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Application of Concurrent Design Strategy on the Design of Multifunction Hydrotherapy Bucket †

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Abstract: This study employs a systematic concurrent design approach to achieve product outcomes. It involves market research and analysis of products from various manufacturers. Through functional analysis and problem identification, TRIZ theory and a morphological diagram method are utilized for finding solutions. The best design scheme is then determined using the PUGH method. Additionally, a 3D model is created to present the concept that meets design goals, aiding the development of related products and boosting market share for home hydrotherapy buckets.

Keywords: concurrent design; morphological diagram method; PUGH method; TRIZ theory

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1. Introduction

Rehabilitation is undoubtedly a difficult road for patients with physical disabilities or limb injuries. Regularly going to institutions for rehabilitation has become routine. Therefore, when operating cold rehabilitation equipment and the arduous rehabilitation process, they often feel uncomfortable. As Kim opinions [1], the fundamental principle of a human-centered design is premised on maintaining dignity. Therefore, when designing this functional physiotherapy rehabilitation equipment, the primary consideration is the user's psychological feelings. A successful product should be able to solve consumers' problems, or bring a more convenient life to the public, so designers and planners must identify problems and implement effective solutions when designing products and strive to develop solutions that can bring consumers high-quality products with different benefits [2]. At present, most of the multi-functional rehabilitation hydrotherapy pools provided by rehabilitation institutions are large-sized products used by many people, while personal rehabilitation hydrotherapy buckets take up little space but often have a single function. Considering that users may not be able to afford the huge cost of large-sized products and may not have sufficient space, this design case reduces the size of the multi-functional hydrotherapy bucket and modulates it for home use. In this way, the burden on the body, movement, and use of the rehabilitated person can be effectively reduced. At the same time, the developability and popularity of the product can be considered, and production costs and product size can be reduced as much as possible to benefit more users and enable them to perform personal rehabilitation with dignity. According to Cooper and Kleinschmidt [3], key factors for the success of a product to be launched are the design of the product itself, the characteristics of the product, the production methods, techniques aimed at producing a quality product, the implementation of collaborative production and design, and the benefits that the product brings to the user. In addition, a good product should carefully evaluate every detail during the development phase. Therefore, to study the competitiveness of products, we should start with the market performance, analyze the direct factors such as cost, price and quality, and then analyze the indirect factors

such as resources, materials, capital and technology, and finally, find the specific reasons and ways to improve competitiveness. In this study, a concurrent design strategy was used as the main approach for the multifunctional hydrotherapy bucket, and different research methods were used to analyze and propose solutions for each problem in a clear box process, in the hope that the selected design solutions could effectively improve the problematic points of the product.

2. Background

2.1. Hydrotherapy

Lynda Huey, a Santa Monica, Calif.-based kinesiologist and sports trainer, considers that the 1970s were dominated by running and the 1980s by aerobics, but the 1990s belong to water exercise [4]. "Swimming is no longer the only form of activity for the water", says Huey. In fact, aquatic fitness has become popular because of the publication of "Deep Water Exercise for Health and Fitness". Author Glenn McWaters is a former Marine combat helicopter pilot who tried walking in water using a flotation belt while recovering from a thigh wound sustained in Vietnam [5]. He considers that deep-water running can improve exercise efficiency, because the resistance encountered in water movement is 12 times that of air movement. "A 20-min workout in the water is the equivalent of a 30- to 35-min workout on land", McWaters explains. Aquatic fitness was initially used in injured athletes but has since been applied to other patient users in orthopedics, rheumatology, and cardiology. This kind of program usually focuses on improving aerobic capacity, and the principles of traditional hydrotherapy are used to increase the difficulty of walking in water. Therefore, Aqua jogging has popped up, with programs covering many different aquatic fitness exercises, such as shallow water walking, aqua-aerobic, aqua-steps, aqua-nastics, hydrorobics, hydropower, and aqua-dynamics. The greatest advantage of rehabilitation in a hydrotherapy pool is that users are not afraid of falling, and reducing fear will help arouse their willingness to complete activities. Many experts in the field of rehabilitation believe that changes in the motor skills of the user can be seen when balance training in water, and if balance training in a hydrotherapy pool is effective, the chances of successful rehabilitation on land will increase; this argument is also confirmed in clinical research [6]. In addition, "Coaches found that athletes were coming out of rehabilitation in better shape than before they were injured", says Ruth Sova [7], president of the Aquatic Exercise Association in Port Washington, Wis., a research organization for professionals in aquatic fitness and therapy. Hence, we know that running in water and many other aquatic exercises trace their roots in therapy. In addition, there are several advantages of using hydrotherapy: improved movement ability by increasing joint range of motion and relaxation; use of an easy and simple method to strengthen weak muscles; movement can be performed with less force; low mechanical shock enhances cardiovascular endurance; stability, equilibrium, and adequate balance reactions can be facilitated; increased proprioceptive and exteroceptive input; reduced subjective complaints, such as shoulder pain, motivation and self-esteem can be increased; and body image can be improved [8]. To sum up, aquatic fitness in a hydrotherapy pool can provide a pleasurable and enjoyable situation for users and can encourage them to be active, reduce the distraction of rehabilitation on dry land, and at the same time, have substantial benefits for physical rehabilitation.

