Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2019, 6(8):38-44

Research Article ISSN: 2394 - 658X

Comparison of PLA and ABS on Robot Arm Model and 3D Technology

Hasan DEMİR and Atıl Emre COŞGUN

Department of Mechatronics, Aksaray University, Aksaray, Turkey
hasandemir@aksaray.edu.tr

ABSTRACT

The rapid growth of the population has led to the emergence of new technologies in production like 3D technologies. Today, 3D design and production is a technological issue that has gained considerable importance. Manufacturing product is producing in a short time. This is a great chance for the manufacturing industry. Also, many schools and workshops use 3D printers to support and develop children's imagination. In addition to, 3D design and printing are used in healthcare, aviation, military, daily life, engineering, fashion, footwear, and many other fields. When compared traditional manufacturing method, it has required low cost. Furthermore, it has easy installation and portable features. This paper is related to the strength comparison of the robotic arm produced with the raw material Poly-Lactic Acid (PLA) and Acrylonitrile Butadiene Styrene (ABS). Also, the carrying capacity of the robot was examined with the analyses program. Static analysis of the robot arm was carried out with 5N and 10N loads. The robotic arm has designed with 3D designed program. The robotic arm has 3 degre of freedom and a bi-directional gripper.

Key words: 3d print, pla, abs, robot arm

INTRODUCTION

The Three-Dimensional (3D) production, can be defined as additive manufacturing. The objects are produced by printers beginning from bottom side and continue to layer-by-layer to up side until the finish part. In the design process layer by layer production provide to much greater creativity and flexibility. While the product is producing, there is no any wastage. Stereolithography process, the first commercial rapid prototyping technology, and the STL file format has invented by Charles Hull [1]. As the raw material photopolymers was used on stereolithography process to get desired shape and size of the wanted product. Laser light was applied liquid the raw material for production [2]. After the Laser light production, selective laser sintering (SLS) and Fused Deposition Modelling (FDM) method were developed 1980s, and 1990. The 3D printer was developed in 1995 by Massachusetts Institute of Technology (MIT) [3]. To production the product it usually uses polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), polycarbonate (PC), and polyamide (PA) as consumables. First 3D printing application in the medical field is human bladder in 1999. After that it progressed by producing human kidney in 2000 and then producing prosthetic leg in 2009 [3]. In the construction industry field rapidly constructing 10 houses in less than 24 hours by a Chinese company of its huge 3D printer machine by in 2014 [4]. In the transportation field using with 3D printing technology, car and aeroplane parts are being printed [5]. Almost all the industries, 3D production techniques are being used such as healthcare, aviation, military, daily life, engineering, education, fashion, footwear, and many other fields. Some of the reasons preference of its all over the world are its to produce any type of product, required low cost, easy installation and being portable. In this paper is based on the strength comparison of the robotic arm produced with the raw material PLA and ABS. Also, the carrying capacity of the robot was examined with the analyses program. Static analysis of the robot arm was realized with 5N and 10N loads. The robotic arm has created with 3D designed program. The robotic arm has 3 degree of freedom and a bi-directional gripper.

3D PRINT TECHNOLOGIES AND MATERIALS

3D printing technology is one of manufacturing method known as ‘Additive manufacturing’. To create the desired shape which is used to instead of removing material to create a part [6]. 3D printing technologies are given in Figure1. 3D printing begins with a virtual design of the object. Process of 3D printing as shown in Figure 2. To be created a physical object virtual design is used. It is created with using 3D model program such as CAD (Computer Aided Design). Other than this, to be created an object, 3D scanner can be used. It provides 3D digital copy of an object for using to 3D modelling program [7].

