Journal of Engineering and Architecture
December 2022, Vol. 10, No. 2, pp. 24-30
ISSN: 2334-2986 (Print), 2334-2994 (Online)

Published by American Research Institute for Policy Development
DOI: 10.15640/jea.v10n2a4
URL: https://doi.org/10.15640/jea.v10n2a4

Designing and Manufacturing of a Shock-Absorbing Basket Swing for Use in the Playground

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Abstract

In this study, a basket swing comprising a seat section with impact surfaces (impact regions) is produced in double/single-walled form was designed by a plastic injection method (volume molding method) to obtain a flexible and shock-absorbing surface during impact.

Basket swings were designed in a leaf-shaped form for maximum displacement. All designs and analyses were made by using Solidworks under a 10 kg (100 Newton) load. Traditional and newly designed basket swings were produced from polyethylene and ICOREN9104 low elasticity modulus (E) with an aluminum rotational molding die as double-walled. The impact tests of basket swings were made according to EN 1176-2. After the design change, leaf-shaped basket swings have high displacement values. The basket swing with this design was successful in impact tests if it was produced from a material with a low modulus of elasticity, but failed in the impact tests if it was produced from a material with a high modulus of elasticity.

Keywords: basket swing, displacement, impact damping, playground equipment

1. Introduction

Playgrounds are among the first places where a kid would start to socialize outside of the home. Playgrounds are very effective for the body (motor) development of kids during childhood, which is the most significant period of human development. Motion is a significant need for a kid. In this stage, games and sports, etc. activities support the motion. Nowadays, various playgrounds are present for kids to pass an enjoyable time and kids want to be in these places. Various game groups are present in these playgrounds. The drawback of these game groups is that their equipment's are made of hard materials. The accidents caused by these hard materials make families worried. The playgrounds need structures that won't harm kids and their friends playing with them. Playgrounds should be constructed with the site selection, floor covering, planting, safety, etc., and design principles in light of the tendencies and expectations of kids.

One of the most appealing types of equipment to kids in playgrounds is the swing. Swinging allows a child to develop coordinated movements. It is almost impossible to teach a child how to swing (Trautner, 2018). Through lots of practice (the motion of moving back and forth) and the vestibular system, they are successful in learning how to make a swing move (Glover, 2004). The vestibular system is a sensory system that creates a sense of balance and spatial orientation for the purpose of coordinating movement with balance. Our sensory system organizes and interprets information. This is the system that allows us to regulate our bodies when the environment is loud, quiet, has a strange smell, etc. And so it allows us to cope in a variety of different situations.

Swinging is one of the best activities for young children to develop their sensory system (Kouri, 2019; Ghai *et al.*, 2019). When a child swings, they are developing their ability to adapt to different sensations. Other benefits of swinging can be given calming, encouraging social interaction and development, increasing spatial awareness, helping develop gross motor skills (pumping legs, running, jumping), developing fine motor skills (grip strength, hand, arm and finger coordination), and developing core muscles (Trautner, 2018; Leigh An, 2015; Mohsen & Samy, 2020).

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However, swing may cause impacts and crushes due to its swinging function. According to playground equipment injuries in USA recorded by National Electronic Injury Surveillance System (NEISS) between 2002 and 2004 years swings at school are the most common mechanism of injury for traumatic brain injuries (TBIs) (Loder, 2008). Some researchers have examined the playground equipment and they found a large number of non-compliances. They reported the most common problems in the playground equipment examined are the lack of structural integrity and the inadequacy of the impact areas in terms of size and features (Senyen& Erdoğan, 2019; Metin, 2003; Ranaldi, 1993).

When the standards related to playground elements are examined, they emphasize that the most important factor to be considered is safety. however, despite all these standards, there are many dangers and risks in playgrounds, mostly due to the lack of oversight and many of them due to the playground equipment and its design. According to the reports of The United States Consumer Product Safety Commission, more than 200,000 children apply to the emergency room every year due to injuries caused by playground equipments (Chait, 2016). According to a report published in England, the number of children injured in accidents in playgrounds is around 40,000. As regards this report, these accidents are mostly caused by reasons such as swings, falls, swing hits, hand and foot jamming) (Ruth, 2017). The remarkable thing in this report is that 20% of these accidents occurred as a result of swing strikes.