2.2. Lifestyle Change

Due to the large-scale spread of the Coronavirus Disease (COVID-19), many countries have created policies and legislation to reduce social interaction and curb the massive spread of this pandemic disease. Governments in most countries have imposed a blockade on all non-essential infrastructure. These rules include closing sports clubs, fitness centers, and community sports fields. Additionally, social gatherings of more than two people are banned, further limiting opportunities to exercise and exercise together. Therefore, many people have replaced organized physical activity with individual home-based workouts. Home-based workouts are definitely an easier and time-saving approach for those who al-

ready have the required equipment. They are able to continue exercising without assistance and instructions in this situation, but adequate space at home is necessary [9]. From this, it can be seen that if we want to design a home-type multifunctional hydrotherapy bucket, how to reduce storage space is also one of the key points that must be considered. Some experts even suggest people can take online exercise classes and use video- or app-guided aerobics training at home, because there are many useful workout videos available that can assist people in exercising on their own [10].

3. Materials and Methods

This research uses a concurrent design to solve the black box problem in design, and considers the practicality of the multi-functional hydrotherapy bucket, the storage capacity of household types, and safety during exercise. This research constructs a systematic, efficient, and fair design process.

3.1. Objectives Tree Method

The objectives tree method can effectively help designers to clarify the main objectives of the design and effectively organize consumer needs to make the design process more fluid. In addition, the ambiguity between consumers and the design team is minimized. The objectives tree method is presented in a graphical format so that the interrelationship between design goals and secondary goals is clearly presented [11].

3.2. TRIZ Theory

TRIZ is a combination of the initials of the Russian word "Teoriya Resheniya Izobreatatelskikh Zadatch", proposed by Soviet engineer Altshuller in 1946. TRIZ theory stands for "Theory of Inventive Problem Solving"; its English translation is "Theory of Inventive Problem Solving". The principle is that inventions should be universal and that certain principles inherent in creative inventions are usually the same or similar. Therefore, Altshuller uses these assumptions as the basis of TRIZ theory and integrates these principles. TRIZ theory compiles and summarizes 39 engineering parameters and 40 principles for solving inventive problems, and emphasizes that inventions or innovations can be made in accordance with certain procedures and steps [12]. As a result, TRIZ theory is regarded as a comprehensive, systematic solution to the problem of the invention and realization of technical innovation.

3.3. Morphological Chart Method

The morphological chart method is a method of analyzing and systematizing all generated concepts, and this method is based on the functional analysis method [13,14]. A new component is composed of abstract parameters built from concrete technical principles. The parameters and components are expanded and confirmed in parallel on the final morphology chart. Finally, the components are selected from each parameter, and each component that is combined together is considered a solution to the problem.

3.4. PUGH Method

The PUGH method is completed by comparing many problem options and is often used to select the best design solution. All question options have a weight that is used to compare with the datum [15,16]. If the question option is better than the datum, it is indicated by "+"; conversely, if it is worse than the datum, it is indicated by "−". If the question option is difficult to compare with the datum, it is indicated by "S". Finally, the relative scores of each option are used to obtain an optimal result.

4. Case Study

Most of the users of the multi-functional hydrotherapy bucket are physically disabled or disabled. Therefore, in addition to the free entry and exit of the bucket, it is more important to include multiple rehabilitation functions without taking up space. In this

case, products of different brands on the market were selected for analysis and comparison, and their problem points were summarized using functional analysis. The solution to the problem was found using TRIZ theory and the morphological chart method. Finally, the best design scheme was obtained using the PUGH method.