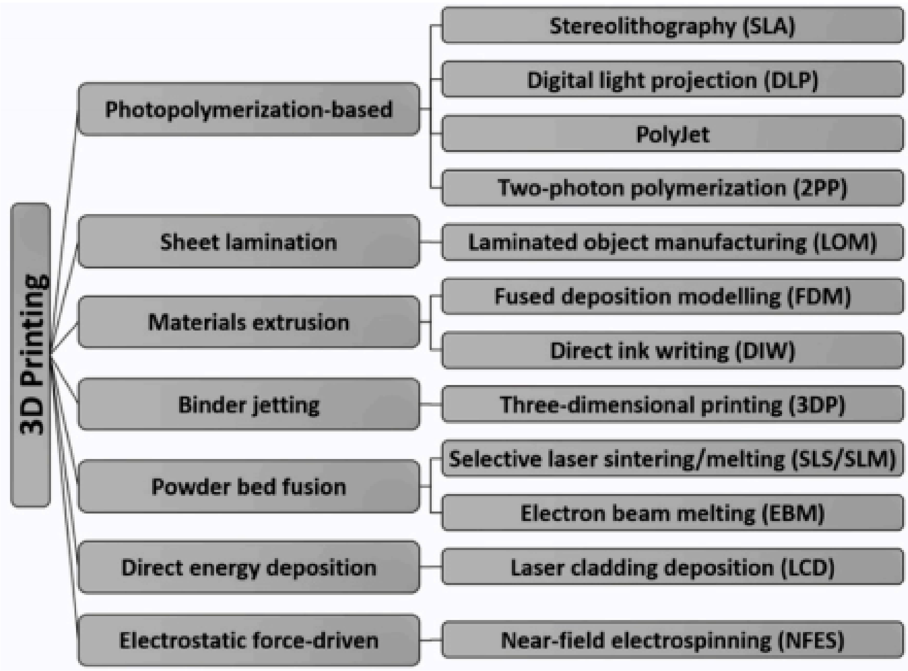

Fig. 1 3D printing technologies [8]

Then the CAD model file is converted to STL file format which includes the data for each single layer. After then, 3D printer machine use the STL file. There are some machine settings like layer thickness (0.01mm thick or less), infill rate of parts, knowledge of using raw materials such as PLA that is the most-used printing materials, ABS that is the second main plastic used in 3D printer machine, High Impact Polystyrene (HIBS), Polyvinyl Alcohol (PVA) that is used usually supportive materials, Nyalon, Carbon Fiber, Polycarbonate (sometimes called PC) that has transparent appearance. Objects are printed automatically without using any operator [9]. 3D Printing allows significantly speeds to produce the product.

Fig. 2 Process of 3D printing (from design to printing) [10]

EXPERIMENTAL STUDY

Series robot with three degrees of freedom and three rotating joints (RRR) is designed as a solid model. The robot consists of five parts: base, arm 1, arm 2, joint 2 and joint 3. Joint 1 is embedded in the base part. Joints are connected to each other by arms and base pins. The solid model drawing of the design is given in Figure 3.

