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Water park of the future: Monarch butterfly slide with eco-friendly design and smart water management

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Abstract: In this study, an innovative water park concept slide that aims to keep water consumption low was designed and produced. Traditional water parks are out of use at a rate of approximately 65% because they are inefficient in water and energy consumption. This work will be a pioneering step in the sector with the combination of environmentally friendly design, smart water management systems, and sustainable technologies. Users entering the 43% inclined butterfly body will reach a speed of 16 m/sec while performing the vertical swing movement and will move with an acceleration of 0.5m/sec^2 on the horizontal axis. Since the high-pressure water coming from the nozzles on the slide will be used only when there is movement, approximately 70% water and 50% energy savings will be achieved and sliding safety will also be increased. The proposed saving system will be produced using the inverter, integrated circuit, smart card, and software developed to be added to the pump and will be adapted to all slides. The fact that this study is a first in the sector will inspire other water parks and lead to the development of projects that consider sustainability and savings issues.

Keywords: waterslide, eco-friendly design, water saving, polgün

1. Introduction

Nowadays, environmental sustainability and the protection of natural resources are becoming increasingly important around the world. Water is one of the most important elements for the continuation of life on Earth. With increasing economic growth and population, water demand also increases; Water availability is constantly being depleted, and increasing pressure on freshwater resources requires monitoring of water consumption. In addition to controlling water supply through an efficient water management system, automation of the system in terms of both monitoring and operation has attracted great attention in recent years and helps reduce operating costs and save energy [1,2]. The responsibility of protecting water resources, reducing clean water consumption, and leaving a cleaner environment for future generations has become a global necessity [3]. In this context, rational and effective use of water, sustainable management of water resources, and reduction of energy consumption are of great importance, especially in the water-related entertainment sector [4].

Rapid urbanization and population growth have affected the environment in many ways, including greenhouse gas emissions (e.g. CO_2). In addition, increasing prosperity has increased human mobility in the world, and the tourism sector has received a large share of this [5]. To reduce energy consumption and use energy more effectively and efficiently in tourism sectors, it is important where and how energy is used [6]. In line with this information, it will be possible to determine the areas where energy savings will be made and to focus on these areas. Performance, optional materials, energy consumption, phase of use, durability, recycling, reuse, and disposal have an important place in eco-design, as well as efficiency issues [7,8]. Eco-design is an industrial approach that aims to reduce environmental impact at every stage of the product life cycle [9]. While early developments in sustainable design stemmed from the desire to reduce environmental impacts throughout the life cycle, recent focus has brought the three aspects of sustainability (environment, economy, and society) into the spotlight more broadly

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[10]. Considering the environmental knowledge and attitudes of tourists in recent years, it has been understood that nature-based water parks are more important in recreational ecosystem services [11,12]. Sustainable development has emerged by including sustainability social, economic, and environmental factors [13]. Over time, the concept of sustainability has taken different dimensions and emerged in different fields such as sustainable tourism, sustainable business, and sustainable living [14]. It is seen that smart applications in tourism are becoming increasingly widespread in these areas. In this context, concepts such as smart tourism, smart destination, smart hotel, smart transportation, and smart activity are frequently encountered [15].

Since tourism-related activities require higher energy consumption, tourism-based growth is achieved at the expense of environmental damage. Additionally, leisure tourism, a subsector of the tourism industry, has a significant and positive impact on energy consumption and economic growth [16]. When the symmetric and asymmetric effects of hotel services on general customer satisfaction are investigated, one of the highest effects is entertainment services. The accelerating development in the tourism sector has led to an increase in the use of theme parks, amusement parks, and water parks. Water parks, established to meet people's needs for many cultural and social activities such as playing games, resting, and doing sports, are water-based active recreational areas that can be designed in different scales and sizes with various activities included [17]. Traditional water parks cause negative environmental impacts in terms of water consumption, water management, and energy.

Therefore, water parks must have innovative and environmentally friendly eco designs and be operated based on sustainability principles. The daily water consumption of a water park can vary greatly depending on its concept, number of visitors, and technological infrastructure. Such parks may attempt to reduce water consumption by using energy efficiency and water conservation techniques [18]. Theme parks generate billions of dollars in revenue, have a substantial effect on local economies and therefore, are considered a significant driver of the hospitality industry [19].

