Gazi Mühendislik Bilimleri Dergisi
2020, 6(1): 62-69
Konferans Bildirisi/Conference Paper
https://dergipark.org.tr/gmbd

Araç Lastiklerinin Sırt Desen Tasarımında Üç Boyutlu Baskı Teknolojilerinin Kullanılabilirliğinin İncelenmesi Üzerine Deneysel Bir Çalışma

Derviş EROL[*,a], Battal DOĞAN[b], Mustafa BOZDEMİR[c]

[a,*] *Kırıkkale University, Department of Automotive Technology, ORCID:0000-0002-3438-9312, 71450, KIRIKKALE, TÜRKİYE*
[b] *Karatekin University, Department of Mechanical Engineering, ORCID:0000-0001-5542-4853, 18100, ÇANKIRI, TÜRKİYE*
[c] *Kırıkkale University, Department of Automotive Technology, ORCID:0000-0002-9332-2054, 71450, KIRIKKALE, TÜRKİYE*

MAKALE BİLGİSİ

Alınma: 06.02.2020
Kabul: 29.04.2020

***Anahtar Kelimeler**:*
3D prototip,
3D baskı teknolojisi,
Eklemeli imalat,
Lastik sırt desen tasarımı

[*]Sorumlu Yazar:
e-posta:
derol40@gmail.com

ÖZET

Taşıt lastiklerinin sırt desenlerinin; sürüş güvenliği, sürüş konforu, yakıt tüketimi, frenleme ve gürültü performans değerleri gibi farklı parametrelere bağlı olarak bilgisayar destekli tasarım programları yardımıyla üç boyutlu olarak tasarım çalışmaları yapılmaktadır. Lastik üretim kalıpları; yapıları itibariyle oldukça karmaşık ve imalatları çok pahalı olan sistemlerdir. Kaliteli bir taşıt lastiği üretiminde, lastik üretim kalıpları oldukça önemli bir yere sahiptir. Bilgisayar ortamında yapılan tasarımlardaki hatalar çoğu zaman tasarım sırasında fark edilememesinden dolayı imalat sırasında ortaya çıkmaktadır. Lastik kalıplarının imalatı yapıldıktan sonra ortaya çıkan tasarım hatalarından dolayı zaman ve maliyet açısından büyük zararlar yaşanmaktadır. Bu çalışma kapsamında lastik sırt desen prototip imalatı için; eklemeli üretim (Additive Manufacturing) yöntemlerinde deneysel çalışmalar yapılarak en uygun prototoip üretim yöntemin bulunması hedeflenmiştir. Bu amaçla geliştirilen lastik sırt desen prototip imalatı; Fused Deposition Modelling (FDM) ve Binder Jetting (3DP) teknolojilerine sahip olan iki farklı üç boyutlu baskı makineleri kullanılarak yapılmıştır. Ortaya çıkan üç boyutlu katı modellerin görüntü, kalite ve prototip üretim süreleri gibi teknik özellikler birbirleriyle karşılaştırılmıştır.

https://dx.doi.org/10.30855/gmbd.2020.01.06

An Experimental Study on Examination of the Usability of Three Dimensional Printing Technologies in Tread Pattern Design of Vehicle Tires

ARTICLE INFO

Received: 06.02.2020
Accepted: 29.04.2020

Keywords:
3D prototype,
3D printing technology,
Additive manufacturing,
Tire tread pattern design

[*]Corresponding Authors
e-mail:
derol40@gmail.com

ABSTRACT

Depending on different parameters such as driving safety, driving comfort, fuel consumption, braking and noise performance values, three-dimensional design studies of tread patterns of vehicle tires are carried out with the help of computer aided design programs. Tire production molds are the systems which are very complex and very expensive to manufacture due to their structure. In the production of a quality vehicle tire, tire production molds have a very important role. Errors in computer-generated designs are often unrecognizable in the process of designing and appear during the manufacturing process. Due to the design faults that occur after the manufacturing of the tire molds, there are great losses in terms of time and cost. In the scope of this study for the production of prototypes of the tire tread pattern; it is aimed to find the most suitable prototype production method by making experimental studies in additive manufacturing methods. Tire tread pattern prototype developed for this purpose is manufactured by using different three-dimensional printing machines with Stereolithography (SLA), Fused Deposition Modeling (FDM) and Binder Jetting (3DP) technologies. Technical properties such as image, quality and prototype production durations of the three dimensional solid models produced are compared with each other.

https://dx.doi.org/10.30855/gmbd.2020.01.06

1. INTRODUCTION *(GİRİŞ)*

Vehicle tires consist of a combination of rubber, cord fabric and steel wires and various chemicals. It is one of the most important parts as they enable the transfer of engine torque to the road by means of direct contact with the road. In the vehicles used today; pneumatic tires designed to hold compressed air are used. The first pneumatic tires were developed by John Boyd Dunlop in 1887 [1]. Vehicle tires; with the rapid development of science and technology, it is seen that it continues to develop very quickly until today.