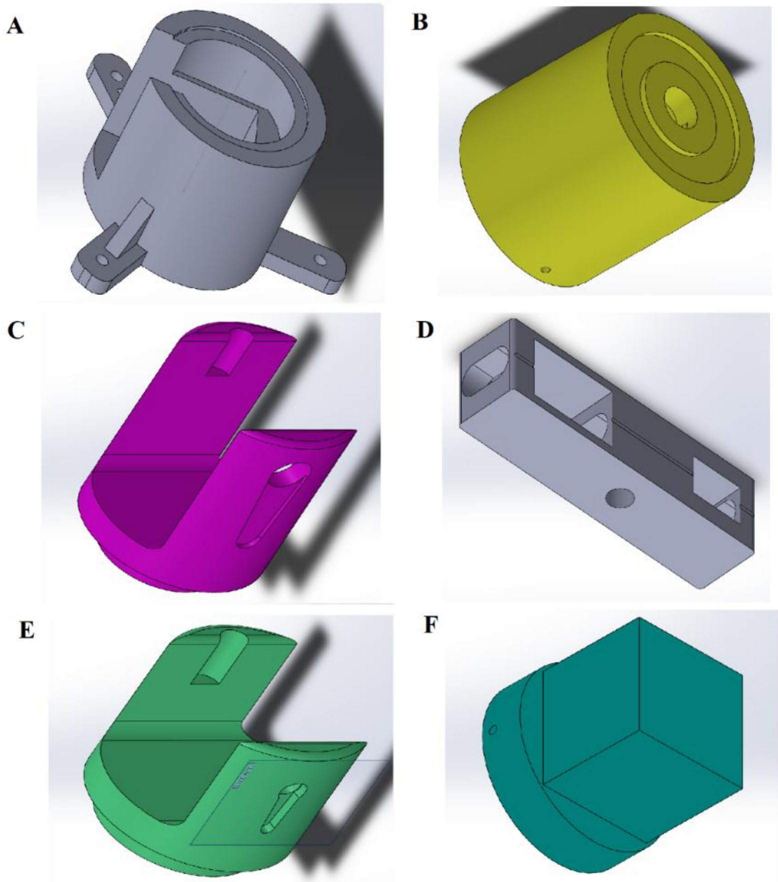

Fig. 3 RRR robot arm component: A) Base, B) Arm 1, C) Joint 1, D) Arm 2, E) Joint 3 and F) Load.

The robotic arm given in Figure 4 was formed by assembling with the designed and solid model components. The mounting points are connected by pins. Pin stiffness is given as the holding torque of the servo motors in the joints.

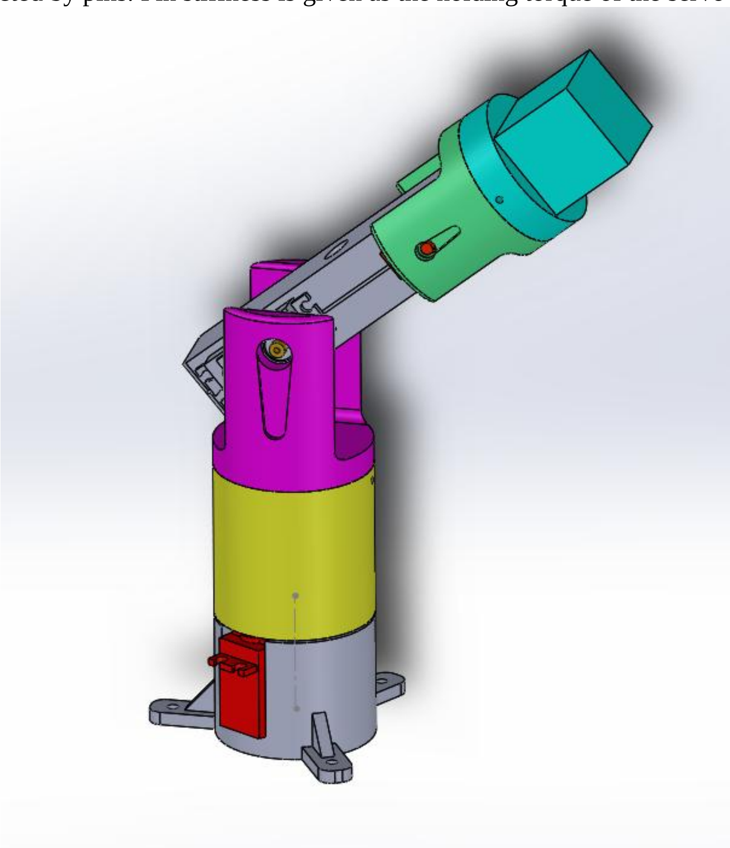

Fig. 4 The model of RRR robotic arm

The lengths of the designed robot part are given in Table 1. The lengths were determined regardless of any source. The analysis values of the 3D print of the robot design were examined by keeping the part lengths short.

Table -1 The lengths of the robot arm

Base	115 mm
Arm 1	45 mm
Arm 2	72 mm
Joint 3	47 mm

In the experimental studies, static analysis was made for PLA and ABS materials using the same design and two different load values. PLA and ABS materials are widely used in 3d printer technology due to its cheap cost. The mechanical properties of both materials are different. Stress values that occur in the material depend on their mechanical properties. Mechanical properties of the materials are given in Table 2.

Table -2 Mechanical Properties of PLA and ABS

Mechanical Properties	PLA	ABS
Density	1300 kg/m^3	1020 kg/m^3
Elastic (Young's, Tensile) Modulus	3.5 GPa	2 GPa
Poisson Rate	0.36	0.394
Tensile Strength	50 MPa	30 Mpa

The material mechanical properties given in Table 2 are defined as PLA and ABS mechanical properties in Solidworks static analysis simulation. Mesh element size was selected as 6mm and mesh tolerance as 0.3mm in all analyzes. The mesh element size was chosen to be small because the result of the analysis was desired to be close to real. Static analyzes were performed under 5N and 10N loads. As a result of the analysis, von Mises stresses and displacement results were found.

