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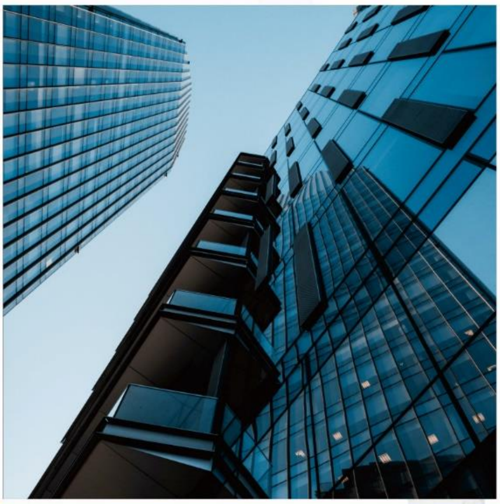

Prosiding Simposium Nasional

RAPI XXI 2022

Rekayasa Aplikasi Perancangan dan Industri

Peran Engineer dalam Mendukung Perwujudan “Konsumsi yang Bertanggung Jawab”

FAKULTAS TEKNIK
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Pelaksanaan	Selasa-Rabu, 13-14 Desember 2022
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Kata Pengantar

Fakultas Teknik Universitas Muhammadiyah Surakarta memprakarsai konferensi tingkat nasional pada tahun 2001 (Rekayasa Aplikasi Perancangan dan Industri atau RAPI). Pada tahun 2013, telah diselenggarakan ICETIA (International Conference on Engineering, Technology, and Industrial Application) pertama sebagai versi internasional dari RAPI. Sejak itu, kedua ICETIA berlangsung bersamaan dengan RAPI.

Tahun ini, ICETIA dan RAPI 2022 mengambil tema “Peran Engineer dalam Mendukung Perwujudan "Konsumsi yang Bertanggung Jawab". Melalui tema ini, RAPI berupaya untuk menghadirkan inovasi dan terobosan teknik yang berbeda, terutama yang relevan dengan konsumsi sumber daya alam yang bertanggung jawab yang merupakan 1 dari 17 tujuan dari *Sustainable Development Goals* (SDs) atau Tujuan Pembangunan Berkelanjutan (TPB). TPB/SDGs merupakan komitmen global dan nasional dalam upaya untuk menyejahterakan masyarakat dalam rangka pembangunan yang menjaga peningkatan kesejahteraan ekonomi masyarakat secara berkesinambungan, pembangunan yang menjaga keberlanjutan kehidupan sosial masyarakat, pembangunan yang menjaga kualitas lingkungan hidup serta pembangunan yang menjamin keadilan dan terlaksananya tata kelola yang mampu menjaga peningkatan kualitas hidup dari satu generasi ke generasi berikutnya.

RAPI berupaya mewadahi munculnya ide, konsep, aplikasi, praktik terbaik, dan penelitian dari teknik elektro, teknik industri, teknik mesin, teknik kimia, lingkungan binaan, teknik sipil dan bidang terkait lainnya di bidang teknik dalam upaya mencapai tujuan Komsumsi yang Bertanggung Jawab. Terdapat 28 artikel yang akan dikelompokkan menjadi 7 sub-tema yaitu: Teknologi Informasi Ramah Lingkungan; Desain dan Manajemen Produk; Optimisasi Sistem Industri; Manajemen Air dan Sumber Daya Air; Pembangunan Lingkungan Berkelanjutan; dan Rekayasa Material. Prosiding ini menjadi dokumen penting yang berisi kumpulan makalah yang telah dipresentasikan dan bisa dipergunakan sebagai referensi semua pihak yang membutuhkan.

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Tema 3:
OPTIMISASI SISTEM INDUSTRI

Tema 4:
DESAIN DAN MANAJEMEN PRODUK

Tema 5:
MANAJEMEN AIR DAN SUMBER DAYA AIR

Tema 6:
PEMBANGUNAN LINGKUNGAN BERKELANJUTAN

2022: Prosiding Simposium Nasional Rekayasa Aplikasi Perancangan dan Industri

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Front Matter

Articles

THE EFFECT OF PRINTING SPEED AND NOZZLE TEMPERATURE ON TENSILE STRENGTH, GEOMETRY, AND SURFACE ROUGHNESS OF A PRODUCT PRINTED USING ABS FILAMENT

