PRELIMINARY STUDY USING HEAT TREATED WOOD IN ENGINEERING THERMOPLASTIC COMPOSITES

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Alper Kiziltas, Douglas Gardner and Gokhan Gunduz

SPE ACCE Conference-Sustainable Composites
September 10, 2014

THE UNIVERSITY OF MAINE
ADVANCED STRUCTURES & composites center
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OUTLINE

- **Background-Thermowood**
- **Objectives**
- **Materials and Methods**
- **Results**
- **Conclusions**
- **Acknowledgements**

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FINISH INNOVATION- THERMOWOOD

- **Improves woods dimensional stability and durability against decay and gives it a pleasant deep-brown colour.**

- **ThermoWood is a heat-treatment technology for wood developed and patented by VTT. Today the industrial scale of wood heat treatment process, under trade name ThermoWood®, has licensed to the members of the Finnish Thermowood Association**

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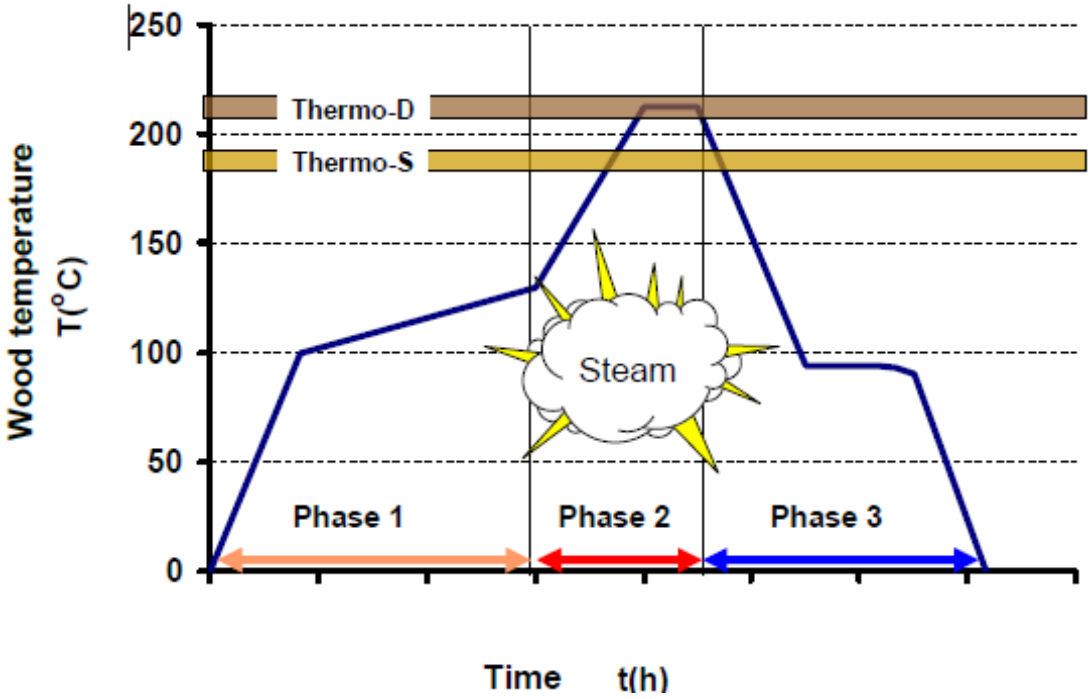
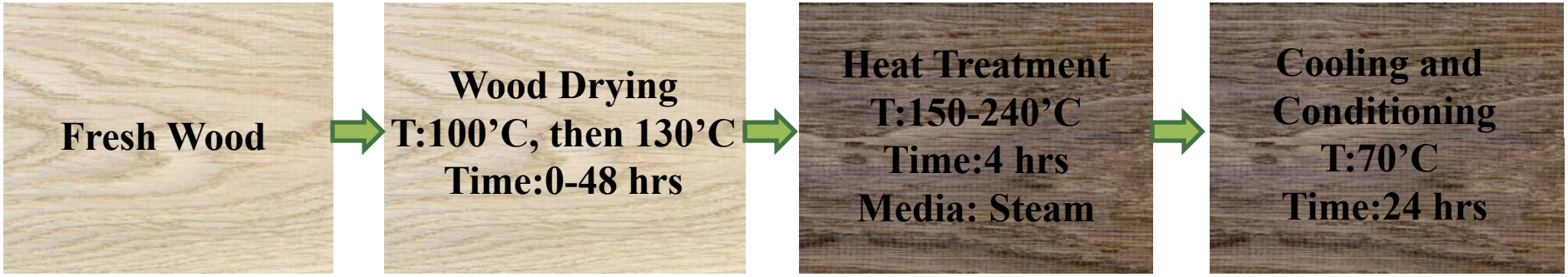
THERMOWOOD PROCESS