Driving safety and driving comfort of the vehicle is one of the foremost important performance requirements of the tire. In addition to these performance characteristics, the tires are also considerably responsible for the fuel consumption of the vehicle. To put it simply, tires with a high fuel efficiency create less rolling resistance between the road and the tire during travel, resulting in less energy consumption. This means less fuel consumption. In addition to the fuel consumption performance of a tire, having a good braking performance in wet and dry ground conditions is a very important design criteria. Tire noise is known as the source of noise caused by the air trapped between the tire and the road. Tire noise is a very important parameter for the driving comfort and attention of the vehicle users for a long time. This noise can be disturbing not only for the driver but also for the people in the environment. For these reasons, the driving safety, driving comfort, fuel consumption, braking and noise performance values must be considered together in the tire design [2-4].

Tire consists of four main parts: tread, shoulder, sidewall and bead. Tread section of tire is the rubber part that comes into contact with the road. In this section; there are patterns consisting of canals and blocks to hold the road, traction, throw road surface water and cool the tire. Since the tread of the tire is in direct contact with the road, the wear is very high in this area. The causes of these wears are vehicle speed, road surface temperature, and other conditions of the road. Tread part must be resistant to wear and cutter materials on the road. Tread patterns are very important because of that it is contact area with road of the tire. Different tread pattern designs are used according to the conditions where each tire will be used. There are differences between the tread patterns of the summer tire and the winter tire [5-6].

In this study, the potential use of three-dimensional printing technologies in the automotive tire industry will be examined in various aspects. Tire tread pattern prototype developed for this purpose will be investigated by using different three-dimensional printing machines with Stereolithography (SLA), Fused Deposition Modeling (FDM) and Binder Jetting (3DP) technologies. Technical properties such as image, quality and prototype production durations of the three dimensional solid models produced are compared with each other. With the pre-prototype manufactured as a result of the study, it is foreseen that unexpected design errors and corresponding time and cost losses will be prevented without spending high costs during manufacturing process.

2. ADDITIVE MANUFACTURING TECHNOLOGIES *(EKLEMELİ İMALAT TEKNOLOJİLERİ)*

Three-dimensional printing technologies, one of the current technological developments; is widely used in many countries and firms throughout the worldwide. Three-dimensional printing technologies have a great potential to reduce both the design time and cost of a prototype product. Additive Manufacturing has the advantages of using many different materials such as plastic, ceramic, metal and composite as well as not limiting the design in terms of the manufacturing method. In additive manufacturing method; in contrast to traditional manufacturing methods which work with the principle of shaping or reducing the material by using known turning/milling type machines, manufacturing is done by adding and integrating material.

Three-dimensional printing technologies are various in terms of the way forming of layers and the structure of the material used, but they are identical in terms of the additive manufacturing principle. Some additive manufacturing methods produce the prototype product directly by dissolving the materials and others by combining the powdered material. Nowadays, the most widely used three-dimensional printing technologies are known as; Stereolithography (SLA), Selective Laser Sintering (SLS), Fused Deposition Modelling (FDM), Binder Jetting (3DP) and Direct Metal Laser Sintering (DMLS) [7].

2.1. Stereolithography (SLA)

Stereolithography production method; Californian designer Charles, W. Hull designed and manufactured the first machine that could produce a three-dimensional prototype of an item in the 1980's. This design registered as Stereolithography method in 1986

PRINT ISSN: 2149-4916 E-ISSN: 2149-9373

with the original patent number US4575330, has started a new process in the manufacturing sector [8-9]. Stereolithography is a process of ossification of photopolymer resin in a liquid state by means of an intensified point ultraviolet laser beam source. After each layer is created, tray of the printer is slightly lowered down during printing process. This process is repeated until the prototype product printed completely. As soon as, all the layers have been completed, the prototype product is taken as solid model from the photopolymer resin pool in liquid form. Three-dimensional printing method, as called Stereolithography is the first additive manufacturing technology to be commercialized and patented [6-7].