RESULTS

Stress and displacement results obtained from the analyzes are given in the figures. The results of the analysis using ABS material and a weight of 5N are given in Figure 5. The highest von Mises stress was observed in the second arm and the maximum stress is caused by the structural weakness in the pin connection slots. In other parts, stresses not exceeding 1Mpa were measured. The displacement graph shows the highest displacement in the third joint and its value is 85 mm.

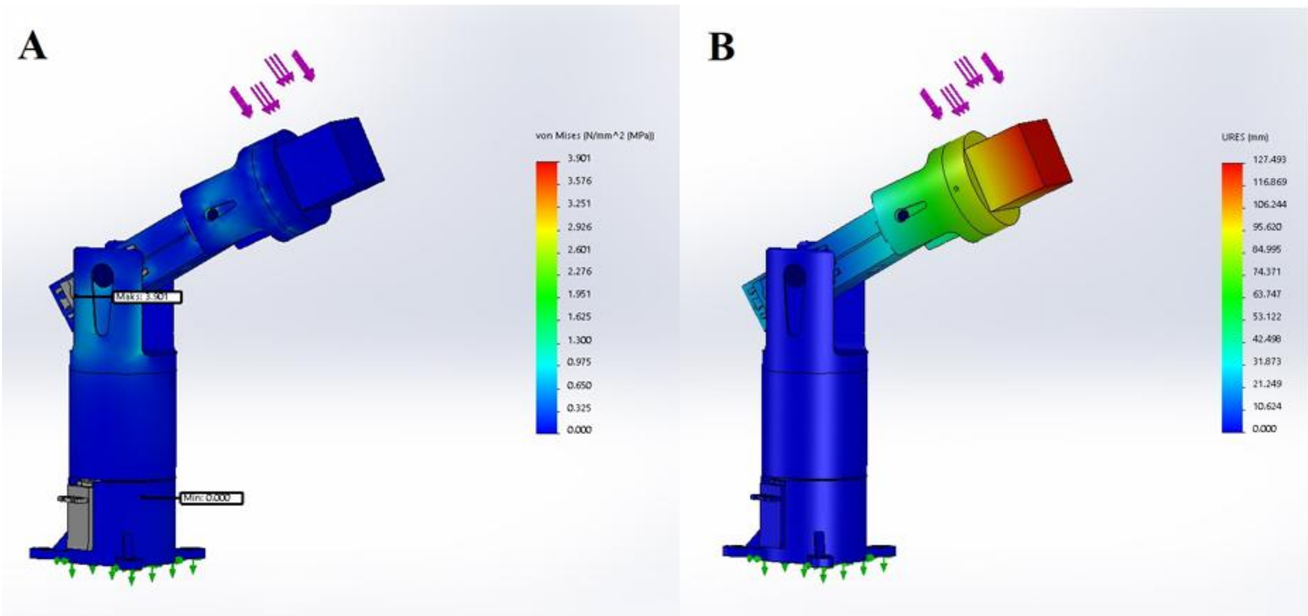

Fig. 5 Analysis results using ABS material and 5N load: A) von Mises Stress and B) Displacement

In the second analysis, 10N load was applied to the robot arm made of ABS material. The stresses and displacement graphs of the robot as the result of the analysis are given in Figure 6. Stress of 1.5 MPa was formed in the second joint in the robot body. However, the highest stress on the second arm was 7.8 MPa in the servo motor housing. Approximately 180 mm displacement was measured while the robot arm held the load statically.