The aim of this study is to be a pioneer in the sector by offering innovative water parks, environmentally friendly design, smart water management systems and sustainable technologies together. The design of the Monarch Butterfly slide presented in the study was developed to allow four people to slide at the same time, with different geometry and sliding behavior. Efficient use of water will be ensured thanks to smart sensors and software installed to control the flow of water during users' sliding movements. This innovative water park concept will provide a significant source of inspiration to the water park and composite manufacturing industry by offering an approach centered on sustainability and water-energy saving, leading to the development of more environmentally friendly projects in the future. This study will contribute to the protection of water resources, energy savings and the dissemination of environmentally friendly entertainment options.

2. Materials and Methods

2.1. Materials

In this study, the Monarch Butterfly waterslide was designed inspired by the butterfly known in nature as the Monarch butterfly. Motifs like those found on the Monarch butterfly are included in the design of the slide. Glass fiber and resin were used as composite materials in the slide (Table 1). The RTM method was preferred because it allows the production of safer and smooth surfaces with precise tolerances. In addition, this system also enables the necessary acoustic and visual designs.

Table 1. Glass-reinforced polyester laminate specification

Material	Material Type	Material Description
Pigmented Gelcoat	İlkester Gin-413	Isophthalic / Neopentyl Glycol / Ultraviolet Lights Gelcoat
Barrier Coat	Bisphenol epoxy	Vinyl ester resin
Reinforcement	Metycore-max-HFD7	RTM / Multiaxial / Roving glass fiber
Polyester Resin	Dewilux Dewester 779 Polyester	RTM / Spray up type polyester resin
Body		6 mm
Flange	S235JR-10	10 mm
Surface Brilliance		Min. 70 gloss
Surface Roughness		Max. 0.08 micron

Raschel fabric used as a pattern is a type of fabric obtained by knitting polyester threads. Thanks to the features and ease of use offered by the fabric, it is frequently preferred in many different sectors. In addition, raschel fabric is preferred over other fabrics due to its weaving structure being durable, flexible, and lightweight. The thinnest version of the raschel fabric is applied between two layers of gelcot to reinforce the composite and give color.

2.2. Methods

Monarch Butterfly will be produced using the Resin Transfer Method (RTM), which is a composite material production technique and is generally used in the manufacturing of parts and hardware in the aviation industry. The most important advantages of this method are that the outer and inner surfaces of the products have the same surface sensitivity, offer excellent visuality, hold less dust, are easy to clean, produce high-quality products, provide standard production, have very low error tolerances, faster and error-free production. It can be expressed as being easier and more importantly, creating less waste in the environment, having more environmentally friendly working conditions, and being sustainable because it is an environmentally friendly technology. At the same time, it is planned to have a transparent production with natural light effects and closed sections that will allow ambient light into the slide with different colors and patterns.

In production, after the model is designed, it is separated into molds. In the model design, the model that best reflects the Monarch Butterfly figure, using convex and concave parts with the same radius and slope, was used to give the design a modular structure with minimum cost and a low number of molds. All molds are suitable for production with RTM, and the parts to be removed from the molds are reinforced with 45º woven fibers to provide the desired strength. Patterns will be applied to the parts at the mold stage. These patterns will be machined using RTM technology, a closed molding method in which pre-cut or pre-shaped reinforcing materials are sealed by placing them between the male and female mold. It has become a high-value product with the innovative feature provided by the LED lighting placed on the slide surfaces so that the slide and sensors work at night. RTM process stages are shown in Figure 1.

The metal construction that will ensure the statics of the body is designed by the theme and serves as a hydromechanical installation (Figure 2). This method, used for the first time in the industry, prevents visual pollution caused by PVC pipes.

S235JR was used as steel material (see Figure 3). This steel structure goes through the hot dip galvanization process. It is painted with acrylic-based polyurethane paint as needed. A4 quality stainless steel was used in the fasteners.

Sensors to be placed at critical points on the body of the slide will detect the position of the user and convey the necessary information for the pump, which transfers water to the nozzles on the body, to operate at low or high speed. This system will save approximately 70% of water and 50% of energy when the slide is not used, or the user has not yet reached the body and will increase sliding safety by directing the high-pressure water from the nozzles to the user only when needed. The system will be created using an inverter, integrated circuit, smart card, and developed software to be added to the pump (see Figure 4). In the future, this technology will be adapted to all existing slides. This method, which will be used for the first time in the industry, will lead to the design of sliding geometries that could not be designed before due to safety concerns.

