in this figure. This system conveys the mixing tank and the extruder through the electric motor and the moving belt cam mechanism. After mixing with the mince, the mince is transferred to the extruder. Here, the meatballs are pressed in the desired form. The rotary blades at the exit of the extruder cut the meatballs to the appropriate size and immediately drops on the conveyor. The conveyor carries the meatball, and stores it in containers.

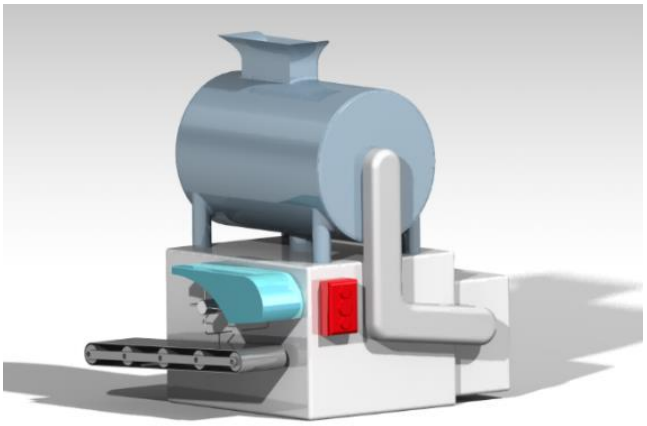


Fig. 7 Final selected conceptual design (Variant 5)

4. Brief Remarks

The conceptual design process begins with a requirements list definition and ends with a solution that will meet the requirements (the best variant). If the design variants are too many, the optimal solution is achieved by applying a selection process. Conceptual design aims to obtain creative, optimum and accurate solutions. It divides the problem into smaller pieces and develops solutions for them. By abstracting, different creative solutions are suggested from existing solutions. Among these solutions (variants), the most valuable are selected using evaluation methods (selection chart, goal tree, value profile graph, etc.).

In this study, a set of project work done within the framework of the methodical design course, the steps of the

[DOI: 10.1299/jamdsm.2018jamdsm0036]
© 2018 The Japan Society of Mechanical Engineers

conceptual design of an innovative meatball forming machine are explained. These steps can also be used in the design of many different machines. The features and needs of the meatball forming machine are listed in the table (Table 1). The design was developed under the guidance of these requirements. Accurate identification of needs will greatly contribute to achieving the ideal solution. The most important parameters for the meatball forming machine are production speed, production cost, production quantity, ergonomics and easy maintenance. By abstraction, basic functions and sub functions are determined. A solution for each sub function has been developed. For example; three options have been selected to control the system. These; control panel, control, and manual control. It is aimed to find creative solution options by combining the solution with a proposed morphological matrix. Using this matrix, suitable options (design variants) for the meatball forming machine were determined and evaluated. Solution options; to follow the needs list and the basic function, the "selection chart" is evaluated with the evaluation chart and evaluation profile and the ideal solution (the best variant) is reached.

Design of a new machine following the suggested steps in the field of methodical design science through a sample project, given in this article, explored the steps of the methodical design teaching, and identified the gaps in implementation at the same time. For example; it has been found that the criticism that the method is time consuming is irrelevant as the total time spent throughout the process is actually reduced due to the reduction of the redesign requirements. The influence of the designer's creativity and experience in the discovery of design alternatives is still among missing topics. New method proposals are needed in this regard. For example, the use of design catalogs suggested by Roth in adapting the TRIZ methodology to the methodical design teaching or proposing alternative solutions may be suggested in terms of supporting the designer. In the process of choosing the optimal design using the weight factors of the designs, the designer's experience is also at the foreground in determining the weight factors. It is impossible for an inexperienced designer to determine the appropriate weight factor value at this stage. Studies with explanations of how these numbers (values) are determined, and giving weight factors in various sample systems are urgently needed.