Studies on the safety of playgrounds show that there are significant relationships between the structural characteristics of playground elements, such as height and less absorbent contact surfaces, and fall injuries. Studies reveal that the risk of falling injury increases in playgrounds that do not meet accepted safety standards, such as having suitable surface materials of sufficient depth and appropriate guardrails (Sethi *et. al.*, 2008; Sherker& Ozanne-Smith, 2005; CPSC, 2015).

Todays, there are swings with different precautions against this risk of collision and accident. To minimize the hazard of impact, some designers had offered to use tires. Nevertheless, it has some potential protrusion or laceration hazards because of the exposed steel belts or wires. For this reason, some researchers recommend that plastic materials could be used instead of car tires (CPSC, 2015). However, plastic materials do not have as good shock absorbing properties as rubber (elastomer) materials. The ability of an elastomer to convert the energy of motion enables it to absorb vibration. Elastomers have higher absorption compared to plastics (Valentini, & Lopez-Manchado, 2020; Birinci, 2020).

When seats placed on swings or carousels containing single independent seating sections are tested in a suitable test setup, acceleration values and surface compression should comply with the relevant article of the standard, permanent damage and deformations should not occur in the components of the suspension system (EN 1176-2, 2017). According to Senyen & Erdoğan's study, in the interview with accredited laboratory officials with experimental qualifications, they stated that all of the swing seats made of polyethylene, which were brought to them for testing, received insufficient results from the experiments (Senyen, & Erdoğan, 2019).

For this reason, in this study, basket swing designs have been made that will reduce the risks of accidents such as falling, hand and foot jamming caused by the design, and provide higher impact damping. Basket swings produced by making improvements in the design and choosing the appropriate material were tested and comparatively examined according to the analyzes made in Solidworks and the experimental setup established in accordance with EN 1176-2.

2. Experimental Works

In the study, three criteria were taken into consideration in the design of the basket swing in order to provide an appropriate shock damping.

1- The selected material should have a suitable modulus of elasticity: In order to prevent the material (swing) from being damaged during the impact, the stresses created by the impact must remain below the yield strength of the swing material and must make maximum displacement (flexing) at these stress values.

2- The selected material should be suitable for rotation molding: The materials to be subjected to rotation molding processes should melt between 150-200 degrees, but should not burn or stick to the mold at these temperatures. In addition, in order for the material to spread well on all surfaces of the mold, it must have a suitable melt flow index (close to the values of polyethylene).

3- The basket swing should have a design that can absorb the impact by flexing at the maximum displacement during impact.

The first two of these criteria are provided by choosing the appropriate material and the third by designing a suitable basket swing.

2.1. Materials

To obtain a flexible and shock-absorbing surface during impact a basket swing was designed which has a seat section having a double-walled impact surface. The double-walled baby swing used in experimental works were made of polyethylene and ICORENE 9104. ICORENE 9104 is a thermoplastic elastomer specifically developed for rotational molding by A. Schulman Speciality Powders and API Spa. Table 1 is shown standard polyethylene and ICORENE 9104 material's physical properties.

Table 1. Some properties of polyethylene and ICORENE 9104 materials

	E (N/mm^2)	Melt flow rate (190^OC)	Yield Point (MPa)	Mass density (kg/m^3)	Flexural Modulus (MPa)	Melting Temperature (^OC)
Polyethilene for injection moulding	1070	3-6 g/10 min.	26-31	952	700	130-137
ICORENE 9104	10	4,5 g/10 min.	18	890	700	123

2.2. Design

While designing the basket swing, designs have been made that will reduce the risks of accidents such as falling, hand and foot jamming caused by the design. In addition, in order to increase the amount of stretching (displacement), areas that can move freely are created on the impact surfaces of the basket swing. In order to absorb the impact that may occur at any point on the swing, the basket must have a shape that can stretch in the form of a spring on the swing. For this reason, a leaf-shaped design was obtained by creating slits on the swing. Then, various protrusions were formed on these leaf springs to increase the amount of stretching. Whether all the designs made have a suitable displacement capability was analyzed with the Solidworks program. In all analyzes carried out in the study, the force on the swing was selected the same and applied as a maximum of 100N. The maximum impact damping under these forces was evaluated by considering the displacements in the wishbone.