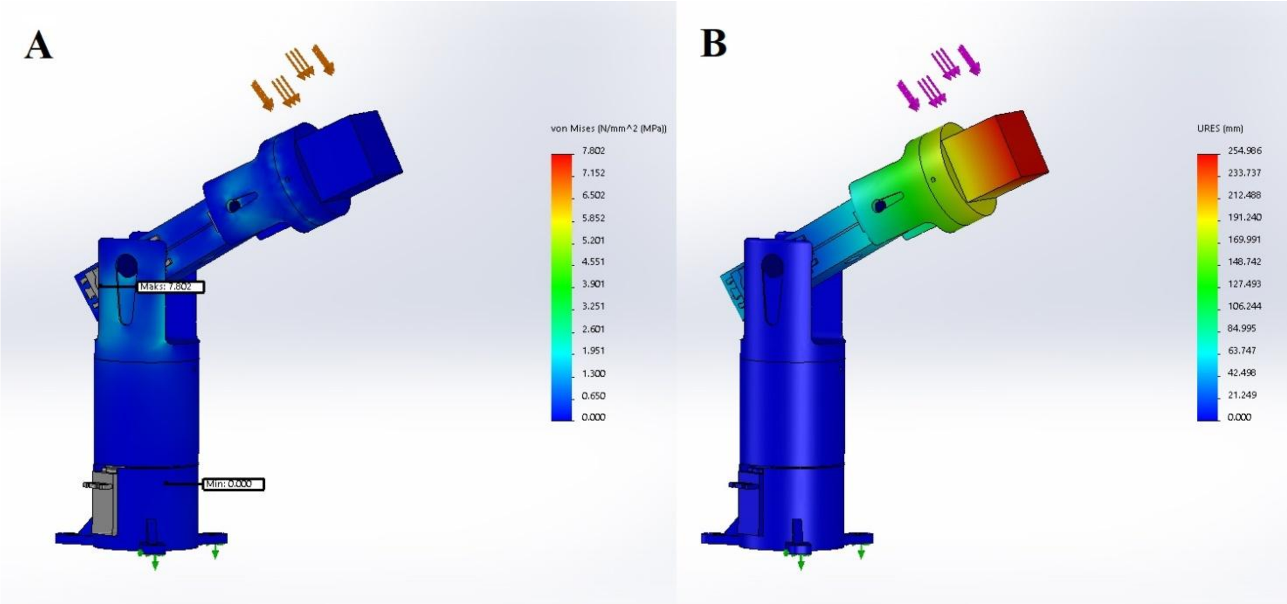

Fig. 6 ABS material and 10N load analysis results: A) von Mises Stress and B) Displacement

In the second part of the experimental studies, PLA was used as the material. Static analysis was performed on the robot arm with 5N and 10N. First, the analysis was performed under 5N load and stress and displacement were measured. The highest stress is in the servo motor housing in the second arm, while the stress on the robot arm is generally 1.3 Mpa. The maximum displacement on the robot arm is approximately 70 mm. The graphs of this analysis are given in Figure 7.