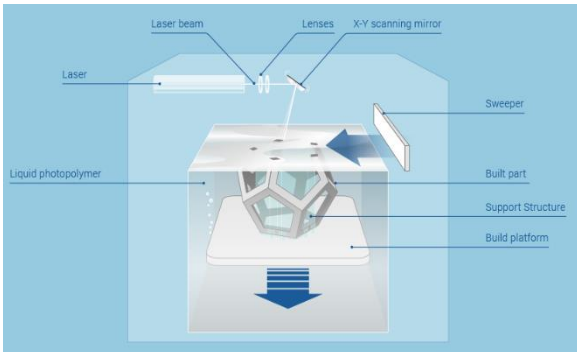

Figure 1. Schematic view of Stereolithography (SLA) system [10]
(Stereolitografi (SLA) sisteminin şematik görünümü)

2.2. Fused Deposition Modelling (FDM)

Fused Deposition Modeling (FDM) production method is one of the most preferred and accepted additive manufacturing techniques with its potential application areas today and in the near future. In 1989, Scott Crump, the founder of Stratasys Company, designed and manufactured the machine which can produce three-dimensional prototypes known as Fused Deposition Modeling (FDM) technology.

Fused Deposition Modeling production method, Polylactic Acid (PLA), Acrylonitrile Butadine Styrene (ABS), Polyamide, Polycarbonate, Polyethylene, Polypropylene and investment casting wax model materials can be used as raw material. These model materials are in the form of thin plastic wire (Filament).

The plastic material in the filament form is melted in a temperature-controlled nozzle and transferred to a moving head which follows the section geometry of the part and the thermoplastic material is laid on top of the production table in a way to overlap and in accordance with the shape of the solid model formed in the computer-aided design program. After this process, one of the layers forming the model geometry is completed. After each layer is created, tray of the printer is slightly lowered down during printing process. Resistance of the parts produced by this additive manufacturing method to stretching, bending, breakage, elongation, water and moisture is quite high. Depending on the geometry of the three-dimensional prototype model to be produced, there is a need for support structures in certain parts of the building, such as the skeletal structure built next to an apartment building. These support structures can be easily cleaned after the prototype production of the model is completed. Some post-processing such as painting, polishing and coating can be applied to the parts produced with Fused Deposition Modeling technology [11-13].

Compared to other additive manufacturing techniques, the low cost of three-dimensional printing machines and the high availability of consumables are the main advantages of Fused Deposition Modeling production technique.

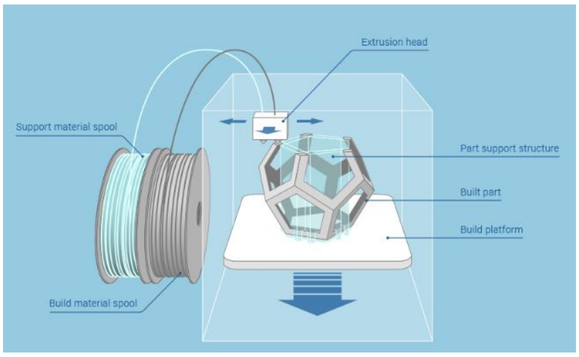

Figure 2. Schematic view of Fused Deposition Modelling (FDM) system [12]
(Fused Deposition Modelling (FDM) sisteminin şematik görünümü)

2.3. Binder Jetting (3DP)

Binder Jetting (3DP) method was developed by the Massachusetts Institute of Technology company using Ink-jet technology in two-dimensional printers. Binder Jetting technology; unlike other three-dimensional printing technologies, the material dispensed from the print head is not a building material, but a liquid adhesive material used to bring together the raw material in powder form. In this additive manufacturing method; solidification is carried out layer by layer according to the solid model designed in computer environment by spraying the liquid binder material from the nozzles in an Ink-jet head to certain parts of the powdered material. After each layer is created, tray of the printer is slightly lowered down during printing. The raw material in powder form is relaid as a very thin layer with the help of the movable roller mechanism onto the layer formed on the production table. This process is repeated until the prototype product is completely printed.