2.3. Manufacturing of Basket Swing and Impact Test

An aluminum rotational molding die was used for production of the basket swing in all experiments. The specific parameters used in rotational molding are the oven temperature of 250^OC, cooling time of 40 min, the rotation speed of 6 RPM, and forced air-cooling. The same rotational molding parameters were used for both materials because they both have approximately the same melting temperature and melt flow rate (190^OC) values.All designs and analyses were made by using Solidworks. All analyzes were created by being fixed at the same support points under 10 kg (100 Newton) of load. Simulations were made by choosing a temperature of 24.85 degrees.

The impact tests were made according to "EN 1176-2: Playground equipment and surfacing - Part 2: Additional specific safety requirements and test methods for swings". In the experiments, an aluminum sphere with a diameter of 160 mm ± 5 mm, a mass of 4.6 kg ± 0.05 kg, a homogeneous and gapless impact zone between the surface impact and the accelerometer, and a surface roughness of less than 25 μm was used. The experimental setup according to EN1176-II Annex B is shown in Figure 1.

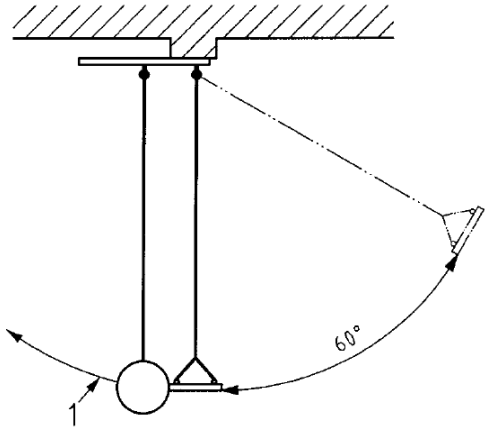

Figure 1. The experimental setup of impact test according to EN1176-II Annex B.

3. Results and Discussion

In the study, first of all, the traditionally produced swings with basket design were analyzed. As a result of these analyzes, it was observed that these designs have very low displacement values (Figure 2).