Wang and Cooper 2010, Ala-Viikari 2008

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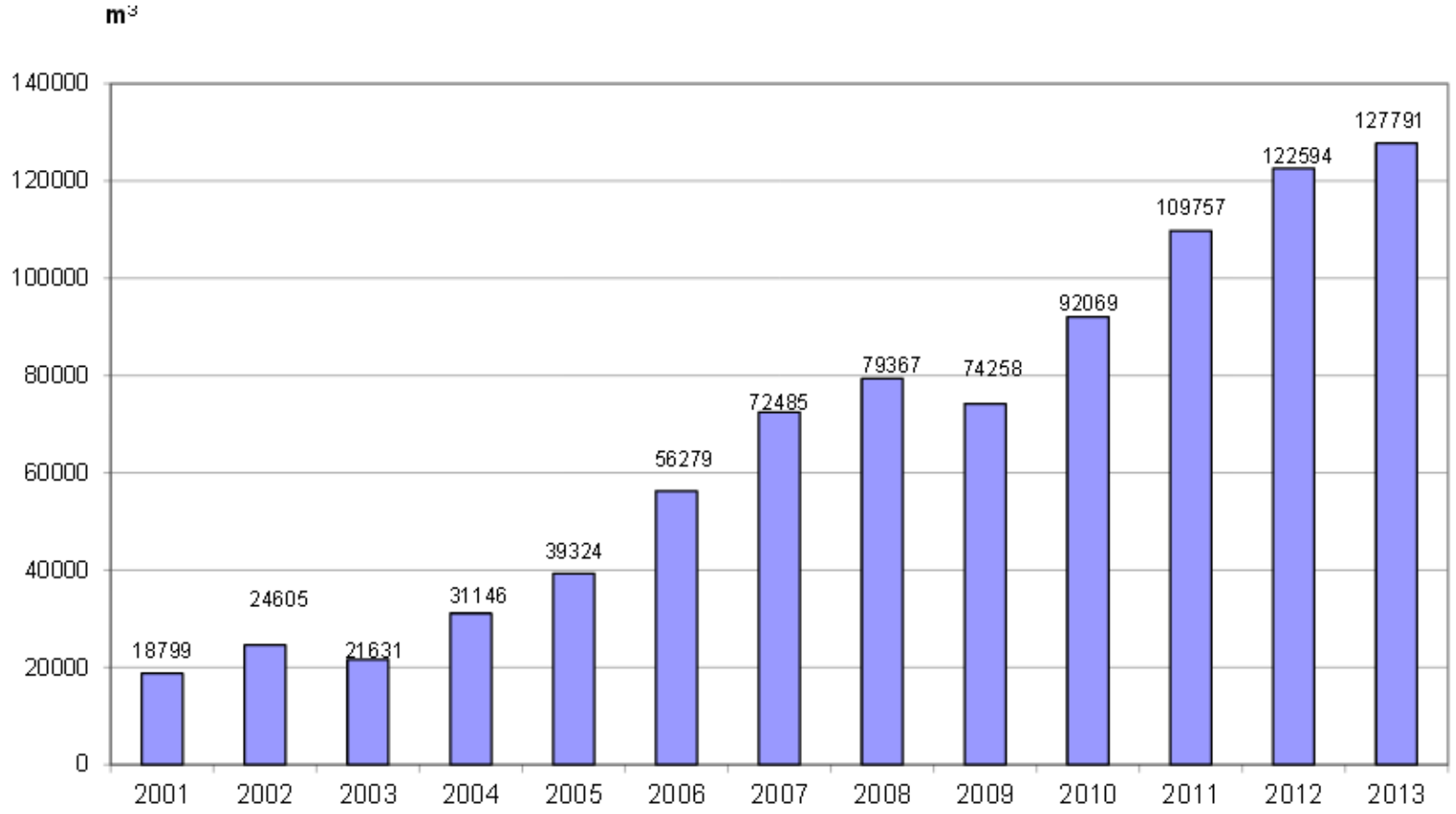
THERMOWOOD SALES PRODUCTION



