PARALLEL COMPUTING FOR SIMULATING NANOSCALE TEMPERATURE BEHAVIOUR ON LASER GLASS INTERACTION

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To daddy who supports and encourage me,

To mummy for love and care.

To my siblings who allow me to lead by example,

Thank you.

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ABSTRACT

Glass materials are widely used in optical, optoelectronic and windshields. Glass is very brittle because the molecules are arranged closely and have strong bonds between them. To break up these bonds and produce fine quality glass, the glass needs to be cut by using a high temperature machine which uses the laser technique. Experimental method involves high expertise and costly and due to this an analytical method is preferred. The objective of this research is to develop a parallel algorithm to simulate the temperature behavior of laser glass cutting. Partial Difference Equation (PDE) mathematical model is used to represent the numerical simulation and this equation is discretised before solving by using multicore platform. The methodology used in the study is the parallel computing platform that is based on masters and workers concept. The parameters and initial values are input to the simulation which uses Alternating Group Explicit (AGE) BRIAN Three Dimensional method to solve the problem. In order to develop the parallel algorithm for the simulation, a sequential algorithm is developed initially and instructions that can be parallelized from this sequential algorithm are identified using the Microsoft Parallel Studio. Based on this, the parallel algorithm is developed using OpenMP language. The results from both sequential and parallel algorithms are recorded, analyzed and compared using Amdahl's law. The results proved that the simulation using parallel computing algorithm is faster and cost effective. Furthermore, the time execution to simulate the program is reduced by 53% and the speed up is boosted up to 11%. The research illustrated that the analytical simulation using parallel algorithm is cheaper and faster and thus proves that parallel programs are best in simulating the temperature behavior of laser glass cutting.

ABSTRAK

Bahan yang diperbuat dari kaca banyak diguna pakai dalam industri seperti optikal, optoelektronik dan cermin kereta. Struktur atomik kaca mempunyai molekul yang berkedudukan sangat rapat antara satu sama lain di mana daya ikatan di antara molekul sangat kuat. Oleh itu, untuk memotong kaca bagi menghasilkan kaca yang berkualiti tinggi, kaca harus dikenakan suhu laser yang tinggi bagi memisahkan ikatan molekul yang sedia ada. Dalam teknik ini, kaedah eksperimen dan kaedah simulasi digunakan. Walau bagaimanapun, kaedah yang pertama memakan kos dan kepakaran yang tinggi berbanding dengan kedah simulasi. Oleh itu objektif penyelidikan ini adalah untuk memperbaiki kaedah simulasi dengan membangunkan algoritma selari untuk menjalankan simulasi bagi menentukan perlakuan suhu yang sesuai untuk memotong kaca. Mulanya, simulasi diwakilkan dengan menggunakan persamaan terbitan separa (PDE) dan didiskretkan sebelum dilarikan dengan menggunakan kaedah berbilang teras. Metodologi yang digunakan adalah perkomputeran selari yang menggunakan konsep tuan dan pekerja. Dalam simulasi ini, nilai-nilai awal dan kesemua pembolehubah adalah input kepada aturcara dan dilarikan menggunakan kaedah Kelas Tak Tersirat Kumpulan Berarah Selang Seli (AGE BRIAN) tiga dimensi. Dalam membangunkan algoritma selari, algoritma berjujukan dibangunkan terlebih dahulu dan arahan-arahan yang dapat diselarikan dikenalpasti dengan menggunakan Microsoft Parallel Studio. Dengan menggunakan bahasa OpenMP, algoritma selari dibangunkan dengan menambahkan arahan-arahan selari yang telah dikenalpasti.. Keputusan simulasi dari algoritma berjujukan dan selari direkod, dibanding dan dianaliskan dengan menggunakan hukum Amdahl. Keputusan membuktikan bahawa simulasi yang dijalankan mengunnakan aturcara komputeran selari adalah lebih laju dan kos efektif. Tambahan lagi, masa pelaksanaan simulasi dapat diturunkan sebanyak 53% dan kadar kelajuan pemproses dapat ditinggikan sebanyak 11%. Penyelidikan ini membuktikan bahawa simulasi analitikal yang menggunakan algoritma selari adalah baik dalam menjalankan simulasi menentukan perlakuan suhu yang sesuai untuk pemotongan kaca.

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LIST OF ABBREVIATIONS

FDM	-	*Finite Differential Method*
ODE	-	*Ordinary Differential Equation*
PDE	-	*Partial Differential Equation*
AGE	-	*Aternating Group Explicit*
GSRB	-	Gauss Seidel Red Black

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CHAPTER 1

INTRODUCTION

1.1 Background of Problem

Nowadays, glass materials are widely used such as in optical, optoelectronic, devices, bottles, microfluidic and windshields [1,2,3]. Glass is said to be a very brittle material where particles are arranged closely and having strong bonds between them [4,5]. In order to break up these bonds and produce fine quality glass, the glass need to be cut by using a high temperature machine which is the laser technique [6, 7].Before the laser technique are used for glass cutting, there were the traditional method by using mechanical scribe and break process. This process is done by using a tool such as diamond tip or cutting wheel to create a scratching zone that will break the glass [8, 12].