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Abstract

3D printing is an additive manufacturing technology that can quickly create 3D models by softening thermoplastic filaments layer by layer. In making objects using 3D printing technology, there are several parameters that affect the strength of the printed objects, including the printing speed and nozzle temperature. This study aims to investigate effect of printing speed and nozzle temperature on tensile strength, geometry, and surface roughness of a product printed using ABS filament. The printing speeds were varied at 30, 40, and 50 mm/s while the nozzle temperature vaeried at 235, 245, and 255 °C. The tensile test was carried out on the printed specimens according to ASTM D-638-02a. The surface roughness and geometry tests were carried out on the printed specimen with dimensions of 30x30x40 mm. The surface roughness and geometry tests were performed on the vertical side in order to examine the layer and the change of height. The results concluded that the optimum printing speed and nozzle temperature based on the research conducted were 30 mm/s and 255 °C where the tensile strength as high as 33.52 MPa was obtained.

Keywords: *3D printing, printing speed, nozzle temperature*

Introduction

3D printing is an additive manufacturing technology that can create three-dimensional objects based on designs by pushing softened thermoplastic polymer filaments through the nozzle layer by layer (Shahrubudin, Lee, & Ramlan, 2019; Wang, Blache, & Xu, 2017). This technology was first introduced by Charles Hull in the late 80's (Malloy, 2010). Recently, 3D printing is widely used in many sectors including agriculture, automotive, aviation and health. Through this technology, many products can be produced quickly, accurately, and efficiently (Keleş, Blevins, & Bowman, 2017). Based on ASTM F2792-12a terminology, 3D printing technology is grouped into 7 groups, namely binding jetting, directed energy deposition, extrusion material, jetting material, powder bed fusion, sheet lamination and vat photo polymerization (ISO/ASTM, 2013). From these various types, 3D printing technology is currently not only used for prototyping but can be used to make various kinds of products that can be used directly (Wang et al., 2017). In the process of making prototypes and final products, there are several important parameters that need to be considered to produce a prototype or final product in accordance with the design made and have the strength as expected. Several important parameters in the manufacturing process using FDM type 3D printing are printing speed, nozzle temperature, infill density, layer orientation, and some other parameters. Some of these parameters are very influential on the printing results so that it is necessary to determine the best parameters to obtain the desired mechanical properties.

Research on the effect of parameters on the tensile strength of FDM type 3D printing has been reported, including research conducted by Hasdiansah & Suzen (2021). In this study, the nozzle temperature was varied at 205, 215, and 225 °C but the filament used was PLA+Sugoi. As a result, the highest tensile strength of 32.40 MPa was obtained with a nozzle temperature of 205 °C with a concentric infill type where the higher the nozzle temperature, the lower the tensile strength. However, different results are shown in the infill lines, cubic, octet, and zigzag types where the higher the nozzle temperature, the higher the tensile strength even though it is only in the range of 20-25 MPa. From this study, the higher the temperature is not directly proportional to the tensile strength produced (Hasdiansah & Suzen, 2021). To the contrary, another study stated that the nozzle temperature is directly proportional to the tensile strength reported by other researchers where the higher the nozzle temperature, the higher the tensile strength in specimens made using PLA filaments (Pamasaria, Herianto, & Saputra, 2019). From these two research results, it is necessary to confirm the effect of nozzle temperature on the resulting tensile strength.

In addition to the nozzle temperature, an important parameter to produce the highest tensile strength is the printing speed. Effect of the printing speed was also reported that the lower the speed the better tensile strength. But, this study uses PLA filament (Setiawan, 2017). Thus, there are several things that need to be confirmed to ensure the effect of nozzle temperature and printing speed on tensile strength of a 3D printing product. Most of the research that has been done is using PLA filament because the operating temperature is lower than ABS filament. However, ABS filament has better strength than PLA as reported by Ikhsanto & Zainuddin (2019). Based on the results of several previous studies, one of the important factors to get the best mechanical properties (tensile strength) is infill density followed by printing orientation and layer thickness. The higher the infill density (can reach 100%) and the layer thickness, the higher the tensile strength, which is in the range of 11-13 MPa (Radhwan, Shayfull, Abdellah, Irfan, & Kamarudin, 2019). However, using an infill density of 100% has drawbacks such as requiring a lot of material and making the product heavier. As a comparison, other researchers said that only 80% infill density can produce an optimal tensile strength of 32.64 MPa (Samykano et al., 2019). Another parameter that affects the mechanical property is the nozzle temperature. This result has been reported by previous research that the higher the nozzle temperature, the higher the bending strength where the highest bending strength is obtained at a nozzle temperature of 244 ^{o}C (Ikhsanto & Zainuddin, 2019). Nevertheless, the varied temperatures are still quite far from the maximum operating temperature that can be applied to ABS material, which is 260 ^{o}C. The results of other studies have also reported that print speed influences the tensile strength. Other researchers have also concluded in their research that the speed of 100 mm/s produces lower tensile strength when compared to the speed of 80 mm/s but this study used PLA material for the manufacture of test specimens (Setiawan, 2017). These parameters affect the quality of the printing results such as surface roughness, dimensions, and product geometry.