Sustainability-oriented approaches such as efficient use of water used in the study and energy saving play an important role in the design and operation of modern water parks. Additionally, steps have been taken to achieve lower water consumption and high energy efficiency by adopting innovative technologies. These innovations will both sup-

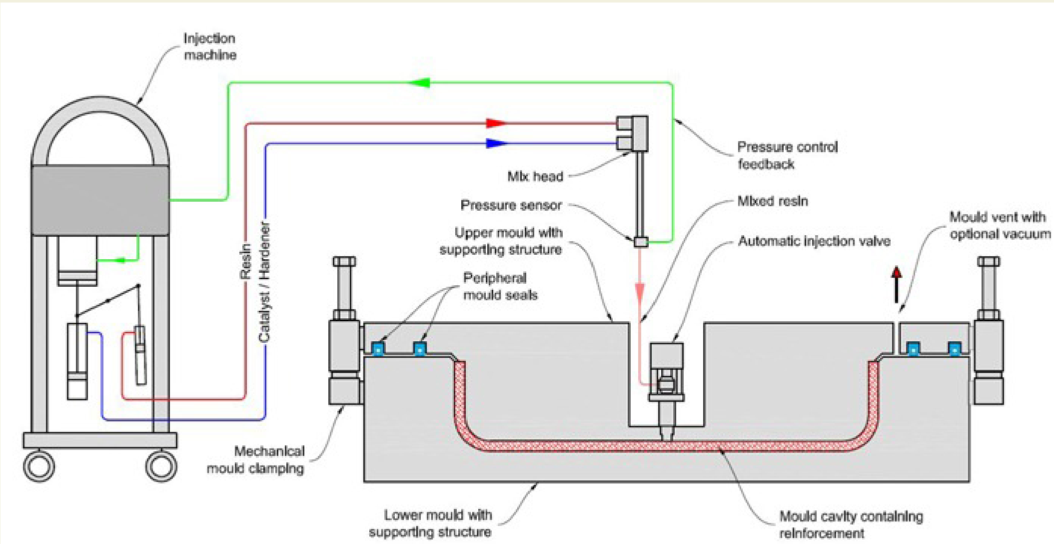

Figure 1. RTM process stages [20]

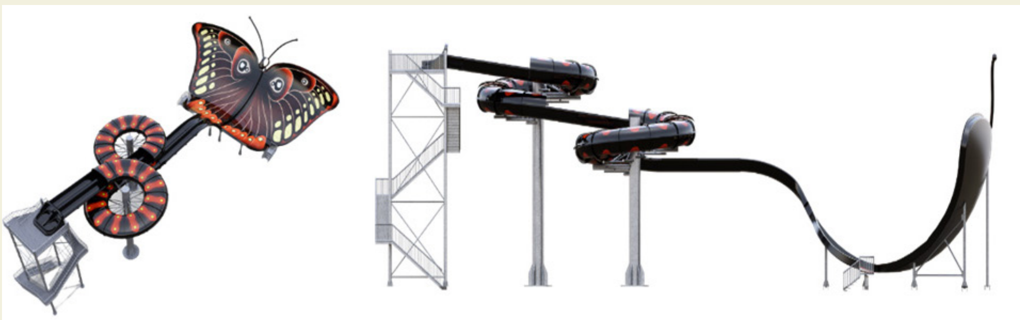

Figure 2. Monarch Butterfly installation design.

port environmental sustainability and optimize operating energy costs. The comparative technical specifications of the Monarch Butterfly slide are given in Table 2.

Different perspectives of the Monarch Butterfly waterslide are shown in Figure 5.

3. Results and Discussions

The designed waterslide is unique with its unique sliding path, pattern inspired by the Monarch Butterfly, and different color combinations. The slide provides group activity at the same time, allowing 4 people with two boats to have fun by competing. The boats go through bends until they reach the hull, and after a hard landing, the boats that reach the hull rise again and accelerate on the horizontal axis. It gives users the feeling of competition and intense adrenaline at the same time.

Monarch Butterfly offers different geometry and different gliding behaviors together. The slide has three different sliding dynamics. These;

- First, the slide body is reached through the linear classical slide with a near-constant slope. Here, right, and left bends can be preferred within the same section.
- By free falling and climbing within the body, one moves in a valley, first descending, then ascending, and then following the same behavior again.
- While ascending and descending movements are made, with the outward tilt given to the body of the slide, it moves in the horizontal axis within the body and at the same time moves towards the exit of the body.