4.1. Market Research

Generally speaking, market research is a good way to understand a consumer market. Through it, designers can better understand a market's needs. Therefore, this research starts with market research and current status analysis of related products by collecting data, so as to accurately understand the market demand for hydrotherapy pools and hydrotherapy buckets in the early stage of design. The market data reference sources in this research for the preliminary work are related product web pages, books, journals, as well as field visits to merchants, special education schools, and physiotherapy rehabilitation clinics to obtain the most authentic information. In addition to grasping the functional structure of the existing hydrotherapy buckets, the main design and improvement guidelines can also be obtained from the problem points. This study collects hydrotherapy pools and buckets launched in different countries. After collecting data and compiling the results, it was found that the small or individual hydrotherapy buckets on the market do not take up space, but most of them are single-use and single-function. Except for slightly different materials, the appearance has not changed much. The main function is rehabilitation, to relieve physical fatigue and soreness, and there are no other additional functions that can be used.

4.2. Design Specification

In order to clearly understand the hierarchical relationship between design goals, the results of market research, product analysis and field visits are drawn into a target tree diagram with a master–slave relationship (as shown in Figure 1).

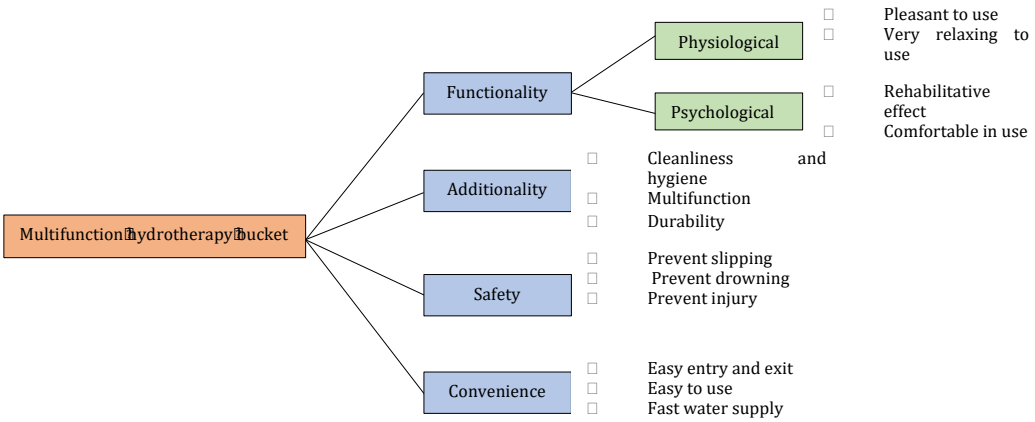

Figure 1. The total items of the objectives tree.

Then the TRIZ method was used to find out the parameters of improving features and worsening features. With the above methods, a set of design criteria was developed (Table 1), with D (Demand) indicating the design requirement as the "need" for essential functions and W (Wish) as the "expectation" for non-essential functions. Since most of the users who need hydrotherapy rehabilitation have physical disabilities or physical injuries, this product will consider both physical and psychological factors in terms of functionality, expecting that users can not only relieve physical pain, but that they also feel relaxed during the rehabilitation process. In this study, the focus was on the safety, functionality, and ease of use of the device, such as preventing slips, drowning, and injuries, which were considered as desired goals.

Table 1. Design specifications.

Functionality		**Additionality**		**Safety(Prevent)**		**Convenience**	
Pleasant	W	Hygiene	D	Slipping	D	Entry and exit	D
Relaxing	W	Multifunction	D	Drowning	D	Easy to use	D
Rehabilitation	D	Durability	D	Injury	D	Fast water supply	W
Comfortable	W						

4.3. Development Strategies

This product is still in the development stage, and there is still room for improvement in terms of acceptability, convenience, and ease of use, so this study uses different design strategies to improve the deficiencies.

4.3.1. TRIZ Theory

In this stage, TRIZ theory is used to explore the inadequate function of the hydrotherapy bucket, the problems accompanying its use, and the problem-solving model according to TRIZ theory. The steps are as follows.