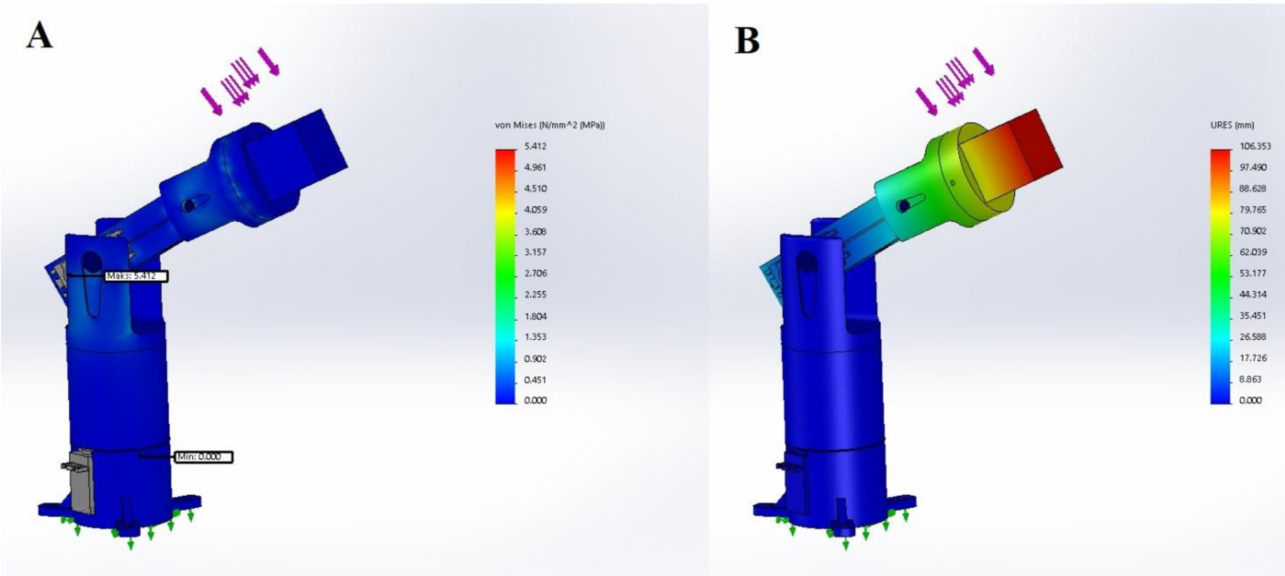

Fig. 7 Results of static analysis of PLA with 5N: A) von Mises Stress and B) Displacement

In the last analysis, PLA material and 10N weight were used. The results of the analysis are given in Figure 8. The stress in the servo motor housing in the second arm, which is the weakest structurally in the robot body, was measured as 10.8 MPa. The stress level in the robot arm body was measured as 2.7 MPa. The maximum displacement on the robot is about 130 mm.

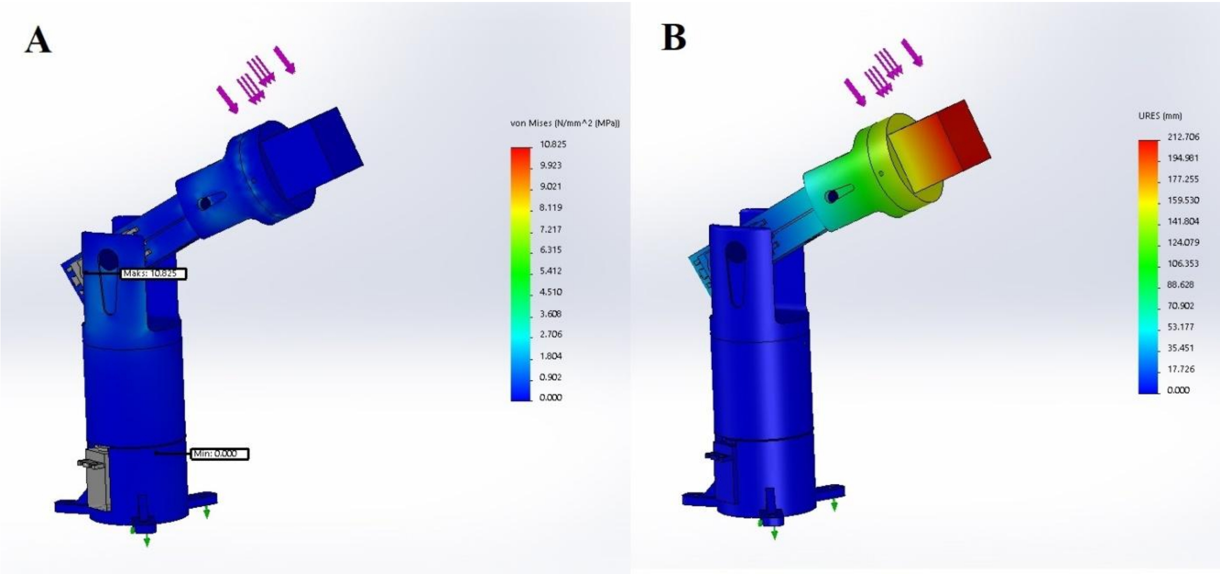

Fig. 8 Analysis results using 10N and PLA material: A) von Mises Stress and B) Displacement

The data obtained as a result of the analysis are given in Table 3. It shows the von Mises stress and displacement values of 5N and 10N loads on PLA and ABS materials. Figures 5, 6, 7 and 8 show where stress and displacement occur on the model robot. While Von Mises shows the stress on the model with the effect of stress load, the displacement patterns show the load and displacement on the robot arm.