In this 3D printing technology, uncombined powders. Can support the overhanging structures of the model so it does not need additional support structures. As soon as, all the layers have been completed, the prototype product is taken from the powder bed. In addition, unused powders during three-dimensional printing process can be reused [13-15].

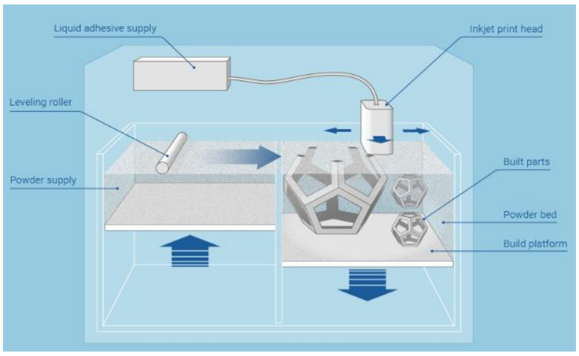

Figure 3. Schematic view of Binder Jetting (3DP) system [16]
(Binder Jetting (3DP) sisteminin şematik görünümü)

3. MATERIAL AND METHOD *(MALZEME VE METOT)*

Nowadays, the manufacturing of the tire production molds is generally carried out by using traditional manufacturing methods such as turning, milling and other machining of a metal material. Tire production molds are the systems which are very complex and very expensive to manufacture due to their structure. In the production of a quality vehicle tire, tire production molds have a very important place. Therefore, the design of the tire production molds developed by the designers is done in three dimensions with the help of computer aided design programs before manufacturing process. Errors in computer-generated designs are often unrecognizable in the process of designing and appear during the manufacturing process. Due to the design faults that occur after the manufacturing of the tire molds, there are great losses in terms of time and cost. Revision of faulty tire production molds that are manufactured requires more challenging processes than remanufacturing. Figure 4 shows pictures of vehicle tire molds with different tread patterns.

In this study, tire tread pattern prototype was manufactured by using different three-dimensional printing machines using Stereolithography (SLA), Fused Deposition Modeling (FDM) and Binder Jetting (3DP) technologies. Technical properties such as image, quality and prototype production durations of the three dimensional solid models produced are compared with each other. In the scope of this study, the drawings of vehicle tire models whose pre-prototypes to be manufactured in three-dimensional printer have been realized in a computer-aided design program called as SolidWorks. Figure 5 shows schematic views of the prototype tire tread pattern in SolidWorks environment. After the design of the vehicle tire model to be prototype manufactured, the related design files need to be converted to a software language that can be used by three-dimensional printers. This software language is described as STL (Stereo Lithography). Each piece in the SolidWorks environment has been rebuilt separately in STL format.

Figure 4. Vehicle tire tread pattern molds
(Taşıt lastik sırt desen kalıpları)

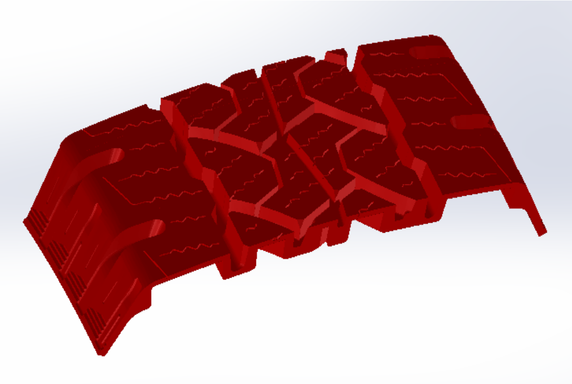

Figure 5. Schematic view of prototype tire tread pattern in the SolidWorks environment
(SolidWorks ortamındaki prototip taşıt lastik sırt desenin şematik görünümü)

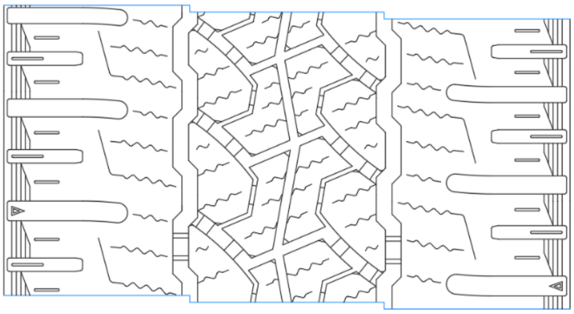

Figure 6. Drawing of tire tread pattern in the AutoCAD environment
(AutoCAD ortamındaki prototip taşıt lastik sırt desenin görünümü)

In the scope of this experimental study, prototype manufacturing of the vehicle tire model has been carried out by using Stereolithography (SLA), Fused Deposition Modeling (FDM) and Binder Jetting (3DP) technologies using the machines shown in Figure 7, 9 and 11 respectively.