http://www.thermowood.fi/

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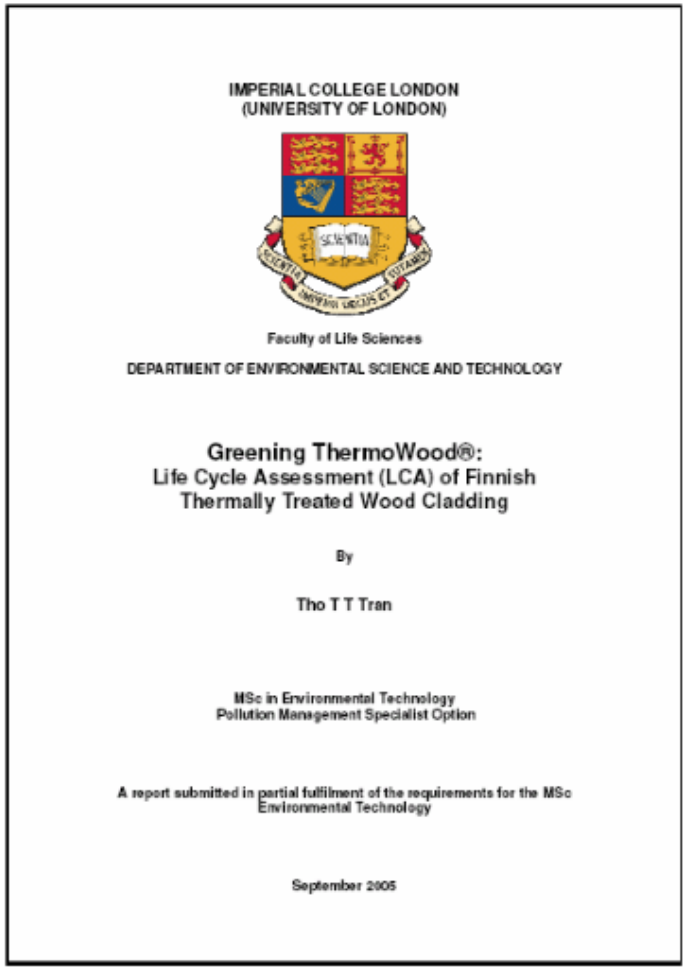
LIFE CYCLE ASSESSMENT (LCA)

- **LCA study of ThermoWood was carried out by Imperial college London.**



IMPERIAL COLLEGE LONDON
(UNIVERSITY OF LONDON)

Faculty of Life Sciences

DEPARTMENT OF ENVIRONMENTAL SCIENCE AND TECHNOLOGY

Greening ThermoWood®:
Life Cycle Assessment (LCA) of Finnish
Thermally Treated Wood Cladding

By

Tho T T Tran

MSc in Environmental Technology
Pollution Management Specialist Option

A report submitted in partial fulfilment of the requirements for the MSc
Environmental Technology

September 2005

- **Conclusion:**

  " ThermoWood has a potential of being a ´green´ building material if consideration is made to the production as well as the use and disposal at the end of its life cycle using best available technologies"

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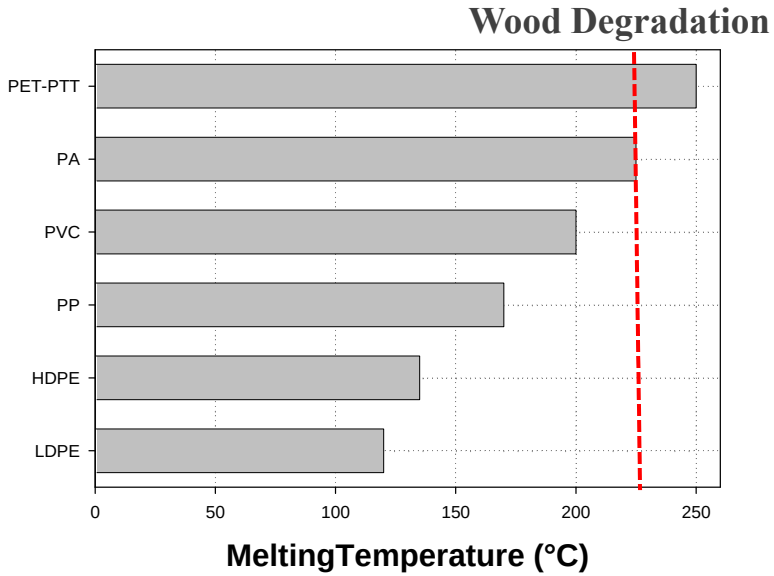
HEAT TREATMENT-WPC