However, this technique can cause fragmentation, microcracks and may generate particles on the surface which result into an edgy surface [1,6,8]. Glass that has cracks, debris and uneven is a low quality glass. This is because by using the mechanical method, the particle is separated with massive external force that will decrease the refractive index of the glass resulting in poor quality glass [12, 13]. Thus the laser technology is introduced to overcome the disadvantages produced by the mechanical method.

The laser technology is said to be better than the mechanical method because the product from the laser are of high quality, high precision and far more superior compared to the traditional method [1,6,11]. Laser beam is shone on the surface of the glass where the heat generated by the laser beam will be absorbed. This causes thermal stress between the particles in the glass and eventually will melt and vaporize to produce the intend shape or cutting needed [1, 10, 15]. The product of glass that is being cut using the laser method can avoid cracks, micro fissure and produce much more stronger glass [1,14]. However, to simulate the temperature behavior of the laser glass cutting, requires high security, cost, and also expertise [1, 7, 10]. The reason behind this is that, during experimental procedure that uses laser technique, the laser beam that is shone need to be adjusted initially by determining its temperature, wave length, and the power dissipation [10,11]. This requires major expertise for one to handle the experiment which might be dangerous if it is not being handled properly. Furthermore, mistakes and errors cannot be tolerated because if a glass is induced with a high temperature directly or the heat capacity exceeds the heat tension of the glass, the glass will have burn marks, improper fracture and heat affected zone where the glass strength decreases. This will create wastage as the glass produced is impractical or the need of added process such as polishing and grinding is needed to rectify the problem, hence increasing the cost severely[8,12].

Behind these reasons, the analytical method is preferred where numerical simulation is conducted to determine the temperature behavior of the laser glass cutting. This idea is also supported and had been conducted by various researchers such as Jiao and Wang [10] said that using laser technology is impractical due to cost and security and suggest the need of analytical studies where problems are being described in a mathematical model. Adding on, Z.H. Shen *et al.* [15] uses mathematical model to model laser induced heating in metal solids. Therefore, the need of the analytical method is preferred where numerical simulation is conducted to determine the temperature behavior of the laser glass cutting. Partial Differential Equation (PDE) is one of the mathematical models proposed to model a process that has a high complexity, infinite dimensional and process that is difficult to estimate [2]. Normally, the PDE will undergo

discretization to simplify, but because of the simulation of the temperature behavior of the laser technique requires too many numerical computations and analysis, the simplification form is brought to new level by simulating into a parabolic graph. However by simplifying the equation using DE requires great complexity, many iteration and also the need to solve using numerical calculation [3, 16, 18].

Due to advance in the computer science field, the solution for complex scientific and engineering problems can be solved by using high speed computing machine [4,17,18]. Thus, the hybrid parallel computing is introduced that uses the multicore platform, that able to conduct these mathematical analyses to simulate the nanoscale temperature behavior on laser glass interaction. It is the best method due to its superior performance and cost effective allowing performing on procedural paradigm that can be used as an analytical tool in simulating an accurate nanoscale temperature behavior to produce a fine laser glass cutting [5,17].

1.2 Statement of Problem

This research focuses on simulating the nanoscale temperature behavior of the laser glass cutting by first modeling the problem into a mathematical model in the form of PDE. Then by using hybrid computing, algorithms are developed to simulate the temperature behavior of the laser glass cutting using the multicore platform. The calculations can be done fast to produce a consistent and granularity result due to the more grid point that can be obtained in which the sequential programming cannot be done. This result will be compared and analyzed.

The following are the hypotheses that need to be looked upon in this research. “Could the hybrid parallel computing give better computational time and a more accurate result to simulate the temperature behavior of the laser glass cutting?

a) Which mathematical model is best suited in simulating the temperature behavior of laser glass interaction?
b) How to develop parallel computing that can simulate the temperature behavior of the laser glass cutting?
c) What parameter performances need to be considered in analyzing the results of the hybrid parallel computing in simulating the temperature behavior of laser glass cutting?

1.3 Objectives of study

The main goal of the research is to develop hybrid parallel computing algorithm in simulating the temperature behavior of the laser glass cutting interaction. Besides that, the research also aims to meet the three objectives:

a) To identify the mathematical model in simulating the temperature behavior of laser glass interaction.
b) To develop parallel computing algorithm in simulating the temperature behavior of laser glass cutting using Alternating Group Explicit BRIAN (AGEB) Method.
c) To investigate the performance analysis on the parallel computing algorithm developed in simulating the temperature behavior of laser glass cutting.

1.4 Scope of the study

The research concentrates in the five following area:

a) Use on parallel programming to simulating the temperature behavior of the laser glass interaction
b) Using only the Finite Difference Method (FDM) to discretize the PDE equation.
c) Using Alternating Group Explicit Brian (AGEB) method for numerical simulation and Gauss Seidel Red Black (GSRB) method for comparison purpose in simplifying the PDE equation
d) Using parallel computing which consist of 8 threads.

1.5 Significance of study

To summarize, this research introduce multicore processing method to simulate the nanoscale temperature behavior of the laser glass interaction which can provide much faster computer time processing and accurate results. This is important in laser glass cutting because an optimized result can provide better laser glass cutting. Thus, by using hybrid parallel computing the laser glass cutting industry will come up into a new level of innovation that can help others in the near future.

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