MECHANICAL BEHAVIOR AND STATISTICAL ANALYSIS OF POLYETHYLENE TEREPHTHALATE GLYCOL

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DOCTOR OF PHILOSOPHY

UNIVERSITI MALAYSIA PAHANG
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SUPERVISOR'S DECLARATION

I/We* hereby declare that I/We* have checked this thesis/project* and in my/our* opinion, this thesis/project* is adequate in terms of scope and quality for the award of the degree of *Doctor of Philosophy/ Master of Science.

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang Al-Sultan Abdullah or any other institutions.

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ABSTRAK

Perniagaan telah meningkatkan kualiti dan kapasiti pengeluaran dengan beralih daripada teknologi diputar tangan kepada teknologi automatik sepanjang 50 tahun sebelumnya. Percetakan 3D dan pembuatan aditif (AM) menandakan titik perubahan dalam prototaip. Kaedah yang dibangunkan baru-baru ini boleh menjana model fizikal dengan lebih pantas dan dengan geometri yang lebih kompleks, daripada reka bentuk dan prototaip kepada pengeluaran kumpulan kecil. Fused Deposition Modeling (FDM) menjadi lebih menonjol dalam kalangan pendekatan prototaip. Arca geometri polimer termoplastik kompleks paling baik dibuat dengan FDM. FDM ialah pendekatan yang paling menjanjikan untuk pembuatan produk kerana ia boleh bersaing dengan proses pemprosesan polimer standard. PET-G (diubah suai polietilena tereftalat glikol) ialah filamen percetakan 3D termoplastik biasa. Ia mempunyai keseimbangan kekuatan tegangan dan pemanjangan yang baik serta tahan terhadap air, haba dan bahan kimia. Ia biasanya dianggap kalis air dan mempunyai rintangan haba yang sangat baik. Salah satu ciri penting PETG untuk pencetakan 3D ialah ia kurang berkemungkinan menjadi rapuh disebabkan peningkatan fleksibilitinya. Sebagai hasil sampingan minyak, PETG tidak boleh terbiodegradasi walaupun boleh dikitar semula sepenuhnya. Matlamat utama penyelidikan ini adalah untuk mengkaji sifat mekanikal dan ciri struktur sampel PETG yang dicetak FDM dengan mempelbagaikan parameter (corak isian, sudut raster). Sampel telah dicetak kepada tiga fasa berbeza 1) Parameter normal, 2) 4 parameter, dan 3) 5 parameter. Sifat mekanikal (Tegangan, lenturan dan lenturan) spesimen PETG telah disiasat mengikut piawaian ASTM. Metodologi permukaan tindak balas (RSM) kemudiannya digunakan untuk menganalisis data eksperimen untuk mencari parameter yang mempunyai kesan paling ketara terhadap sifat mekanikal. RSM digunakan untuk mencipta model matematik kualiti mekanikal untuk meramal parameter mekanikal yang dikehendaki dengan pelbagai peratusan dan corak infill. Dalam parameter biasa, corak sepusat dengan sudut raster 23° mempunyai kekuatan tinggi dalam sifat tegangan. Corak padu dengan sudut raster 90° mempunyai sifat mampatan dan lentur yang terbaik. Dalam 4 parameter, gabungan dengan corak rectilinear dan concentric mempunyai nilai tertinggi berbanding sifat tegangan, mampatan dan lentur. Begitu juga, dalam 5 parameter, gabungan dengan corak atas/bawah rectilinear dan concentric mempunyai nilai tertinggi berbanding sifat tegangan, mampatan dan lentur. Purata sifat tegangan bagi nilai parameter 4 dan 5 digandakan berbanding dengan parameter biasa. Terdapat sedikit peningkatan dalam sifat mampatan berbanding parameter biasa pada 4 dan 5 parameter sampel PETG yang dicetak. Perbezaan antara sampel bercetak biasa dan dua parameter lain dalam sifat lentur adalah dua kali ganda nilai. Kekuatan lentur maksimum 72.05 MPa telah dicapai dalam 5 parameter, dan ia memberi kesan besar kepada sifat lentur spesimen PETG yang dicetak FDM. Juga, persamaan regresi dicipta menggunakan RSM untuk mencapai sifat maksimum menggunakan PETG. Begitu juga, kesan corak isian dan sudut raster pada sifat mekanikal spesimen yang dicetak telah dianalisis. Nilai Pekali penentuan (R^2) adalah lebih daripada 95% dalam semua model menunjukkan bahawa model regresi adalah sesuai. RSM jelas menggambarkan bahawa kedua-dua corak isian dan sudut raster memberi kesan ketara kepada ciri fizikal bahagian FDM. Dalam kerja akan datang, ketebalan Lapisan, jurang udara, sudut raster, peratusan isian dan corak isian boleh dilaraskan untuk mengkaji cara parameter pencetakan mempengaruhi sifat mekanikal spesimen yang dicetak dan menambah baik spesimen dan produk FDM berasaskan PETG.