- **Presumably, using HTW as filler should not enhance the properties of WPCs to the same extent as untreated wood does.**

- **The changes imposed by HT could reduce polarity of wood and make the wood a more compatible material with non-polar thermoplastic matrix.**



- **Adding HTWF should also lead to an improvement in the thermal stability of the composites.**

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HEAT TREATMENT-WPC-LITERATURE

Polymer	Type of Wood	Heat Treatment (°C)	Reference
PE	Bamboo	160, 175,190, 205, 220	Fang et al. 2013
	Maple	175,190,205	Kaboorani and Faezipour 2009
	Red Balau	180, 200	Lafia-Araga et al. 2012
	Maple	175,190,205	Kaboorani et al. 2008
	Spruce and NF	230	Robin and Breton 2001
PP	Poplar	140	Luo et al. 2013, Luo et al. 2012
	Norway Spruce	200	Sgerholm 2007
	Birch and Spruce		Butylina et al. 2011
	Poplar	180,200	Kaboorani 2009
	Poplar	200	Luo et al. 2014
	Eucalyptus	120,150,180	Ayrilmis et al. 2011
CAB	Norway Spruce	200	Segerholm 2007

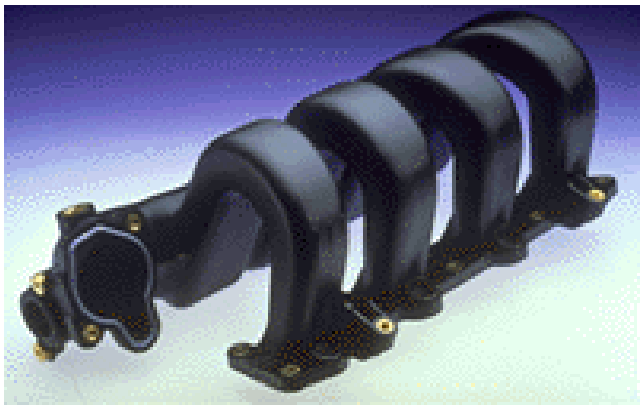
Aydemir et al. 2014

OBJECTIVES

- **To explore the use of PA 6 and HTWF for low-cost and high volume applications especially 'under-the-hood' applications in the automobile industry.**

The upper air intake manifold for the Ford Windstar's 3.8-liter V-6 engine is injection molded from Zytel® nylon 66 resin

- **Produce and evaluate the material properties of natural fiber filled-engineering thermoplastic composite materials developed on the bench scale.**



Manifold used by Dodge and Plymouth Neon small cars uses Zytel® nylon

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MATERIALS-FORMULATIONS

- **Wood flour of pine and maple, greater than 100 mesh and nylon 6 with the trade name Entec NL 2000 (density:1.23 g/cm3) were used.**

Sample Code	Nylon 6	WF	HTWF	Lubricant
PA+L	97	-	-	3
P-5	92	5		3
P-10	87	10		3
P-20	77	20		3
P-30	67	30		3
TP-5	92		5	3
TP-10	87		10	3
TP-20	77		20	3
TP-30	67		30	3

- **The lubricant (TPW113) used as an additive to improve processing conditions, was supplied by Struktol Co.**

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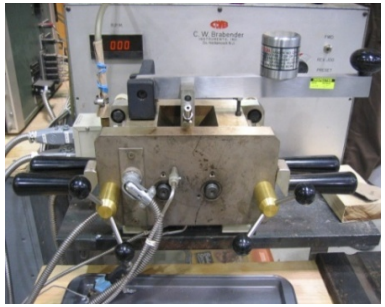
COMPOSITES PRODUCTION- BOWL MIXER