- Analysis of problem points: this research draws up design specifications using functional analysis and use process, and also analyzes three problems, namely (1) the size of the multi-functional hydrotherapy pool is too large, (2) the function of the hydrotherapy buckets for home use is insufficient, (3) large hydrotherapy pools for the general public or medical use are inconvenient for people with physical disabilities to enter and exit.
- TRIZ inventive problem solving: after analyzing the problem, the improvement features were to enhance the equipment and functions with the least possible space, and to reduce the complexity of entering and leaving hydrotherapy buckets to avoid worsening features. These two features must be translated into the context of various engineering parameters of TRIZ. Then, in the contradictions matrix, the contradictions from the list of 39 that best fit the conflict statement must be selected. According to the TRIZ contradictions matrix, parameter 36 "Complexity of device" is introduced into the vertical axis (feature to change) and parameter 33 "Convenience of use" is introduced into the horizontal axis (undesired result). Finally, Principle 9 "Preliminary anti-action", Principle 24 "Intermediary", Principle 26 "Copying" and Principle 27 "Cheap short-living objects" should be expanded and solutions brainstormed. In this case, Principle 24 "Use an intermediary carrier article or intermediary process" and "Merge one object temporarily with another (which can be easily removed)" provided helpful ideas, and this study will use these concepts to solve the problems

4.3.2. Component Development

Generally speaking, regardless of the fact that the appearance and components of a product are always considered by many consumers as purchase factors, the product set up in this study is a multi-functional hydrotherapy bucket, so users' decisions are mostly based on the function, efficacy, practicality, ease of operation, durability, price, size, and other factors for purchase considerations rather than the appearance or the shape. The morphological diagram method is divided into four parts after disassembling the individual components and functions. First of all, Figure 2A shows the different ways of entering and leaving the bucket. Figure 2B is mainly for different massage and pressure relief functions. Figure 2C shows the handrails of different directions, sizes, and shapes. Figure 2D is the treadmill devices used for running or walking training.

