STUDY OF THE FUNCTIONAL 3D HEART MODEL USING SOFT MATERIALS FLEXIBLE THERMOPLASTIC POLYURETHANE (TPU FLEX SHORE 95 A) AND ELASTIC PHOTOPOLYMER RESIN (EPP SHORE 40 A) FOR *CARDIOVASS* MONITORING DEVICE

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MASTER OF SCIENCE

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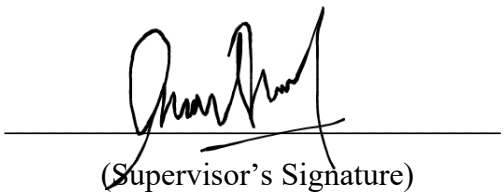
SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of 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 or any other institutions.

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ABSTRAK

Kini, pembangunan teknologi dan kejuruteraan telah berkembang dengan pesat dalam bidang kesihatan perubatan. Bagaimanapun, berdasarkan kajian semasa, masih terdapat kekurangan kajian mengenai sifat mekanikal elastomer, terutamanya poliuretana termoplastik dan resin fotopolimer elastik bagi pembuatan model jantung. Selain itu, kajian mengenai pengeluaran model jantung di Malaysia masih terbatas. Di samping itu, kesukaran yang dihadapi oleh pengamal perubatan dalam memahami keadaan penyakit koronari arteri tersumbat dan kesan aliran darah yang berpatah balik disebabkan oleh pembentukan plak juga menjadi kerisauan utama. Oleh itu, penyelidikan ini dimulakan untuk mengenal pasti sifat mekanikal bahan yang terpilih, poliuretana termoplastik fleksibel (TPU flek jenis 95 A) dan resin fotopolimer elastik (EPP jenis 40 A) dalam pembuatan model jantung. Berdasarkan kaedah kajian, sifat mekanikal bahan lembut tersebut telah diuji dan dikaji melalui ujian kekuatan, ujian kekerasan, dan ujian fraktografi. Kaedah gabungan pemodelan pemendapan (FDM) dan stereolitografi (SLA) digunakan untuk membentuk model jantung 3D yang berfungsi. Ciri-ciri aliran darah pada model jantung 3D tersebut juga diperhatikan dengan cermat. Hasil kajian menunjukkan bahawa TPU flek mempunyai kekuatan (8.81±0.003 MPa) dan keanjalan (34.69±0.288 MPa) yang lebih tinggi berbanding bahan EPP ((1.29±0.002 MPa (kekuatan), 8.97±0.012 MPa (keanjalan)). Tambahan pula, model jantung 3D yang berfungsi menggunakan bahan lembut untuk simulasi alat kardiovaskular (*CardioVASS*) telah dibangunkan dengan baik. Kemudian, aliran fisiologi bagi model jantung tersebut telah berjaya menunjukkan kesan menghidapi penyakit koronari arteri, berdasarkan kadar peratusan penyumbatan tertinggi yang menyebabkan gangguan pengaliran darah yang paling teruk (20%, 40%, 60% and 90%). Kesimpulannya, pembangunan model jantung 3D yang berfungsi untuk alat *CardioVASS* telah berjaya dilaksanakan dengan mengenalpasti sifat mekanikal bahan TPU flek dan EPP, pembuatan model jantung yang berfungsi, dan penyelidikan mengenai ciri-ciri fisiologi aliran darah telah tercapai.

ABSTRACT

Nowadays, advancements in technology and engineering are widely applied in the medical healthcare sector. However, based on the present study, studies are still limited on the mechanical properties of elastomers, particularly thermoplastic polyurethane and elastic photopolymer resin as used in the development of heart models. Besides, there are minimal studies on the production of cardiac models in Malaysia. In addition, the difficulties faced by medical practitioners in understanding the coronary artery disease blockage situation and flow drawbacks due to the formation of plaques are also a major concern. Thus, this research was initiated to determine the mechanical properties of selected materials, flexible thermoplastic polyurethane (TPU flex shore 95 A) and elastic photopolymer resin (EPP shore 40 A) in the development of heart models. With regards to the study method, the mechanical properties of these soft materials were investigated through the strength test, hardness test, and fractography test. The fused deposition modeling (FDM) and stereolithography (SLA) methods were employed to create the functional 3D heart model. The physiological characteristics of blood flow on the 3D heart model were also well observed. The results suggested that the TPU flex possessed higher strength (8.81±0.003 MPa) and elasticity (34.69±0.288 MPa) compared to the EPP ((1.29±0.002 MPa (strength), 8.97±0.012 MPa (elasticity)) material. Additionally, the functional 3D heart model using soft materials for the cardiovascular simulator (*CardioVASS)* device was well developed. Then, the physiological flow of the heart model was able to successfully emulate the consequences of having coronary artery disease, where the highest percentage of blockage resulted in the most severe blood flow obstruction (20%, 40%, 60% and 90%). In conclusion, the development of the functional 3D heart model for the purpose of the *CardioVASS* device has been successfully implemented by determination of the TPU flex and EPP material mechanical properties, fabrication of the functional heart model and investigation regarding physiological characteristics of blood flow were finally achieved.

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