Table -3 Mechanical Properties of PLA and ABS

Load	Von Mises Stress		Displacement	
	PLA	ABS	PLA	ABS
5N	1.3 MPa	1 MPa	70 mm	85 mm
10N	10.8 MPa	1.5 Mpa	130 mm	180 mm

CONCLUSION

3d printer technology has improved rapidly and increased its usage rate in the last decade. In 3d printer technology, materials such as polyamide, polycarbonate, polylactic acid and acrylonitrile butadiene styrene are used as raw materials. 3d printers are capable of fast production and they are used in many fields. This article presents the comparison of the mechanical strengths of ABS and PLA materials used in 3d printers. The three-jointed RRR robot arm was designed as a model. Static analysis of the robot arm was carried out with 5N and 10N loads. As a result of the analyzes, stress and displacements on the robot were observed. The maximum stress point on the model is formed in the servo motor housing on the second arm. When the von Mises stress distributions on the robot were examined, it was observed that the highest stress level was at the junction of the arms and joints. And it has been observed that the stress does not affect the structural integrity of the robot. In general, the stress on the robot design body appears to be less in ABS material. In addition, the stress of PLA material increased by 8.3 times and stress in ABS material increased by 1.5 times when 2 times load increase. This shows that the ABS material used in the analysis has better mechanical strength than PLA material. When the displacement graphs obtained as a result of the analyzes are examined, it is seen that the maximum deformation on the robot design is at the point where the third joint joins the load. In this design given in dimensions, it is seen that PLA has less displacement compared to ABS at 5N and 10N load. The minimum displacement was calculated to be approximately 70 mm under 5N load on PLA material. These displacement dimensions indicate that a 5N load is heavy for this given robot. Especially in robots working in fields such as rotating welding and bonding, position accuracy is very important. Therefore, even the smallest displacement calculated as a result of the analysis is a big error for an industrial robot arm.

In this study, when compared of two used material on robot, the stress resistance of ABS material was found to be better than PLA material. However, it has been found that the displacement property of PLA material is better than ABS. It is thought that the robot arm used in static analysis has low lifting capacity and can be used for training or for the processing of small parts with low load weight. These robotic arms produced with 3d printers are low cost solutions and will be used frequently in daily life in the future.

REFERENCES

[1]. https://en.wikipedia.org/wiki/Chuck_Hull
[2]. L Kumar, Q Tanveer, V Kumar, M Javaid and A Haleem, *Developing low cost 3 D printer* 2016, Int. Journal of Applied Sciences and Engineering Research, Vol. 5, Issue 6, [433-447].

[3]. S Kamble, SA Khoje, JA Lele, Recent Developments in 3D Printing Technologies : Review 2018, *Proceedings of the Second International Conference on Intelligent Computing and Control Systems (ICICCS 2018),* CFP18K74-ART; ISBN:978-1-5386-2842-3, [468-473].

[4]. M Goldin Chinese Company Builds Houses Quickly With 3D Printing, Web: http://mashable.com/2014/04/28/3d-printing-houseschina/, 2014.

[5]. D Basulto, How 3D printing could transform Amazon and online shopping Web: http://www.washingtonpost.com/blogs/innovations/wp/2 014/03/13/how-3d-printing-could-transform-amazonand-online-shopping/, 2014.

[6]. Europan Social Fund, Domain Group 3D Printing Workshop Notes, Web:https://education.gov.mt/en/resources/News/Documents/Youth%20Guarantee/3D%20Printing.pdf

[7]. TP Mpofu, C Mawere, M Mukosera, The Impact and Application of 3D Printing Technology 2014,, *International Journal of Science and Research (IJSR),* Volume 3, Issue 6, [2148-2152].

[8]. C Liu, N Huang, F Xu, J Tong, Z Chen, X Gui, Y Fu and C Lao, 3D Printing Technologies for Flexible Tactile Sensors toward Wearable Electronics and Electronic Skin, 2018, *Polymers 2018*, 629; doi:10.3390/polym10060629, [1-31].

[9]. S Jasveer, X Jianbin, Comparison of Different Types of 3D Printing Technologies 2018, *International Journal of Scientific and Research Publications*, Volume 8, Issue 4, [1-9].

[10]. C Kalnad, A review on 3D Printing, 2016, *International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE),* Volume 5, Issue 7, [2001-2004].