Ain Shams University

Faculty of Engineering

Design and Production Engineering Department

Study of the Potentiality of Utilization of Alternative Agro Residues in Manufacturing Particleboards

A Thesis Submitted in Partial Fulfilment for the Requirements of the

Degree of Master of Science in Mechanical Engineering

By

Mohamad Samir Ahmad El-Kafafy

Supervised by

Prof. Dr. Hamed I. El-Mously Dr. Iman M. Taha

2015

Statement

This thesis is submitted in partial fulfilment for the degree of Master of Science in design and production engineering, to the faculty of engineering, Ain Shams University. The work included in this thesis was carried out by the author, primarily at the laboratories of the Design and Production Engineering Department, Faculty of Engineering, Ain Shams University. No Part of this thesis has been submitted for degree or qualification at any other university.

Mohamad Samir Ahmad El-Kafafy

Signature:

_____

Date:

_____

Curriculum vitae

Name: Mohamad Samir Ahmad El-Kafafy

Birth Date: 31-5-1984

Degree: Bachelor Degree in Mechanical Engineering, Power Section, 2006

Current Job: Consultant, Egyptian Technology Centers for transferring technology and innovation – Ministry of Trade and Industry

Acknowledgment

I would like to express my gratitude to my academic advisors, Prof. Hamed El-Mously and Dr. Iman Taha. I am extremely thankful to Eng. Bahi Edeen Bakeer for providing his help and support during this work. I also want to appreciate the efforts of Eng. Mahmoud Zakaria and my colleagues in design and production engineering department, faculty of engineering, Ain Shams University, Cairo, Egypt. Lastly, I sincerely thank my family, especially my mother for her understanding and patience.

Abstract

This work targets the testing of the potentiality of utilization of alternative underutilized agro residues in the manufacturing of single layer particleboards.

Selection of agro residues has been based on their large amounts and seasonal availability throughout the year. Tomato stalks (TS) have been selected as they are not utilized among the other crop residues and are open field burnt. Chemical analysis of the stalks was performed to prove their suitability for application. Their cellulose content (43.11) % and lignin (12.2 %) make TS comparable with flax shives. Optical microscope was used to investigate the particles morphology. Specimens of particleboards of various resin/fiber compositions were further prepared by compression molding under different pressures and resin concentrations.

The specimens were further examined for their mechanical and physical properties. Comparisons with the European standards (En 312: 2010) for particleboards show the applicability of TS as a natural fiber resource for commercial particleboard manufacturing.

Statistical analysis was performed. It has been proven that at a constant level of pressure, higher resin content values result in higher values of modulus of rupture, modulus of

elasticity, internal bonding and thickness swelling due to increase of bonding force and boards density.

Cost benefit analysis has been carried out to investigate the cost of utilization of tomato stalks for commercial particleboard manufacturing. It was found that tomato stalks with resin on (stage before pressing) cost is 0.25 of cost of casuarina tree particles with resin on.

Contents

Abstract v
1. Introduction 1
2. Literature review 3
2.1 Particleboards 3
2.1.1. Particle preparation 4
2.1.2. Particle classification and conveying 5
2.1.3. Particle drying 6
2.1.4. Addition of resins and wax 7
2.1.5. Mat formation 7
2.1.6. Hot pressing 8
2.1.7. Finishing 9
2.1.8. Properties of particleboard 9
2.1.9. Particleboards in Egypt 10
2.2 Resources for particleboard raw material 11
2.2.1 Land and forestry 11
2.2.2 Availability of wood resources in Egypt 13
2.3 Use of alternative materials (other than wood) 15
2.3.1 Lignocellulosic material 16
2.3.2 Use of agriculture-residues for particleboard production 17

2.3.3 Significance and availability of the plant agricultural residues in Egypt 18
2.4 Tomato plant (botanical description) 19
3. Objective and work plan 27
4. Experimental work 30
4.1 Materials 30
4.2 Characterization of raw materials (tomato stalks) 31
4.2.1 Microscopic investigation 31
4.2.2 Chemical composition 31
4.2.3 Moisture content 31
4.2.4 Density 32
4.2.5 Tensile testing of stalks 33
4.3 Preparation of tomato stalk particleboards specimens 34
4.3.1 Preparation of tomato stalk particles 35
4.3.2 Blending of particleboard composition 37
4.3.3 Particleboard specimens fabrication 38
4.4 Characterization of particleboards 42
4.4.1 Static bending test 42
4.4.2 Internal bonding test 43
4.4.3 Dimensional stability test 45
4.4.4 Density determination 46

4.4.5 Statistical analysis of test results 46
5. Results and discussion 48
5.1 Selection of the underutilized agricultural residues 48
5.2 Characterization of tomato stalks 50
5.2.1 Macrostructure investigation 50
5.2.2 Microscopic investigation 52
5.2.3 Particles density 53
5.2.4 Chemical composition 54
5.2.5 Moisture content 54
5.2.6 Tensile testing of stalks 55
5.3 Preparation of tomato Stalk particleboards specimens 55
5.3.1 Size reduction of tomato stalk 55
5.3.2 Blending of particleboard composition 57
5.3.3 Pressing of tomato stalks particleboard 57
5.4 Characterization of tomato stalk particleboard 58
5.4.1 Physical properties of tomato stalk particleboards 58
5.4.1.1 Dimensional stability 58
5.4.1.2 Density 60
5.4.2 Mechanical properties of tomato stalks particleboards 61
5.4.2.1 Modulus of rupture (MOR) 61

5.4.2.2 Modulus of elasticity (MOE) 62
5.4.2.3 Internal bond test 63
5.5 Statistical analysis of experimental results 64
5.6 General Discussion 65
5.7 Cost benefit analysis for of tomato stalks utilization in particleboard manufacture 66
6. Conclusions and future recommendations 69
6.1 Conclusions 69
6.2 Future recommendations 70
Reference 71
Annex 1: European standard for particleboard (EN312:2010) 81
Annex 2: Field study of sites of tomato plantations in Egypt 92
Annex 3: Field visit to agriculture directorate in El-Sharkiah 98
Annex 4: Chemical composition analysis of tomato stalks in the Regional Center for Food & Fodders, Agriculture Research Center 100
Annex 5: Determination of particles density using ADAM EQUIPMENT PW254, based on Archimedes principle..... 103
Annex 6: CAD drawing of blender, used in blending of TSP composition 104

Annex 7: CAD drawing of wooden mold used in pouring the mix after blending to form the prepress mat 105
Annex 8: CAD drawing of steel plate for pressing TSP specimens 106
Annex 9: Calibration of thermal press for both pressure and temperature..... 107
Annex 10: Internal bond test results. 110
Annex 11: The statistical procedures used with the research results..... 115
Annex 12: Comparing more than two unrelated samples: the Kruskal Wallis H-test 118
Annex 13: Tomato stalks particleboard specimens' ingredients 120
Annex 14: Detailed statistical analysis of results..... 122
Annex 15: Field visit to particleboard plant 135
Annex 16: Detailed cost benefit analysis calculation of TSP as replacement for casuarina particleboard (prevailing material used in PB industry) 138

List of Abbreviations

PB	Particleboard	
TS	Tomato stalks	
TSP	Tomato stalks particleboard	
MOR	Modulus of rupture	[N/mm^2]
MOE	Modulus of elasticity	[N/mm^2]
IB	Internal bond	[N/mm^2]
TS%	Thickness swelling	[%]
UF	Urea - Formaldehyde	[%]