ABSTRACT

Businesses have improved quality and production capacity by switching from hand-cranked to automated technology over the previous 50 years. 3D printing and additive manufacturing (AM) marked a turning point in prototyping. Recently developed methods can generate physical models faster and with more complex geometries, going from designs and prototypes to small-batch production. Fused Deposition Modeling (FDM) is becoming more prominent among prototyping approaches. Complex thermoplastic polymer geometric sculptures are best made with FDM. FDM is the most promising approach for product manufacture since it can compete with standard polymer processing processes. PET-G (polyethylene terephthalate glycol-modified) is a common thermoplastic 3D printing filament. It has a good balance of tensile strength and elongation and is resistant to water, heat, and chemicals. It is usually thought to be waterproof and has excellent thermal resistance. One of the essential features of PETG for 3D printing is that it is less likely to become brittle due to its increased flexibility. As an oil by-product, PETG is not biodegradable despite being completely recyclable. The primary goal of this research was to examine the mechanical properties and structural characteristics of FDM-printed PETG samples by varying the parameters (Infill pattern, raster angle). The samples were printed into three different phases 1) Normal parameters, 2) 4 parameters, and 3) 5 parameters. The mechanical properties (Tensile, bending, and flexural) of PETG specimens were investigated in accordance with ASTM standards. The Response surface methodology (RSM) is then used to analyze the experiment's data to find the parameters that have the most significant effect on mechanical properties. RSM was used to create mathematical models of mechanical qualities to predict desired mechanical parameters with various infill percentages and patterns. In normal parameters, the concentric pattern with a 23° raster angle has a high strength in the tensile properties. The cubic pattern with a 90° raster angle has the best compressive and flexural properties. In 4 parameters, the combination with the rectilinear and concentric pattern has the highest values over the tensile, compressive, and flexural properties. Likewise, in 5 parameters, the combination with the rectilinear and concentric top/bottom pattern has the highest values over the tensile, compressive, and flexural properties. The average tensile properties of the 4 and 5 parameter values were doubled compared with the normal parameters. There is some slight improvement in the compressive properties over the normal parameters on the 4 and 5 parameters printed PETG samples. The difference between the normal printed samples and the other two parameters in the flexural properties were double the values. The maximum flexural strength of 72.05 MPa was achieved in the 5 parameters, and it greatly impacted the flexural properties of the FDM-printed PETG specimens. Also, the regression equations were created using the RSM to achieve the maximum properties using the PETG. Likewise, the effect of the infill pattern and raster angle on the mechanical properties of the printed specimens was analyzed. The Coefficient of determination (R^2) value is more than 95% in all the models showing that the regression models are a good fit. The RSM evidently depicts that both the infill pattern and raster angle significantly affect the physical characteristics of the FDM parts. In future work, the Layer thickness, air gap, raster angle, infill percentage, and infill pattern can be adjusted to study how printing parameters affect the mechanical properties of printed specimens and improve PETG-based FDM specimens and products.

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