PA 6
WF/HTWF
Lubricant

High Speed Mixer

Melt Blend Brabender

Dry Grinded Mixture

Injection Molding

ASTM Test Samples

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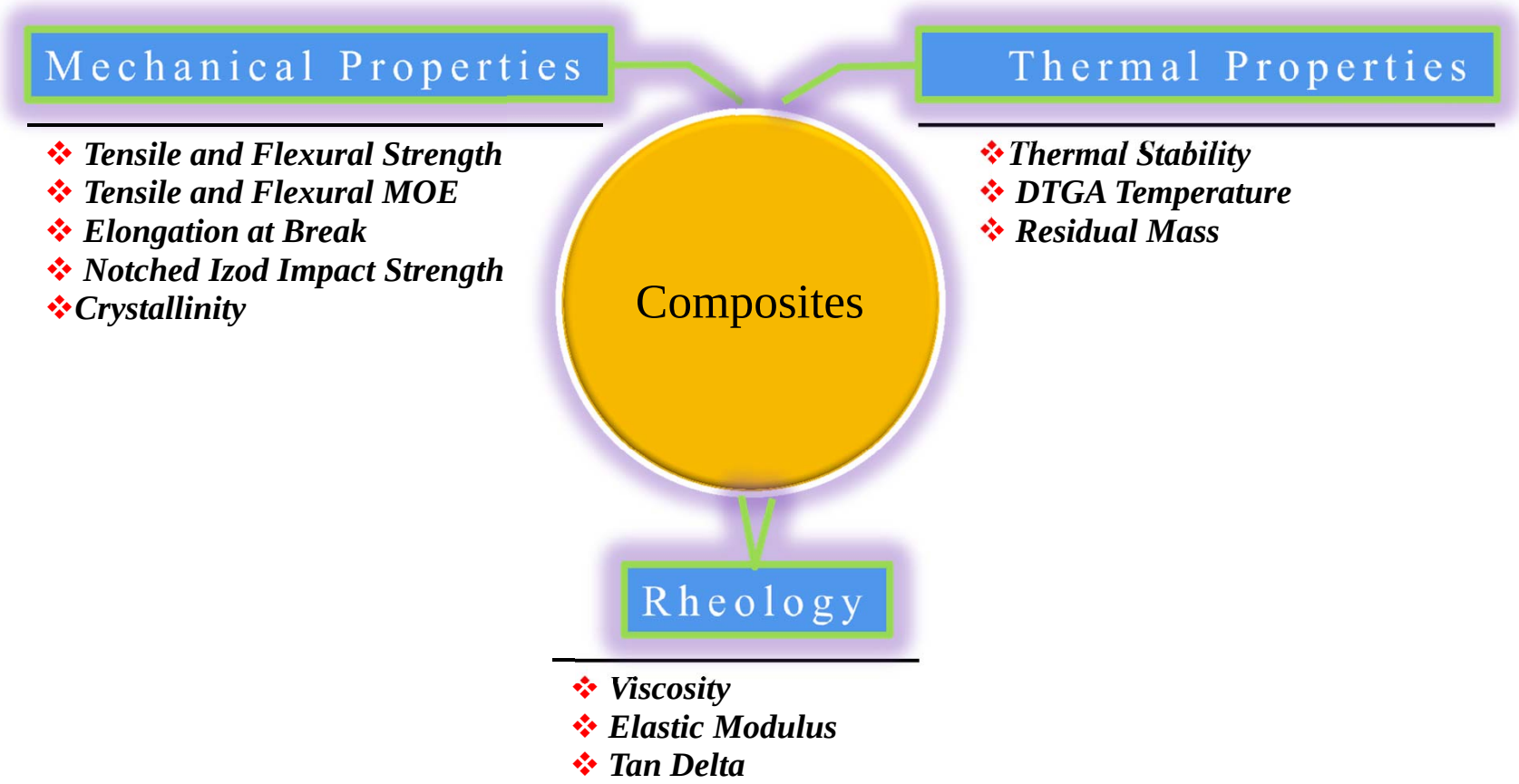
EXPERIMENTAL APPROACHES



