INVESTIGATION OF ULTRASONIC WELDING FOR JOINING POLYLACTIC ACID BASED BIO-DEGRADABLE PACKAGING PRODUCTS

Peterphilipneri Jebasuthan

(198408F)

Degree of Master of Engineering

Department of Mechanical Engineering

Faculty of Engineering

University of Moratuwa

Sri Lanka

February 2023

INVESTIGATION OF ULTRASONIC WELDING FOR JOINING POLYLACTIC ACID BASED BIO-DEGRADABLE PACKAGING PRODUCTS

Peterphilipneri Jebasuthan

(198408F)

Thesis submitted in partial fulfillment of the requirements for the Master of Engineering in Manufacturing Systems Engineering

Department of Mechanical Engineering

Faculty of Engineering

University of Moratuwa

Sri Lanka

February 2023

Declaration:

I declare that this is my own work and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature: Date:

The above candidate has carried out research for the PhD/MPhil/Masters thesis/dissertation under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of the supervisor:

Dr JR Gamage

Senior Lecture

Department of Mechanical Engineering

Unioversity of Moratuwa

Signature of the supervisor: Date:

Acknowledgement

Abstract:

There is a successful formula for biodegradable materials for packaging applications. Joining the developed biodegradable materials is important for sustainable packaging applications. Among the different types of joining methods available for polymer-based materials, ultrasonic welding is popular among manufacturers due to variety of reasons. It is a cost-effective, eco-friendly and time-saving joining method which does not require additional parts or materials, like bonding materials and mechanical fasteners used in adhesive and mechanical joining. However, there is a lack of literature evidence on assessing the joining performance of ultrasonic welding of biodegradable materials. Therefore, this study aims to investigate the possibility of applying ultrasonic welding for joining bio-degradable packaging sheets.

The biodegradable packaging material sheets were developed in the laboratory using the solvent casting technique. The samples were prepared using 'Ceiba Pentandra' as reinforcement fibre and PLA as a matrix polymer to develop sheets of PLA-Ceiba Pentandra fibre composites. Both these raw materials of the composite are biodegradable in the environment. A semi-automatic ultrasonic welding machine(20 kHz) was used to join the PLA/natural fibre composite samples.

The strength of the ultrasonically welded specimens was tested by conducting tensile strength tests with the help of a universal tensile strength machine. The design of experiments (Taguchi method) and variance analysis (ANOVA) were used for the experimentation and analysis process. The parameters influencing the joining strength are the composition of fibre and PLA, welding time, holding pressure, and amplitude. These parameters were changed to see the variation in the output parameters of the joint strength and energy consumption.

Using ANOVA, the optimum set of parameter levels were found to maximize the strength of the joints. The optimum parameter levels are; 0.5% of fibre/PLA composites, a holding pressure of 2.5 bar, a welding time of 1.5 Seconds and an amplitude of 75 μm. Fibre percentage and welding time significantly affect the welding strength and contribute to the tensile strength by 40.1% and 34.1%, respectively. Pressure and amplitude have a minor effect on the welding strength, contributing to the tensile strength by 10.3% and 11.5%, respectively. Time and amplitudes significantly affect the energy used to make the bonds by 87.2% and 10.3%, respectively. Fibre percentage and pressure have a minor effect on energy usage, contributing to the total energy by only 0.5% and 1.9%, respectively. The results were validated using a confirmation test, which compared the calculated results with the experimented results.

Contents

List of Tables

List of Figures

List of Abbreviations

Abbreviation	Description
PLA	Polylactic Acid
DOE	Design of experiment
LDPE	Low-density polyethene
PP	Polypropelene
HDPE	High-density polyethene
ANOVA	Analysis of variance
USW	Ultrasonic welding
PVC	Polyvinyl chloride
PET	Polyethene Terephthalate
S/N	Signal/Noise
GLM	General linear model