NANO ENHANCED PHASE CHANGE MATERIAL PROPERTIES DRIVEN BY ARTIFICIAL INTELLIGENCE METHOD

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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 in Mechanical Engineering.

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STUDENT'S DECLARATION

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

Bahan Pembolehubah Fasa ialah bahan yang berkeupayaan khusus untuk membebaskan atau menyerap tenaga yang mencukupi bagi membekalkan haba untuk kegunaan aplikasi pemanasan ataupun penyejukan. Langkah yang penting dalam penggunaan Bahan Pembolehubah Fasa ini adalah dengan pemilihan bahan yang bersesuaian mengikut ciri-ciri dan aplikasi prospektifnya. Antara kriteria yang perlu diambil kira adalah kadar toksik bahan, kadar pengaliran haba bahan, kestabilan kimia bahan, dan kadar harga bahan. Dikebelakangan ini, terdapat peningkatan dalam penggunaan bahan partikal nano yang digabungkan bersama Bahan Pembolehubah Fasa untuk meningkatkan kadar pengliran haba bahan, terutamanya haba pendam bahan tersebut. Di dalam tesis ini dibahagikan kepada dua bahagian, setiap bahagian membincangkan aspek-aspek berbeza tentang prestasi Bahan Pembolehubah Fasa yang dipertingkatkan. Dibahagian pertama, perbincangan tertumpu kepada penyelidikan terhadap karekteristik haba seperti kadar pengaliran haba, kadar kestabilan haba and haba pendam Bahan Pembolehubah Fasa yang dipertingkatkan dengan kehadiran struktur nano (NePCM) berasaskan eicosane. Eicosane ($CH_3(CH_2)_{18}CH_3$), yang bersuhu lebur 37°C berfungsi sebagai asas Bahan Pembolehubah Fasa. Partikal nano copper (II) oxide (CuO) pula dipilih sebagai bahan partikal nano untuk meningkatkan kadar pengaliran haba bahan. Beberapa campuran eicosane-CuO pada kadar pecahan jisim sebanyak 0.5, 0.7, dan 1 telah dianalisis untuk penilaian pengaruh kadar pecahan jisim ini terhadap karekteristik Bahan Pembolehubah Fasa. Disamping itu, kadar haba pendam bahan ditentukan dengan menggunakan *Differential Scanning Calorimetry* (DSC). Nilai termofizikal NePCM secara menyeluruh, termasuk kadar pengaliran haba telah dinilai berdasarkan kepada beberapa julat suhu dan kepekatan NePCM. Tambahan lagi, analisis NePCM melibatkan penelitian teliti menggunakan FTIR dan SEM. Sementara itu, dibahagian kedua tesis ini, teknik pembelajaran mesin (ANN) digunakan untuk menentukan beberapa karekteristik NePCM dan juga untuk melatih data yang terkumpul semasa eksperimen. Persepsi Berbilang Lapisan (MLP) digunakan sebagai model ANN, dan dua sifat termofizikal NePCM iaitu haba pendam dan kadar pengaliran haba telah ditentukan dengan menggunakan model ini. Data input masuk bagi model ini adalah kadar suhu, fasa NePCM dan kadar konsentrasi partikal nano dalm campuran. Keputusan analisis termofizikal sampel menunjukkan terdapat peningkatan dalam karekteristik Bahan Pembolehubah Fasa tanpa mengubah sifat kimianya. Pencampuran partikal nano CuO kedalam sampel juga meningkatakan kadar pengaliran haba dan nilai haba pendam bahan. Nilai maksimum haba pendam dan kadar pengaliran haba diperolehi adalah ditingkat tertinggi kepekatan partikal nano (1%wt) iaitu pada 44.03 °C dan 0.54 W/mK. Tambahan pula, analisis FT-IR mengesahkan tiada interaksi kimia diantara Bahan Pembolehubah Fasa dan partikal nano CuO. Secara keseluruhannya, penemuan ini telah menggariskan beberapa potensi penggabungan bahan non-organik seperti partikal nano CuO bagi meningkatkan sifat haba Bahan Pembolehubah Fasa untuk kegunaan pelbagai aplikasi. Model yang dibangunkan ini terdiri daripada tiga lapisan utama termasuk lapisan input masuk, lapisan tersembunyi dan lapisan hasil keluaran. Secara amnya, struktur model dibangunkan untuk meramalkan haba pendam dan kadar pengaliran haba masing-masing ialah 10-8-1 dan 10-9-1. Bilangan data ini menunjukkan bilangan neuron dalam lapisan input masuk, lapisan tersembunyi dan lapisan hasil keluaran. Bilangan sampel untuk model kadar pengaliran haba adalah sebanyak 205 dan untuk model haba pendam adalah sebanyak 5408. Sampel-sampel ini telah dibahagikan kepada tiga bahagian termasuk data latihan, data ujian dan data pengesahan (masing-masing 70, 15, dan 15%). Data pengesahan menunjukkan tiada lebihan pembelajaran dalam model dan pekali penentuan (nilai R) masing-masing adalah 0.97213 dan 0.99985 untuk kadar pengaliran haba dan kadar haba pendam. Nilai optimum dalam lapisan sembunyi untuk model ANN yang adalah untuk meramalkan kadar pengaliran haba dan haba pendam, menggunakan data eksperimen. Kecekapan model ANN dan penjajarannya dengan data eksperimen telah membuktikan ketepatan ramalannya. Hasil eksperimen telah menunjukkan penambahan bahan nano berpotentsi untuk meningkatkan keupayaan Bahan Pembolehubah Fasa serta kecekapan model ANN untuk meramalkan termofizikal NePCM secara tepat.