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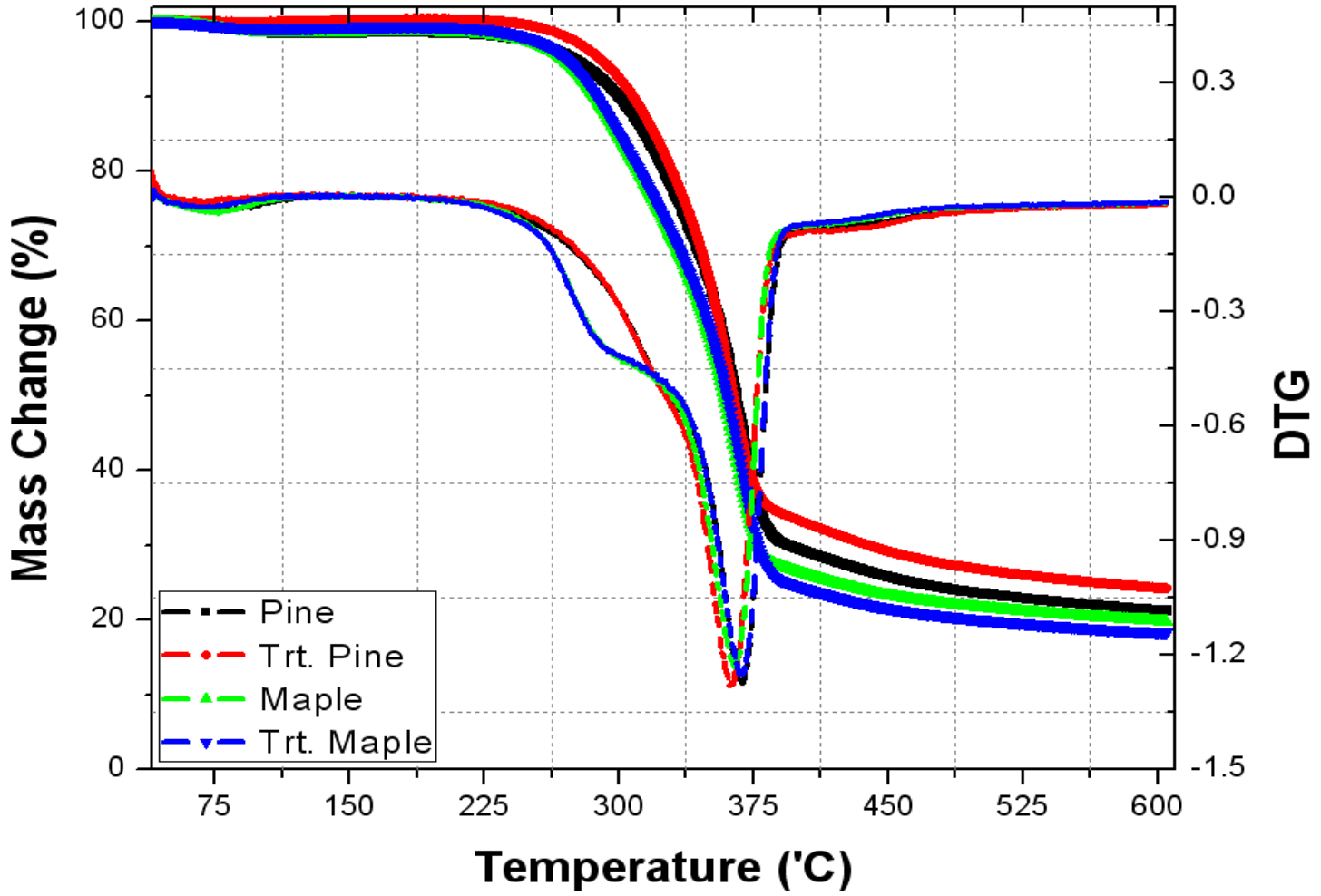
TGA and DTG of WF and HTWF