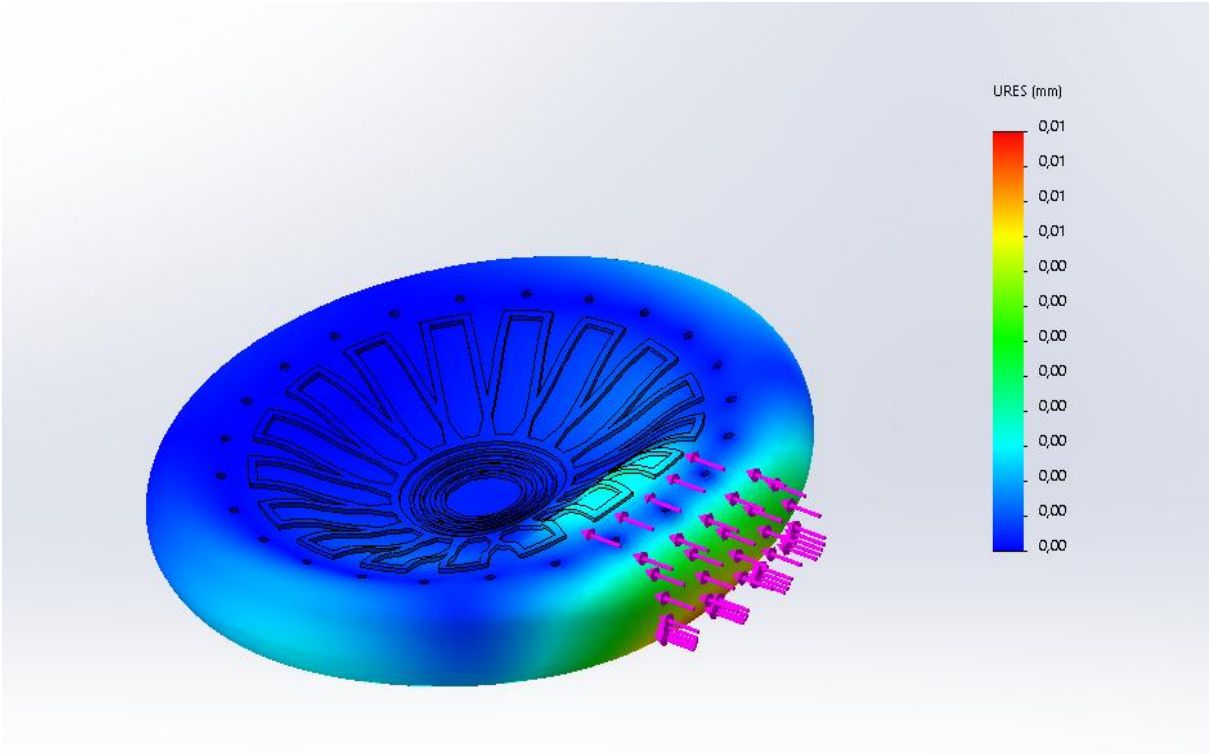

Figure 2. Displacement analysis for polyethylene material of conventional basket swing designs

When the design given in Figure 3 is examined, flat slits have been added to the slopes parts of the double-walled basket swing in order to increase its flexibility (Figure 3a). Thus, the design that gains more freedom, absorbs a higher amount of impact. In addition, by creating a protrusion on the upper part of the swing slopes section (Figure 3b), its displacement values have been increased by providing both high strengths under higher impact conditions and more flexibility.