Research Methodology

An eSun ABS filament with diameter of 1.75 mm was used in this research. The tensile test was carried out using Universal Testing Machine (JTM-UTC 220) on the printed specimens according to ASTM D-638-02a Type I. Surface roughness test was performed using surface roughness tester (SurfcomTouch 5.0). Geometry measurement was also carried out using a digital vernier caliper (Mitutoyo). The surface roughness and geometry tests were carried out on the printed specimen with dimensions of 30x30x40 mm. The surface roughness and geometry tests were performed on the vertical side to examine the layer and the change of height. The ABS test specimens were printed using Flashforge Creator Pro. The printing process performed considering two different parameters as variables which are the printing speed (30, 40, and 50 mm/s) and nozzle temperature (235, 245, and 255 ^{o}C) where the constant value was chosen including 80% infill density, 110 ^{o}C board temperature, and 0.4 mm layer thickness. All the tests were done with three replications for each specimen.

Results and Discussions

The effect of the printing speed on tensile strength is shown in Figure 1. Based on the figure, the tensile stress values for speeds of 30, 40, and 50 mm/s are 32.41, 18.75, and 19.23 MPa, respectively. These results indicate that the printing speed is very influential on the strength where the slower the printing speed, the higher the strength of the specimen printed using ABS filament. These results confirm from the previous research by Setiawan (2017).

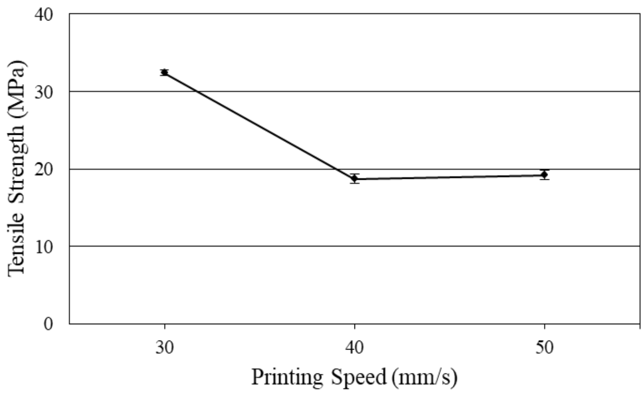

Figure 1. Effect of printing speed on tensile strength

These results affect the roughness value (Ra) obtained from the results of the surface roughness test, the influence of the printing speed on the roughness value as can be seen in Figure 2. Based on this figure, the roughness value (Ra) in the printed specimen has a directly proportional relationship printing speed. The higher the printing speed, the higher the roughness value. The roughness values for the printing speeds at 30, 40, and 50 mm/s were 31.64, 33.02, and 33.18 µm, respectively. Based on these results, it can be concluded that the profile formed between layers is getting wider or rougher along with the faster printing speed given when making the specimen. However, to prove this, it is necessary to test through micro/SEM photos.

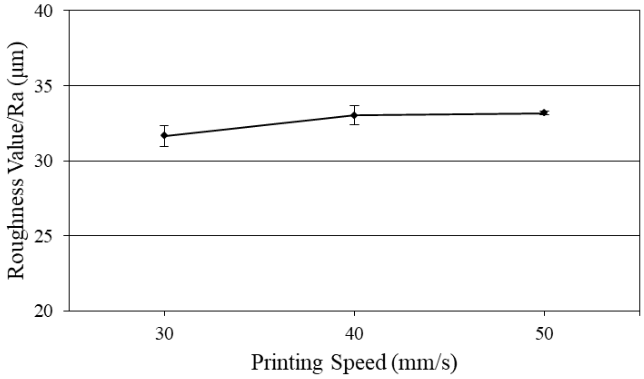

Figure 2. Effect of printing speed on surface roughness

In addition, based on the geometry test to determine the changes in the height of the specimens that have been carried out, the results also show a directly proportional relationship to the printing speed as can be seen in Figure 3. It can be seen in the figure, shrinkage occurs at a printing speed of 30 mm/s. At higher speeds of 40 and 50 mm/s, the height of the specimen increases. This indicates that for a speed of 30 mm/s, there is a better interlayer connection compared to 40 and 50 mm/s which causes the bond between layers to become stronger and has a direct impact on the tensile strength.