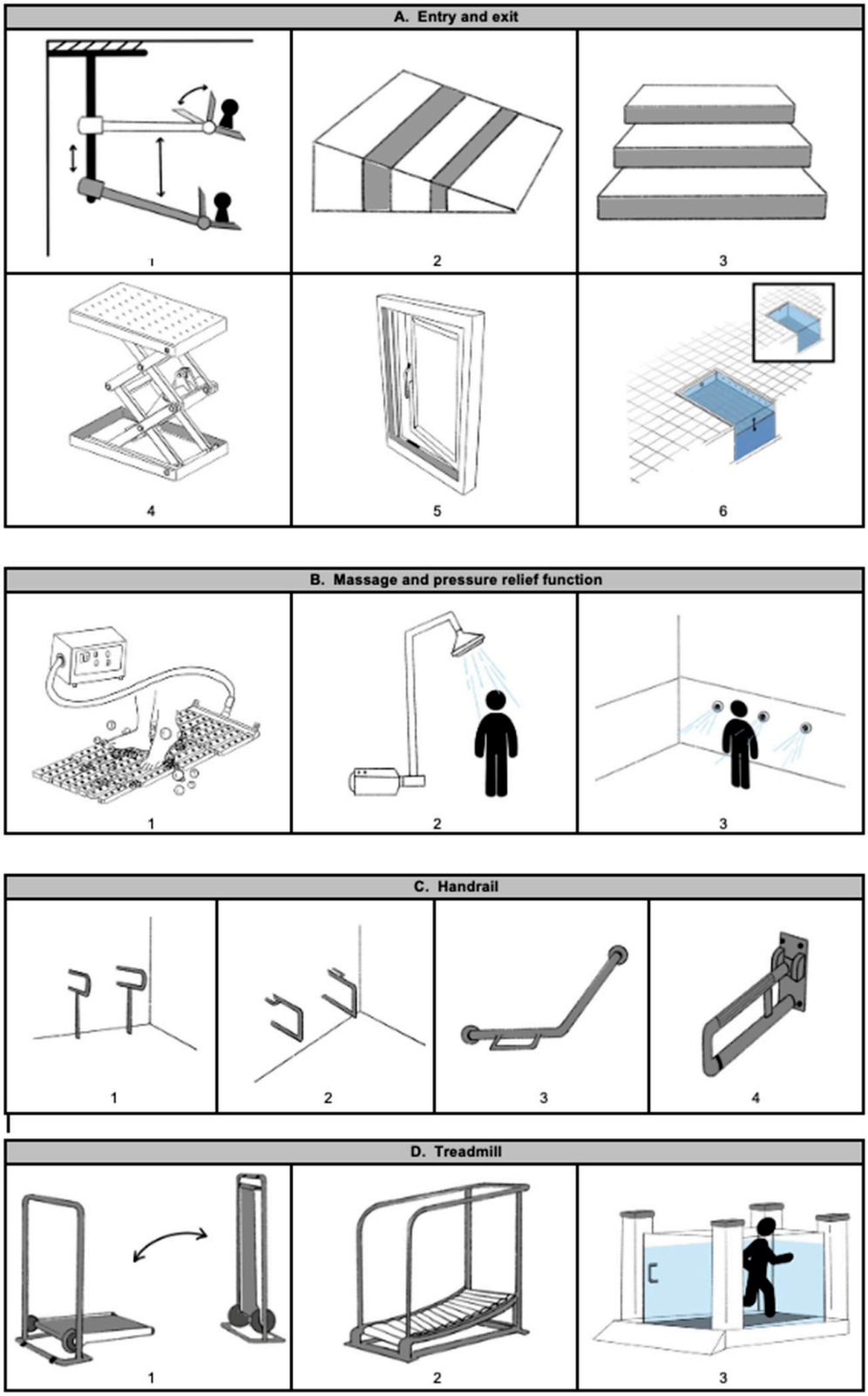

Figure 2. Morphological diagram of each component.

4.3.3. Concept Development

In this stage, the parts disassembled after the morphological diagram are combined to produce a total of four design concepts (Table 2), generated after the initial evaluation of this study for the subsequent screening of the best solution. The four concepts are (A) single function type for single person, (B) multifunction type for single person, (C) convenience type, and (D) combination storage type.

Table 2. Four design concepts.

A. Single function for single person	B. Multifunction type for single person
A6_B2_C3_D3	A5_B3_C1_D2
C. Convenience type	D. Combination storage type
A4_B3_C3_D2	A5_B1_C2_D1

4.3.4. Concept Selection and Evaluation

In this study, there are eight design criteria, which are: 1. does the hydrotherapy bucket take up space? 2. Is the hydrotherapy bucket economical? 3. Is the hydrotherapy bucket easy to access? 4. Is the hydrotherapy bucket easy to use? 5. Is the hydrotherapy bucket easy to assemble? 6. Is it too expensive to buy a hydrotherapy bucket? 7. Does the hydrotherapy bucket contain multiple functions? 8. Is the hydrotherapy bucket safe? Then, the weights of these eight design criteria were obtained using the tabular method (as in Table 3). Finally, the four design concepts (A–D) were compared to a commercially available personal hydrotherapy bucket that was considered a DATUM for this study. This personal hydrotherapy bucket is a movable lower body hydrotherapy bucket equipment set, which not only has wheels to push it but also includes a motor. The size of this hydrotherapy bucket is 107(L) × 51(W) × 71(H) centimeters and the capacity is 68 gallons. The hydrotherapy motor is 18 cm (diameter) × 96 cm (height), with a maximum water output of 55 gallons per minute and a weight of about 21 Kg. Then, the PUGH method (Table 4) was used to evaluate the most suitable decision scheme. After screening, Concept D received the highest score. In terms of cost, all design concepts are inferior to DATUM, but that is because DATUM is a single-function hydrotherapy bucket, so the cost must be much lower than a multi-function one. In addition, Concept D is superior to DATUM in terms of access, use, assembly, function, and even safety.

Table 3. The weight of each policy design criteria.

Criteria	1	2	3	4	5	6	7	8	Total	Weight
1		5	4	3	2	5	3	3	25	0.10
2	3		3	2	3	2	1	1	15	0.07
3	4	5		2	3	2	1	1	18	0.08
4	5	6	6		5	4	4	5	35	0.16
5	6	5	5	3		3	3	4	29	0.13
6	3	6	6	4	5		4	4	33	0.15
7	5	7	7	4	5	4		5	37	0.17
8	5	7	7	3	4	3	3		32	0.14
Total									224	1

Table 4. The weight of each design criteria.