ABSTRACT

A phase change material (PCM) is a substance thatcan remarkably release or absorb adequate energy to provide heat or cooling applications. An essential step in using phase change materials is selecting the proper PCM according to its characteristics and prospective application; many items, such as the extent of toxicity, thermal conductivity, chemical stability, and expenses, can be included. Recently, considerable development has occurred in applying the nano-particles (NPs) combined with the PCMs to augment their thermal conductivity, especially in latent heat. This thesis is divided into two main parts, each addressing the performance of enhanced phase change materials (PCMs). The initial section focuses on investigating the thermal characteristics—thermal conductivity, thermal stability, and latent heat—of nanostructure-enhanced phase change materials (NePCM) based on eicosane. Eicosane ($CH_3(CH_2)_{18}CH_3$), with its melting point at 37°C, serves as the fundamental PCM. Copper (II) oxide (CuO) nano-particles (NPs) are chosen as nanoscale enhancers for thermal conductivity. Multiple eicosane-CuO batches with 0.5, 0.7, and 1 mass fractions are analyzed to assess the influence of these fractions on PCM characteristics. Furthermore, determining latent heat values is executed using differential scanning calorimetry (DSC). Comprehensive thermophysical attributes of NePCM suspensions, including thermal conductivity, have been methodically evaluated across various temperatures and NePCM concentrations. Moreover, the characterization of NePCM involves scrutiny through FTIR and SEM techniques. In the latter part of this thesis, machine learning techniques are employed to predict NePCM characteristics and train on data amassed during the experimental process. MLP (multilayer perceptron) is used as the ANN model, and the model predicted two thermophysical properties of the NePCM (latent heat and thermal conductivity). The input of the models was the temperature and phase of the NePCM and concentrations of NPs. The results of the thermophysical analysis of the samples showed improvement in the desirable characteristics of the PCM without changing the chemical properties of the PCM. Remarkably, the introduction of CuO NPs has enhanced the composite's thermal conductivity and latent heat. The maximum latent and thermal conductivity were observed for the highest concentration of NPs (1%wt), which were 44.03 °C and 0.54 W/mK, respectively. Furthermore, FT-IR analysis has confirmed the absence of chemical interactions between the PCM and CuO NPs. Overall, the findings have underscored the potential of incorporating inorganic materials (CuO NPs) to significantly enhance the thermal properties of phase change materials for diverse applications. The developed model consists of three main layers: input, hidden, and output. Generally, the structure of the developed model to predict latent heat and thermal conductivity was 10-8-1 and 10-9-1, respectively. These numbers show the number of neurons in the input, hidden, and output layers. The number of samples for the thermal conductivity model was 205; for the latent heat model, it was 5408. These samples were divided into training, test, and validation data (70, 15, and 15%, respectively). Validation data showed no overlearning in the models, and the coefficient of determination (R-value) was 0.97213 and 0.99985 for thermal conductivity and latent heat models, respectively. The optimum number in the hidden layer for the developed Artificial Neural Network (ANN) model is to predict thermal conductivity and latent heat, drawing from experimental data. The proficiency of the ANN model and its alignment with experimental data have underscored its predictive prowess. The results demonstrate the potential of adding nano-materials to improve PCM capabilities and the ANN model's ability to predict necessary NePCM attributes correctly.

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