5. The experiences and conclusions

Some difficulties in the lecture of the methodical design, and the experiences acquired in last ten years are abstracted below:

1. Member quantity of the groups must be less than six. Five group members are ideal. Every group must be self-constituted; therefore, this brings efficiency and competence in teamwork. The selection of the group's leader is also very important. Some groups changed their leaders and were ineffectual. In the beginning of the work, the lecturer must explain the decision making processes for team members and the frame of the group democracy.
2. The level of the group projects must be equal. If not, groups are working ineffectively and this brings the small opinion conflicts. On the other hand, candidate engineers are also learning competition.
3. If the groups can determine theirs project themes by themselves, more efficient and creative ideas were observed. To select the project themes, the lecturer compression is affected the team members negatively.
4. A few undisciplined affairs have been experienced during the design projects, too. Some team members wanted to achieve good marks without effort and an expulsion for these students was planned and made.
5. All group members must talk in the workshops. Keeping quiet is not allowable. These technical workshops are very likely the first experience of candidate engineers. Hence, all group members must share this experience. Students may feel many, intensive fear and emotions in presentations, but after the workshops, everyone says that they won many experiences via presentations, they saw that they could do it!
6. Students named that some lecture materials are given late. However, the lectures are an obligation, because the projects must continue parallel with the lecture. This team works is being very well for the student's creativity. Hence, they can also learn to check their future ideas and behaviors.
7. This project work provides new chances for candidate engineers, before their future professional life. Team work is reassured to students because they have seen that they can achieve it!

[DOI: 10.1299/jamdsm.2018jamdsm0036]
© 2018 The Japan Society of Mechanical Engineers

8. Three weeks after the beginning of the team work, the meetings of lecturer and group's leaders were inefficient. A leader clarified a cause that "the creative ideas are stolen in these meetings; he will meet one to one with the lecturer". After this feedback, the meetings were made one to one without period constraints. However, this application is also no good idea, because some leaders meet with lecturer much more and then creativity which we give much importance, is dying! Hence, the lecturer must not be the approver, before the last step of the work!
9. According to the inquiries made in last three years, 90% of the students are satisfied with projects and their results. Manufacturing phase is generally cited as the most difficult and challenging part leading to deficiency of team work.

References

Badke-Schaub P., Daalhuizen J., Roozenburg N., Towards a designer-centred methodology: descriptive considerations and prescriptive reflections, The future of design methodology (2011). London: Springer, pp 181–197.

Börklü, H.R., Engineering Design: Systematic Approach (in Turkish) (2010), Ankara: Hatiboğlu Yayınları.

Bunch, B. and Hellemas, A., The History of Science and Technology (2004), Boston: Hou. Mifflin Com.

Dieter, G.E., Engineering Design (1991). McGraw-Hill Inc.

Franke, H.-J. Construction methodology and design practice-a critical consideration (in German) (1985), 3rd Int. Con. on Eng. Design (ICED'85) (1985), Zurich: Heurista, pp. 910-924.

Koller, R., Design theory for mechanical engineering (in German) (1985), Berlin: Springer.

Luppicini R., Reflective Action Instructional Design (RAID): A Designer's Aid, Int. J of Tech. and Design Education, Vol 13 (2003), pp 75–82.

Mayda, M. and S.-K. Choi, A reliability-based design framework for early stages of design process, Journal of the Brazilian Society of Mechanical Sciences and Engineering, Vol 39, No 6 (2017), pp 2105-2120.

Mayda, M., and Börklü, H.R., Development of an innovative conceptual design process by using Pahl and Beitz's systematic design, TRIZ and QFD, J. of Advanced Mech. Design, Systems, and Manufacturing, Vol 8, No 3 (2014)

Meerkamm, H., and Hochmuth, R., Integrated Product Development based on the Design System mfk., Proceedings of the 5th International Design Conference, (1998), Dubrovnik, 31-38.

Pahl, G., and Beitz, W., Engineering Design (in German) (1997), Berlin: Springer.

Pugh, S., Total Design: Integrated Methods for Successful Product Engineering (1991), Addison-Wesley.

Rodenacker, W. G., Methodical construction (in German) (1991), Berlin: Springer.

Roth, K., Construct with design catalogs Volume 1: Design theory (in German) (2000), Heidelberg: Springer.

Tomiyama T., Gu P., Jin Y., Lutters D., Kind C., Kimura F., Design methodologies: industrial and educational applications, CIRP Ann Manuf Technol, Vol. 58, No 2 (2009), pp. 543–565.

Ullman, D.G., The Mechanical Design Process (1991). McGraw-Hill Inc.

[DOI: 10.1299/jamdsm.2018jamdsm0036]
© 2018 The Japan Society of Mechanical Engineers