Design Criteria		A	B	C	D	Weight
1	DATUM	S	S	S	S	0.10
2		S	S	S	S	0.07
3		S	+	+	+	0.08
4		−	S	+	+	0.16
5		−	S	S	+	0.13
6		−	−	−	−	0.15
7		+	+	+	+	0.17
8		−	S	+	+	0.14
+ Score		0.17	0.25	0.55	0.68	
− Score		0.58	0.15	0.15	0.15	
Total Score		−0.41	0.1	0.34	0.53	

5. Results

After generating the best design solution according to the above methodologies, the main design concept is D. Concept D enhances the function of combination and storage, because its massage and pressure relief functions and treadmill are detachable and storable, so it enhances the ideal of multiple functions of the bucket. Figure 3A–F show the detailed 3D drawing of each component. This product has a water-blocking door with a side anti-leakage plastic strip, so it can achieve the effect of preventing water leakage (Figure 3A). The two-stage closing function can enhance the tightness of the door plate and the hydrotherapy bucket (Figure 3B). Figure 3C combines the air foam cushion with the treadmill, so users can perform running and walking training at the same time as receiving the effect of a massage. In addition, this device can instantly eject small bubbles, a micro-vibration of about 10,000~15,000 times per second, to achieve the massage effect. Figure 3D shows a monitor, which is operated by the therapist and monitored externally, while Figure 3E shows a monitor that can be operated directly by the user from inside. Figure 3F is a schematic diagram of the treadmill and the air foam cushion that can be disassembled and stored.

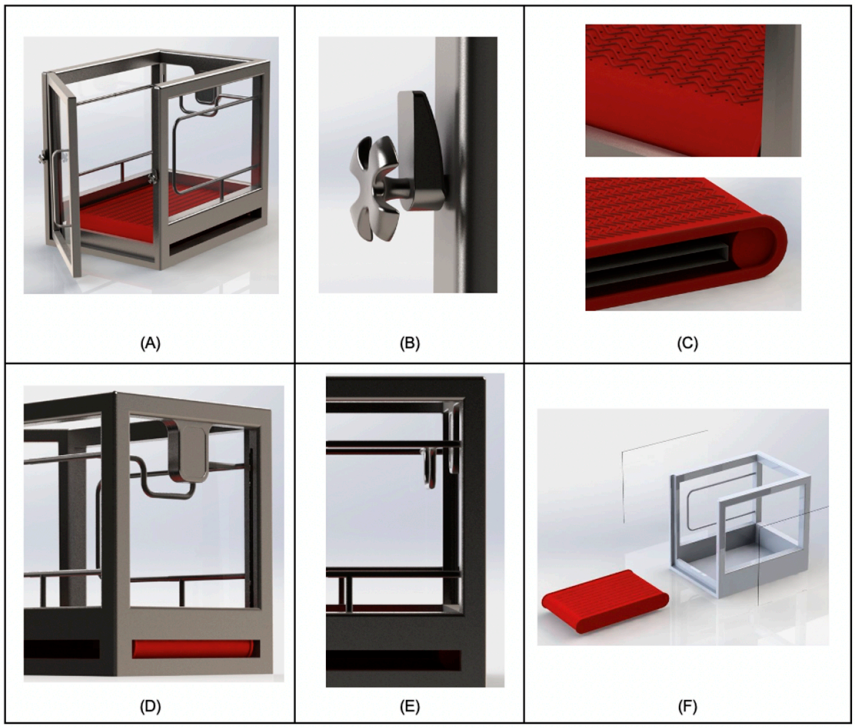

Figure 3. The detailed 3D drawing of each component (**A**–**F**).

6. Conclusions

In this study, the concurrent design strategy is applied to the development and redesign process of the multi-functional hydrotherapy bucket. Pre-design of products is carried out using the objectives tree method for decision making and design specifications. The TRIZ contradictions matrix and morphological diagram are used to find the problematic points and principles for solutions. Throughout the design process, the user experience and the PUGH method are used to select the best version of the design, and finally, the best one is presented in 3D with a computer-aided design.

This study adopts a systematic design process, which can effectively save development and design time, and is also closer to the real needs of users. Overall, this design proposal uses various methodologies and data to select the best solution and by compiling relevant data to build a user-oriented product as much as possible, but whether it can really achieve the effect of rehabilitation is still to be discovered after the test.

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