Anycubic Photon S model three-dimensional printing machine, which is shown in Figure 7, uses Stereolithography (SLA) production technology. The maximum print dimension of this printer model is 115 x 65 x 165 mm. In the prototype manufacturing, special resin material sensitive to ultraviolet light was used. Photon S model can produce high resolution and smooth prototype parts in 25-100 micron layer range. Prototype vehicle tire model, which manufactured by Anycubic Photon S model three-dimensional printing machine is shown in Figure 8.

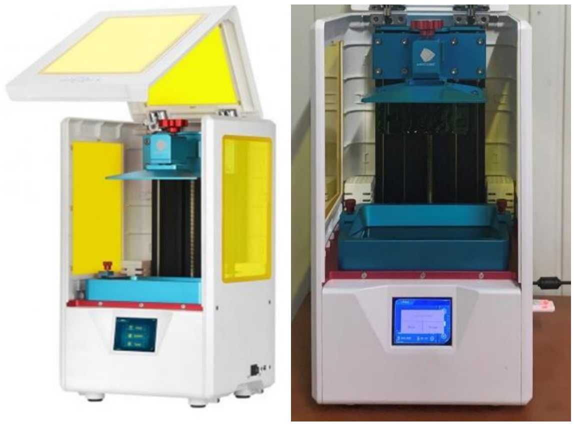

Figure 7. Anycubic Photon S model three dimensional printer *(Anycubic Photon S model üç boyutlu yazıcı)*

Figure 8. Pictorial view of tire tread pattern produced by Anycubic Photon S model three dimensional printer
(Anycubic Photon S model üç boyutlu yazıcıda üretilen lastik sırt desenin şematik görünümü)

The Zortrax M200 model three-dimensional printing machine uses Fused Deposition Modeling (FDM) as production technology. The maximum print dimension of the Zortrax M200 model is 200 x 200 x 180 mm. The Zortrax M200 model can conveniently use wide range of filament materials. In the production of prototypes, Zortrax's own product filament materials, which are known as Z-ABS, were used. Z-ABS filament materials are mostly preferred in the manufacture of parts which are used for the purpose of testing and getting matt and smooth surfaces. Three-dimensional parts with high quality, smooth and high resistance strength are produced with Zortrax M200 model. Prototype vehicle tire model manufactured by Zortrax M200 model three-dimensional printing machine is shown in Figure 10.

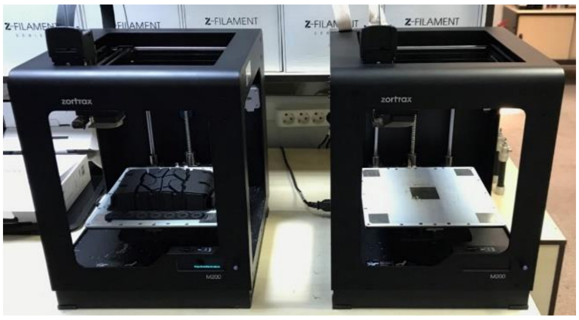

Figure 9. Zortrax M200 model three dimensional printers
(Zortrax M200 model üç boyutlu yazıcılar)

Figure 10. Pictorial view of tire tread pattern produced by Zortrax M200 model three dimensional printer *(Zortrax M200 model üç boyutlu yazıcıda üretilen lastik sırt desenin görünümü)*

The ZPrinter 650 model three-dimensional printing machine was developed by Z Corporation Company. ZPrinter 650 model three-dimensional printing machine uses Binder Jetting (3DP) as production technology. This three-dimensional printing machine can produce high-quality color prototype models with high quality CMYK color system. The maximum print dimension of the ZPrinter 650 model is 254 x 381 x 203 mm. Due to the large production volume, it is possible to produce prototype models in one piece. It provides high precision products with a layer thickness of ~100 µm Prototype vehicle tire model, which manufactured by ZPrinter 650 model three-dimensional printing machine, is shown in Figure 12.