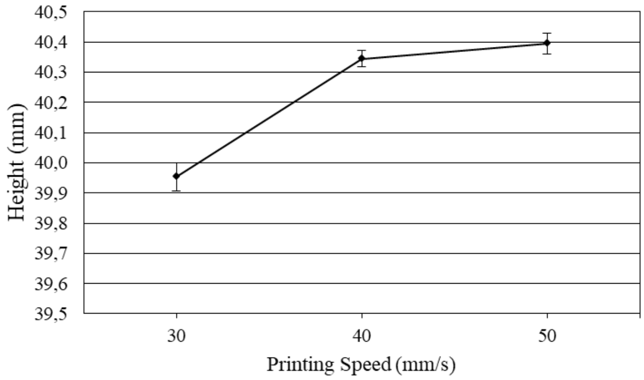

Figure 3. Effect of printing speed on changes of height

From the tensile strength test that has been done on specimens made using the best printing speed obtained from the previous discussion, which is 30 mm/s, the results can be seen in Figure 4. Based on this figure, the tensile stress values for nozzle temperatures are 235 ºC, 245 ºC, and 255 ºC was 31.58, 32.41, and 33.52 MPa, respectively. Compared with a temperature of 245 ºC which is used to determine the effect of printing speed, by using a nozzle temperature of 235 ºC, there is a decrease in tensile strength. However, by using a nozzle temperature of 255 ºC, there is an increase in tensile strength. Thus, these results indicate that the nozzle temperature also affects the tensile strength. The higher the nozzle temperature, the higher the tensile strength of the specimen when it is made with a low printing speed i.e. 30 mm/s.

These results also affect the roughness value (Ra) obtained as can be seen in Figure 5. Based on the figure, the roughness value (Ra) in the printed specimen has an inverse relationship with the nozzle temperature. The higher the nozzle temperature, the lower the roughness value. The roughness values for each nozzle temperature at 235, 245, and 255 oC were 32.66, 31.64, and 30.81 µm, respectively. Based on these results, it can be concluded that the profile formed between layers is getting denser or smoother as the nozzle temperature increases when the specimen is made.

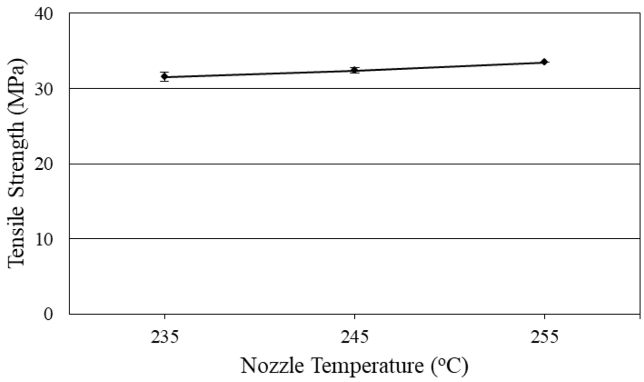

Figure 4. Effect of nozzle temperature on tensile strength

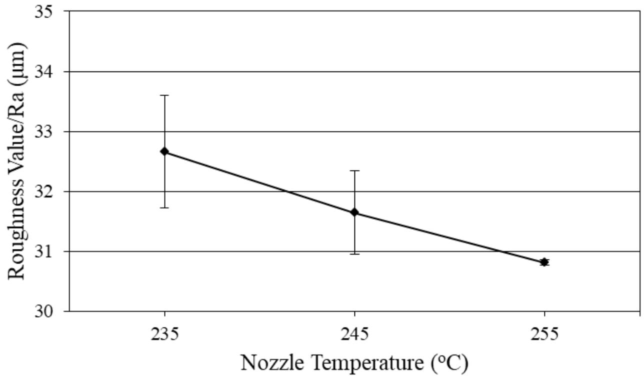

Figure 5. Effect of nozzle temperature on surface roughness

In addition, based on the geometry test to determine the change in the height of the specimen that has been carried out, the results also show a directly proportional relationship to the nozzle temperature as can be seen in Figure 6. It can be seen in the figure, the higher the nozzle temperature, the higher the shrinkage that occurs. Thus, it can also be concluded that the bonding layer by layer is getting tighter and stronger and has a direct impact on the tensile strength. This result is also directly proportional to the surface roughness measured using the surface roughness tester.