The slide has two starting entrances placed on the access platform. The sliding platform of the slide is designed to be 1000 m^2 and the sliding capacity is 240 people/hour. The slide with a cross-section of 1400x700 mm is designed to accommodate descent and climbing with a slope of 43% on the Y axis and a slope of 0.78% on the X axis. If the user descends another 10 m on the Y axis, it will allow the user to accelerate to higher speeds although the slope remains constant. The maximum speed reached by users on the butterfly body has been increased to 16 m/s and the average speed has been increased to 9 m/s (Equation 5).

$$E_p = mgh_1, E_k = \frac{1}{2}mV_1^2 \quad (1)$$

$$E_1 = E_p + E_k \quad (2)$$

$$E_2 = \frac{1}{2}mV_2^2 \quad (3)$$

$$f_s = mgk\Delta_x \quad (4)$$

$$E_1 = E_2 + f_s \quad (5)$$

where; h_1 is the initial altitude, V_1 is the initial speed, Δ_x is the total altitude, k is the friction coefficient and V_2 is the final attainable speed (if h_1= 9.08 m, Δ_x = 20.9 m, k= 0.05 (for human), and V_1=10 m/sec then V_2= 16.05 m/sec).

During the swing movement, it will move with an acceleration of 0.5 m/sec^2 on the horizontal axis. A 10 cm deep puddle was created at the exit point of the slide, allowing users to evacuate safely from the slide. The water requirement for Monarch Butterfly is determined as 200m^3/h. Requiring 30% less water than its counterparts, the slide has a significant competitive advantage in water saving. Jet nozzles placed on the sliding surface will be driven by entry and exit sensors, and only when the user reaches the relevant part of the slide, the pump connected to the nozzles will be activated and its speed will be increased by the software and will convey the user to the desired position. This makes the slide an interactive slide according to user behavior. Operating the pump at high speed only when necessary and at idle speed in other cases will reduce the operating costs of the slide. The estimated energy saving is estimated to be approximately 50%.

Monarch Butterfly Waterslide is unique in the industry

Table 2. Comparative technical specifications.

Technical Specifications	Monarch Butterfly	Domestic Competitor	Foreign Competitor
Water consumption	200 m^3/h	250 m^3/h	280 m^3/h
Energy consumption	12 kW	20 kW	24 kW
User capacity in one ride	4 people	4 people	2 people
Used technology	RTM	Hand deposit & RTM	Hand deposit & RTM
Width	24.8 m	24.5 m	20 m
Length	24 m	18.5 m	-
Height	12.7 m	10.5 m	9 m
Tilt	%43	%40	%45-50
Total capacity	240 Persons/h	240 Persons/h	350 Person/h
Start	Platform/Slide	Slide	Platform
Theme	Contains	Contains	Not contain

Figure 3. Preparation of S235JR steel construction

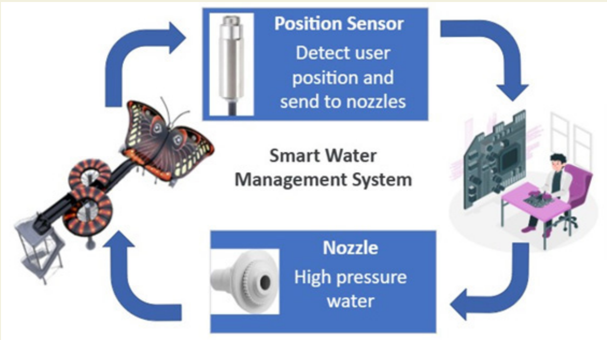

Figure 4. Integrated circuit simulation.