Figure 11. ZPrinter 650 model three dimensional printer*(ZPrinter 650 model üç boyutlu yazıcı)*

Figure 12. Pictorial view of tire tread pattern produced by ZPrinter 650 model three dimensional printer *(ZPrinter 650 model üç boyutlu yazıcıda üretilen lastik sırt desenin görünümü)*

4. CONCLUSIONS *(SONUÇLAR)*

The use of rapid prototyping technologies, also known as additive manufacturing methods; research and development activities are much more efficient, errors in design can be solved very quickly and new designs can be improved more easily in terms of efficiency. In the scope of this study for the prototype production of the tire tread pattern; it is aimed to find the most appropriate method by making comparisons in additive manufacturing methods. The drawings of the vehicle tire models were made in the SolidWorks program, a computer-aided design program. Tire tread pattern prototype developed for this purpose was manufactured by using different three-dimensional printing machines with Stereolithography (SLA), Fused Deposition Modeling (FDM) and Binder Jetting (3DP) technologies. Technical properties such as image, quality and prototype production durations of the three dimensional solid models produced are compared with each other. As a result of the experimental studies, the following conclusions may be made for Stereolithography (SLA), Fused Deposition Modeling (FDM) and Binder Jetting (3DP) production methods.

- It is determined that prototype tire pattern samples produced by Stereolithography (SLA) and Binder Jetting additive manufacturing methods were produced faster and higher visual quality than the prototypes produced by Fused Deposition Modeling method.

- Some parts of the prototypes produced by Fused Deposition Modeling method have been damaged during production. It is determined that Stereolithography (SLA) and Binder Jetting production methods did not cause any damage during the manufacturing of prototype parts.

- Comparing with the differences such as the image quality, production time and cost obtained from prototype parts; the printer using the Stereolithography (SLA) technology has been found to be more advantageous.

- Stereolithography (SLA) production technology offered higher resolution and quality prints than the Fused Deposition Modeling (FDM) production technology. It is determined that prototype models produced with FDM technology have clear layer traces. However, compared to cost of printer and material used, the printers using Stereolithography (SLA) and Fused Deposition Modeling technologies comes to the forefront.

- Maximum print dimensions of the printer with Stereolithography (SLA) technology; Since Fused Deposition Modeling (FDM) and Binder Jetting (3DP) technology is lower than printers, prototype tire pattern is produced 50% smaller than its actual design.

For these reasons, it is determined that the correct determination of the three-dimensional printing technology to be used in the prototype production provides important contributions in terms of prototype print dimension, image quality, production time and cost.

NOTES

This study was published and presented in The Fourth International Congress on 3D Printing (Additive Manufacturing) Technologies and Digital Industry (3D-PTC2019) (11-14 April, 2019, Antalya, Turkey).

CONFLICT OF INTEREST *(ÇIKAR ÇATIŞMASI BİLDİRİMİ)*

No potential conflict of interest was reported by the authors.

REFERENCES *(KAYNAKLAR)*

[1] Erol, D., “Vehicle Tires” *Electronic Journal of Vehicle Technologies*, vol. 3, no. 3, pp. 37-50, 2011.

[2] Graham, W. R., “Modelling the vibration of tyre sidewalls” *Journal of Sound and Vibration*, vol. 332, no. 21, pp. 5345-5374, October 2013. Doi: https://doi.org/10.1016/j.jsv.2013.04.047

[3] Wei, Y., Yang, Y., Chen, Y., Wang, H., Xiang, D., and Li, Z., “Analysis of coast-by noise of heavy truck tires” *Journal of Traffic and Transportation Engineering*, vol. 3, no. 2, pp. 172-179, March 2016. Doi: https://doi.org/10.1016/j.jtte.2016.03.006

[4] Curtiss, W. W., “Principles of Tire Design” *Tire Science and Technology*, vol. 1, no. 1, pp. 77-98, February 1973. Doi: https://doi.org/10.2346/1.2167156

[5] Chu, C. H., Song, M. C., and Luo, V. C., “Computer aided parametric design for 3D tire mold production” *Computers in Industry*, vol. 57, no. 1, pp. 11-25, January 2006. Doi: https://doi.org/10.1016/j.compind.2005.04.005

[6] Dong, Y., Su, F., Sun, G., Liu, Y., and Zhang, F., “A feature-based method for tire pattern reverse modeling” *Advances in Engineering Software*, vol. 124, no. 1, pp. 73-89, October 2018. Doi: https://doi.org/10.1016/j.advengsoft.2018.08.008

[7] Dizon, J. R. C., Espera Jr, A. H., Chen, Q., and Advincula, R. C., “Mechanical characterization of 3D-printed polymers” *Additive Manufacturing*, vol. 20, no. 1, pp. 44-67, March 2018. Doi: https://doi.org/10.1016/j.addma.2017.12.002

[8] Hull, C. W., “Apparatus for production of three dimensional objects by stereolithography” *United States Patent No: US4575330*, 1986.