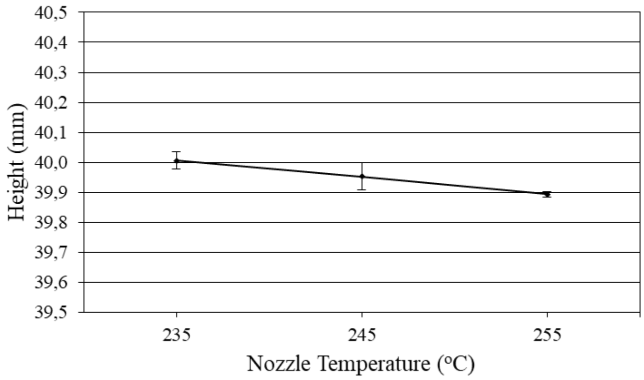

Figure 6. Effect of nozzle temperature on changes of height

Conclusions

Based on the description of the results and discussions that have been done, several conclusions can be obtained as follows:

1. Printing speed has an inverse relationship to tensile strength. The higher the printing speed, the lower the tensile strength. This result is related to the roughness and shrinkage of the size in the vertical direction (height of the specimen). The higher the printing speed, the higher the roughness value. This indicates that the profile formed between layers is getting wider or coarser with the faster the printing speed. However, the lower the printing speed i.e. at a printing speed of 30 mm/s, the greater the height reduction. This

indicates that for the speed of 30 mm/s, there is a better interlayer connection compared to 40 and 50 mm/s which causes the bond between layers to become stronger and has a direct impact on the tensile strength.

2. The nozzle temperature also has an influence on the tensile strength. However, the nozzle temperature has a directly proportional relationship to the tensile strength. The higher the nozzle temperature, the higher the tensile strength. A high tensile strength of 33.52 MPa was obtained at a temperature of 255 ^oC. In addition, the higher the nozzle temperature, the lower the surface roughness and the higher the shrinkage. These results also indicate that the merging between layers is getting better and the bonds between layers are getting stronger, resulting in higher tensile strength.

References

Hasdiansah, H., & Suzen, Z. S. (2021). Pengaruh Geometri Infill terhadap Kekuatan Tarik Spesimen Uji Tarik ASTM D638 Type IV Menggunakan Filamen PLA+ Sugoi. Jurnal Rekayasa Mesin, 16(2), 140.

Ikhsanto, L. N., & Zainuddin, Z. (2019). Analisa Kekuatan Bending Filamen Abs Dan Pla Pada Hasil 3D Printer Dengan Variasi Suhu Nozzle. Media Mesin: Majalah Teknik Mesin, 21(1), 9–17.

ISO/ASTM. (2013). Additive Manufacturing - General Principles Terminology (ASTM52900). Rapid Manufacturing Association, 10–12.

Keleş, Ö., Blevins, C. W., & Bowman, K. J. (2017). Effect of build orientation on the mechanical reliability of 3D printed ABS. Rapid Prototyping Journal, 23(2), 320–328.

Malloy, R. A. (2010). Plastic Part Design for Injection Molding. In Plastic Part Design for Injection Molding.

Pamasaria, H. A., Herianto, & Saputra, T. H. (2019). Pengaruh Parameter Proses 3D Printing Tipe Fdm (Fused Deposition Modeling) Terhadap Kualitas Hasil Produk. Seminar Nasional IENACO, 1–7.

Radhwan, H., Shayfull, Z., Abdellah, A. E. H., Irfan, A. R., & Kamarudin, K. (2019). Optimization parameter effects on the strength of 3D-printing process using Taguchi method. AIP Conference Proceedings, 21-29.

Samykano, M., Selvamani, S. K., Kadirgama, K., Ngui, W. K., Kanagaraj, G., & Sudhakar, K. (2019). Mechanical property of FDM printed ABS: influence of printing parameters. International Journal of Advanced Manufacturing Technology, 102(9–12), 2779–2796.

Setiawan, A. (2017). Pengaruh Parameter Proses Ekstrusi 3D Printer Terhadap Sifat Mekanis Cetak Komponen Berbahan Filament PLA (Poly Lactide Acid). Jurnal Teknika STTKD. ISSN : 2460-1608, 4(2), 20–27.

Shahrubudin, N., Lee, T. C., & Ramlan, R. (2019). An overview on 3D printing technology: Technological, materials, and applications. Procedia Manufacturing, 35, 1286–1296.

Wang, Y., Blache, R., & Xu, X. (2017). Selection of additive manufacturing processes. Rapid Prototyping Journal, 23(2), 434–447.