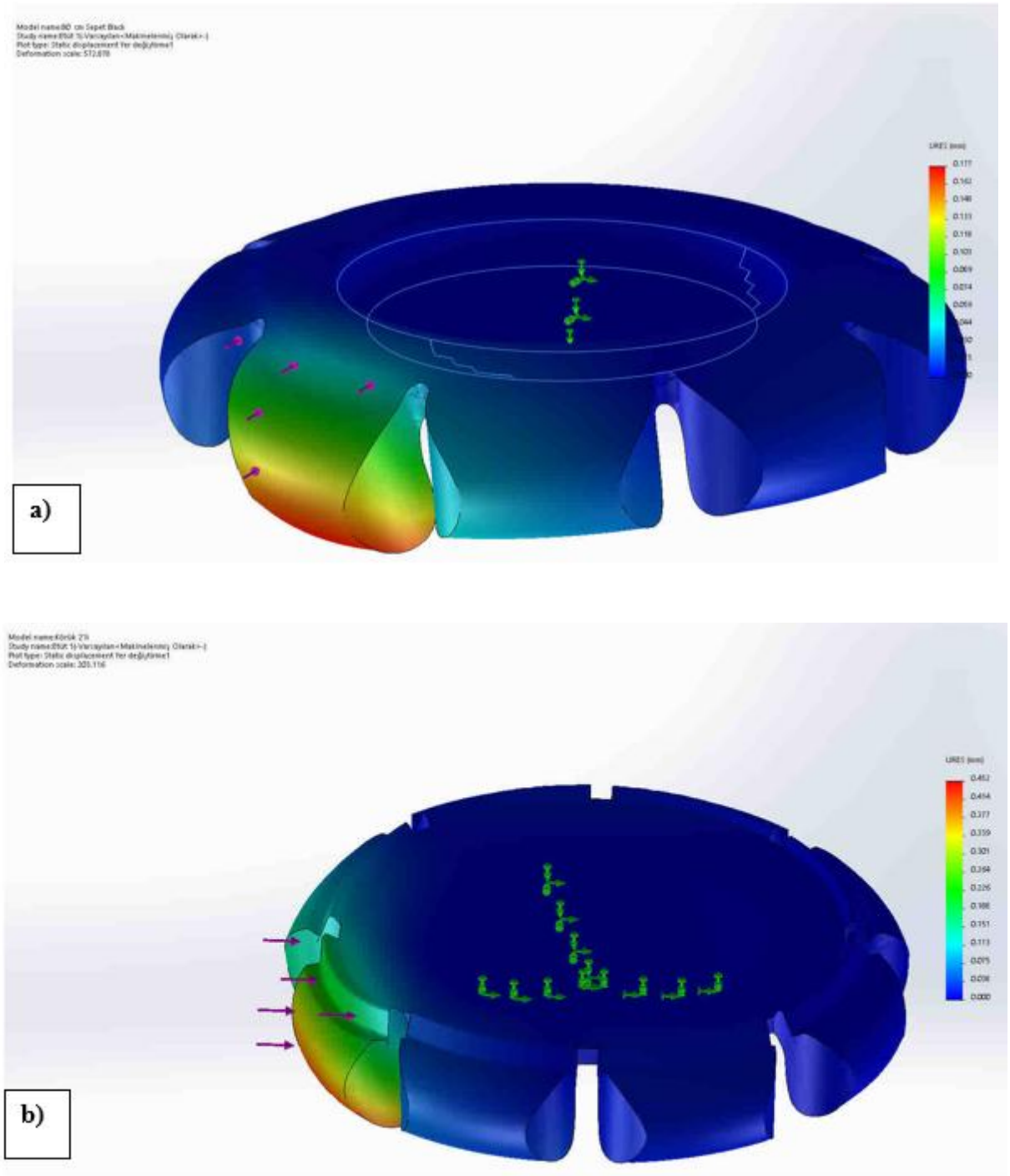

Figure 3. The displacement to be obtained in case of making a leaf design (a) and adding the protrusion (b) form on the leaf design

As a result of this design change, in the analysis made for polyethylene material under 10 kg of impact, the leaf pieces in the basket were max. 0.452 mm (Fig. 4a.) is displaced. If the choosing ICORENE 9104 material is for the swing with the same design, it is seen that ICORENE 9104 material without any damage has approximately 156 times more displacement (flexing) value than polyethylene material (Figure 4b). ICORENE 9104, which has a lower value than the modulus of elasticity (E) of the polyethylene material, has been changed to achieve higher displacement values.