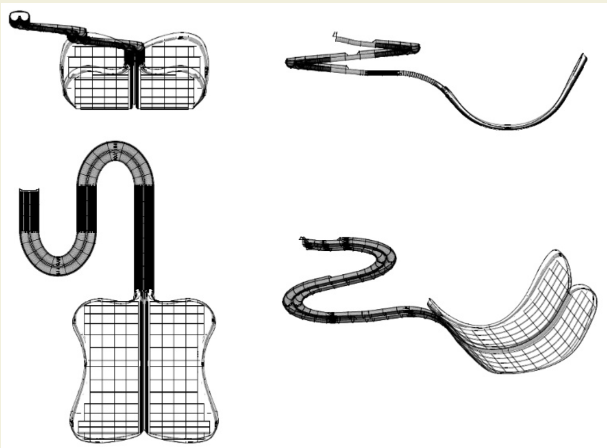

Figure 5. Perspective view of the Monarch Butterfly waterslide

with its design, sliding style, competitive structure, water management technique, and steel construction. With these features, it is aimed to become one of the most prestigious slides in the sector. The Monarch Butterfly waterslide is a slide with double lanes and boats. Since the symmetry used in the slide creates competition between two boats, it is envisaged that the slide will turn into an entertainment vehicle to be slid repeatedly. The developed slide is designed in a way that four people can slide at the same time, unlike general waterslides where a maximum of two people can slide in a single tour. Due to its geometric feature, it provides the user with an entertaining experience thanks to three different sliding dynamics (in the tube, oscillation, and falling) and constantly increasing and decreasing speed. Monarch Butterfly has two starting pieces placed on the access platform. In the two-lane slide, two boats move in the X, Y, and Z axes on the body part after making laps in the same lengths. The sliding platform of the slide is 40 m^2 and the sliding capacity is 200 people/h. High speed (16 m/s) will give users a more enjoyable and exciting sliding experience. The maximum speed reached by users in the sliding process was increased by 15%, from 13m/s to 16m/s. The average speed increased by 6% and reached 9m/s.

According to the laws of physics, individuals with more mass are likely to exceed the height limit because they will slide faster than those with less mass. Placing jet nozzles in the developed slide prevents the user from exceeding the limit levels. The water requirement for Monarch Butterfly is determined as 200 m^3/h and it will provide a significant advantage in saving water as it will require 30% less water than its competitors in the market. Water consumption was measured by placing a flowmeter where the water slide was actively used (PM 15:00 - 21:00). In addition, water and energy efficiency calculations were made by determining the maximum number of users per hour sliding in two lanes, considering sliding speed, acceleration, and safety times between two slides. Considering that 3.3 m^3 of water was consumed per sliding activity and the maximum number of sliding was 60, it was determined that 200 m^3 of water was consumed per hour.

After the sliding process on the Monarch Butterfly waterslide is completed, users will be positioned in the direction of the evacuation ladder. Since the slide has two lanes, the lanes are separated from each other with separators placed in the middle of the body to prevent the transition from lane to lane, and the clean area is protected with propulsion systems. Monarch Butterfly Waterslide was designed to be unique in the industry with its design, sliding style, competitive structure, water technique, and steel construction.

4. Conclusions

The biggest contribution of the developed Monarch Butterfly slide to national development is that it will require 30% less water than its competitors and provides a significant advantage in water saving. This slide is aimed to save water and increase productivity in businesses by consuming less water and providing more entertainment to more people. Energy costs are high in slides produced with traditional technologies. Therefore, energy management needs to be implemented in the system. Thanks to the applied energy management, efficiency increases and approximately 50% energy savings are achieved. It should not be forgotten that the Monarch Butterfly slide, beyond providing energy savings, will also represent an environmentally friendly and sustainable environmental approach. While it is known that traditional slides cause high energy costs, the aim is to minimize the negative effects on the environment thanks to the new energy management approach. In this way, water resources will not only be used economically but also serve the purpose of long-term environmental protection.

The developed slide can also be considered as an example of transformation in the sector. Innovative approaches and sustainability-focused product development can also inspire other businesses. In addition, issues such as water saving, and energy efficiency have an important place in terms of social awareness today. In this respect, it will reach large masses and contribute to increasing water-saving awareness. Safety is of great importance in the design and operation of water parks. Along with the enjoyable properties of water, maintaining balance and minimizing risks should not be ignored. In addition, sustainable use of water resources and minimization of environmental impacts is critical for the future of such recreational areas. Users entering the 43% inclined butterfly body will reach a speed of 16 m/sec while performing the vertical oscillation movement and will move with an acceleration of 0.5m/sec2 on the horizontal axis during this oscillation. Approximately 70% water and energy savings were achieved when there was no movement on the slide body.

When the practices in the sector are examined, the amount of water used in water parks may vary depending on the size of the park, the circulation system of the water, and the type of water games in the park. Water parks often feature large pools, slides, wave pools and other water-themed entertainment areas. With the developed software and automation, energy and water savings were achieved and the consumption rate was reduced. As a result, the advantages that this study will bring to national development, such as water saving and energy efficiency, will have a positive impact not only on the profitability of enterprises, but also on environmental sustainability.

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Research Ethics

Ethical approval not required.

Author Contributions

The author(s) accept full responsibility for the content of this article and have approved its submission.

Competing Interests

The author(s) declare that there are no competing interests.

Research Funding

Not reported.

Data Availability

Not applicable.

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