[9] Ngo, T. D., Kashani, A., Imbalzano, G., Nguyen, K. T., and Hui, D. “Additive manufacturing (3D printing):A review of materials, methods, applications and challenges” *Composites Part B: Engineering*, vol. 143, no. 1, pp. 172-196, June 2018. Doi: https://doi.org/10.1016/j.compositesb.2018.02.012

[10] “Stereolithography Technology (SLA),” www.additively.com, [Online]. Available: https://www.additively.com/en/learn-about/stereolithography [Accessed: Jan.. 12, 2019].

[11] Brenken, B., Barocio, E., Favaloro, A., Kunc, V., and Pipes, R. B., “Fused filament fabrication of fiber-reinforced polymers: A review” *Additive Manufacturing*, vol. 21, no. 1, pp. 1-16, May 2018. Doi: https://doi.org/10.1016/j.addma.2018.01.002

[12] “Fused Deposition Modeling Technology (FDM),” www.additively.com, [Online]. Available: https://www.additively.com/en/learn-about/fused-deposition-modeling, [Accessed: Jan.. 12, 2019].

[13] Holland, S., Tuck, C., and Foster, T., "Selective recrystallization of cellulose composite powders and microstructure creation through 3D binder jetting" *Carbohydrate Polymers*, vol. 200, no. 1, pp. 229-238, November 2018. Doi: https://doi.org/10.1016/j.carbpol.2018.07.064

[14] Liravi, F., and Toyserkani, E., "Additive manufacturing of silicone structures: A review and prospective" *Additive Manufacturing*, vol. 24, no. 1, pp. 232-242, December 2018. Doi: https://doi.org/10.1016/j.addma.2018.10.002

[15] Upadhyay, M., Sivarupan, T., and El Mansori, M., "3D printing for rapid sand casting-A review" *Journal of Manufacturing Processes*, vol. 29, no. 1, pp. 211-220, October 2017. Doi: https://doi.org/10.1016/j.jmapro.2017.07.017

[16] "Binder Jetting Technology (3DP)," www.additively.com, [Online]. Available: https://www.additively.com/en/learn-about/binder-jetting, [Accessed: Jan.. 12, 2019].

Derviş EROL

Derviş Erol was born in Kırşehir, Turkey, on 01 the of June, 1982. He received his BS degree in Automotive Technology Department, Faculty of Technology, Gazi University in 2006, Turkey. He earned his MS degree in the same university in 2009. He is currently a PhD student in Department of Mechanical Engineering, Hitit University. He has been working since 2012 as a lecturer in Automotive Technology Department. He is currently working as a lecturer in Kırıkkale University. His research areas of interest include internal combustion engine, vehicle tires, Stirling engine, alternative renewable fuels and exergy analysis in thermal systems. He has published more than 20 research papers in international and national journals/conferences.

Battal DOĞAN

Battal Doğan was born in Kırıkkale, Turkey, on 21 December 1974. He received his BS degree in Department of Mechanical Engineering, Faculty of Engineering, Kırıkkale university in 2000, Turkey. He earned his MS and PhD degrees in the same university. His main research interest is energy and exergy analyses in thermal systems. His research areas of interest include internal combustion engine, stirling engine, alternative renewable fuels, heat transfer and compresors. He is currently working as an assistant professor at the Department of Mechanical Engineering of Karatekin university. He has published more than 50 research papers in international and national journals/conferences.

Mustafa BOZDEMİR

Mustafa Bozdemir was born in Kırıkkale, Turkey, on 01 January 1973. He received his MS degree in Mechanical Education (1996) and Ph.D. degree in Department of Mechanical Education (2003) from The Gazi University, Turkey. His research interests include design theory and methodology, 3D printers, weapon systems-ballistic, intelligent CAD, and Artificial intelligent. He is currently working as an Professor in Kırıkkale University. He has published more than 100 research papers in international and national journals/conferences.