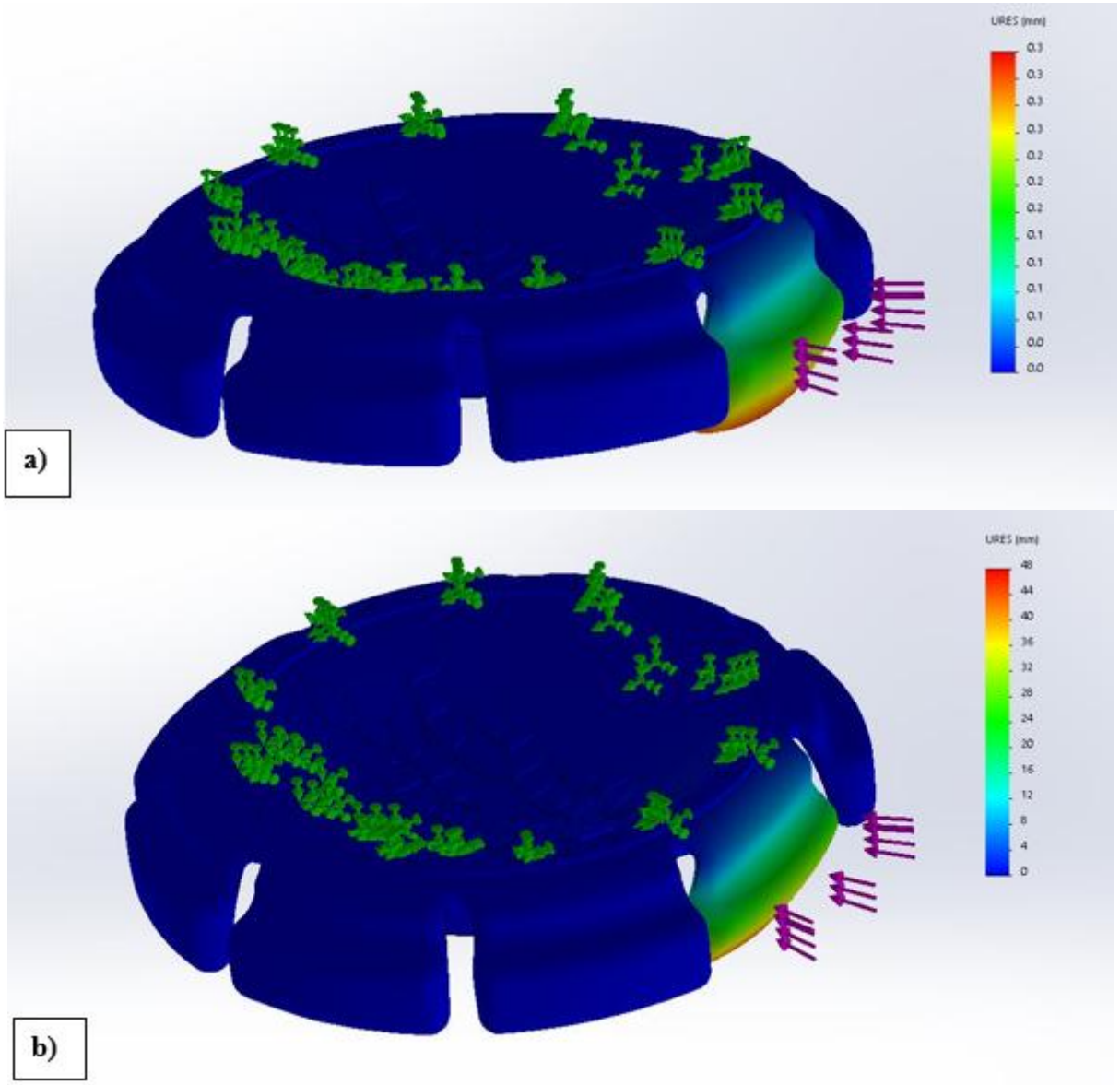

Figure 4. Displacement analysis results for a) polyethylene and b) ICORENE 9104 materials of the leaf design

Impact tests were also carried out for different materials of the analyzed designs. Impact tests were carried out in the test setup (Figure 1) prepared according to TSE EN1176-II Annex B. When tested in accordance with EN1176-II annex B, there shall be no peak values of acceleration greater than 50g and the average surface compression shall not exceed 90N/cm^2. Swing seats are raised and allowed to swing to strike a test mass. The signal emitted by an accelerometer during each impact is processed to determine the peak value of acceleration and the surface compression. The peak acceleration value is recorded as the average of the value of 10 impacts.

Samples with conventional design failed in the impact test with both polyethylene and ICO 9104 material. In the case of a basket swing with a leaf-spring design made of polyethylene material, lower displacement values were obtained as expected from the analysis results, and the impact tests failed due to damage.

The basket swing with leaf spring design produced with ICORENE 9104 material with a lower modulus of elasticity, was successful as expected from the analysis results. The average acceleration value measured as a result of the impact test was 15.1 g and the average surface compression was found to be 18.45 N/cm^3. In addition, no permanent deformities and damages were observed on the tested basked swing in the examinations made with the normal eye and with a magnifying glass, and no loosening was detected in any of the fasteners.

4. Conclusion

In the study, a design with higher displacement capability was made instead of a traditional basket swing in order to minimize the risks that may occur during impact. A thermoplastic elastomer material with lower elasticity than polyethylene has been chosen instead of a standard polyethylene material in order to achieve better impact-damping properties of this basket swing, which has a leaf-shaped design. The effect of the design and the selected materials on the displacement ability was first determined by the analyzes made with the Solidworks program. Then, both the traditionally designed swings and the leaf-shaped new design swings were produced from standard polyethylene and polyethylene with a low elasticity coefficient by rotational molding using aluminum molds. The swings produced were subjected to an impact test in accordance with EN 1176-2 Annex B. According to both analysis and impact test results, it has been revealed that if both the appropriate design and the appropriate material are selected, a basket swing with impact damping feature can be produced from polyethylene material.

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