- **Thermal stability increased with the heat treatment.**

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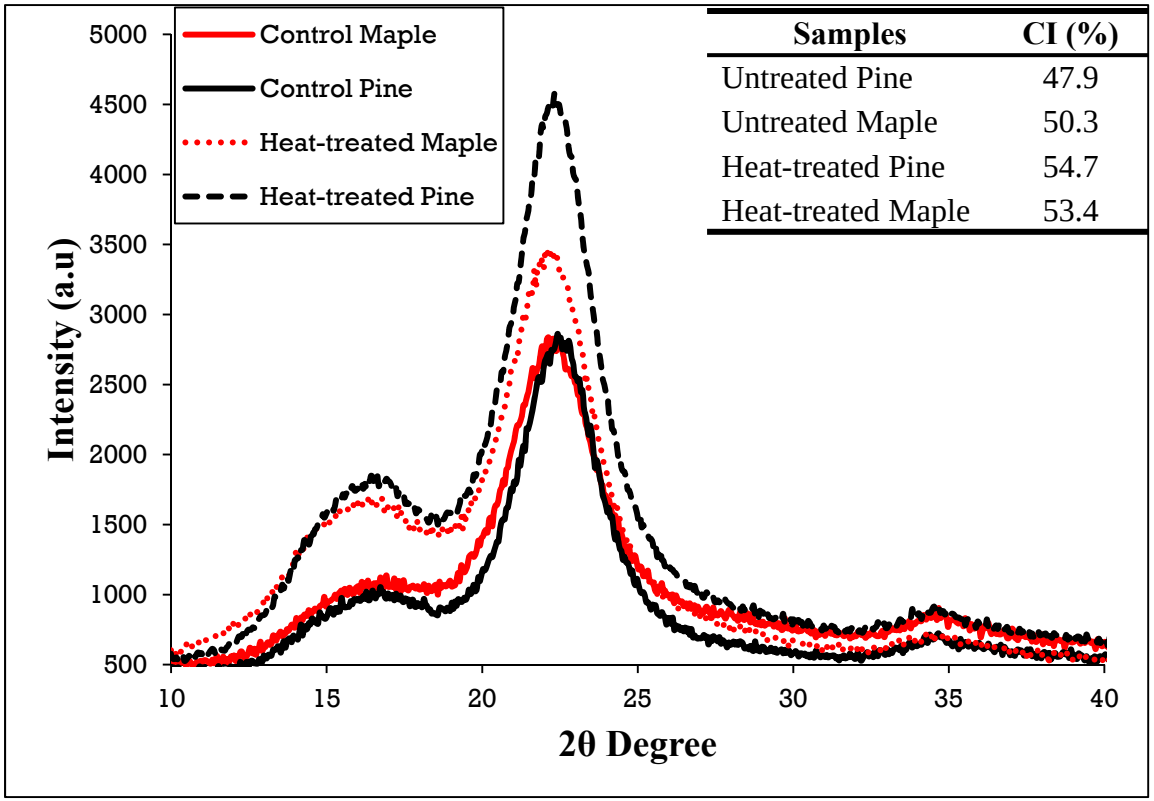
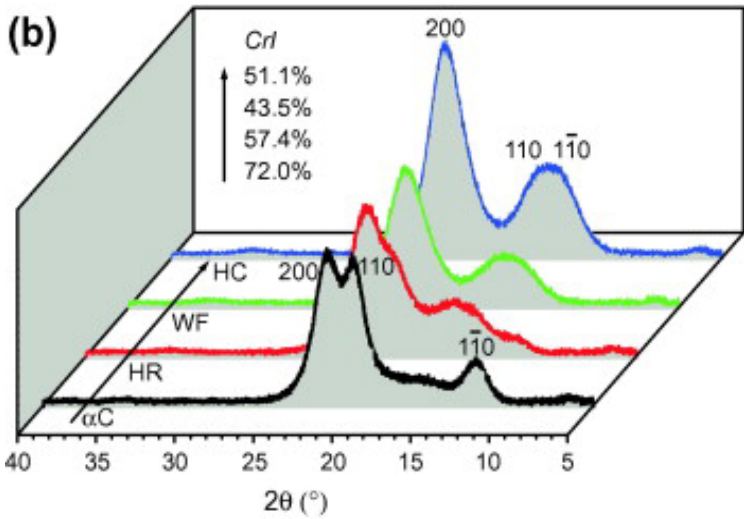
XRD CURVES AND CRYSTALLINITY INDEX



Samples	CI (%)
Untreated Pine	47.9
Untreated Maple	50.3
Heat-treated Pine	54.7
Heat-treated Maple	53.4



➢**The XRD curves indicated that the crystallinity index of wood was increased by heat treatment.**

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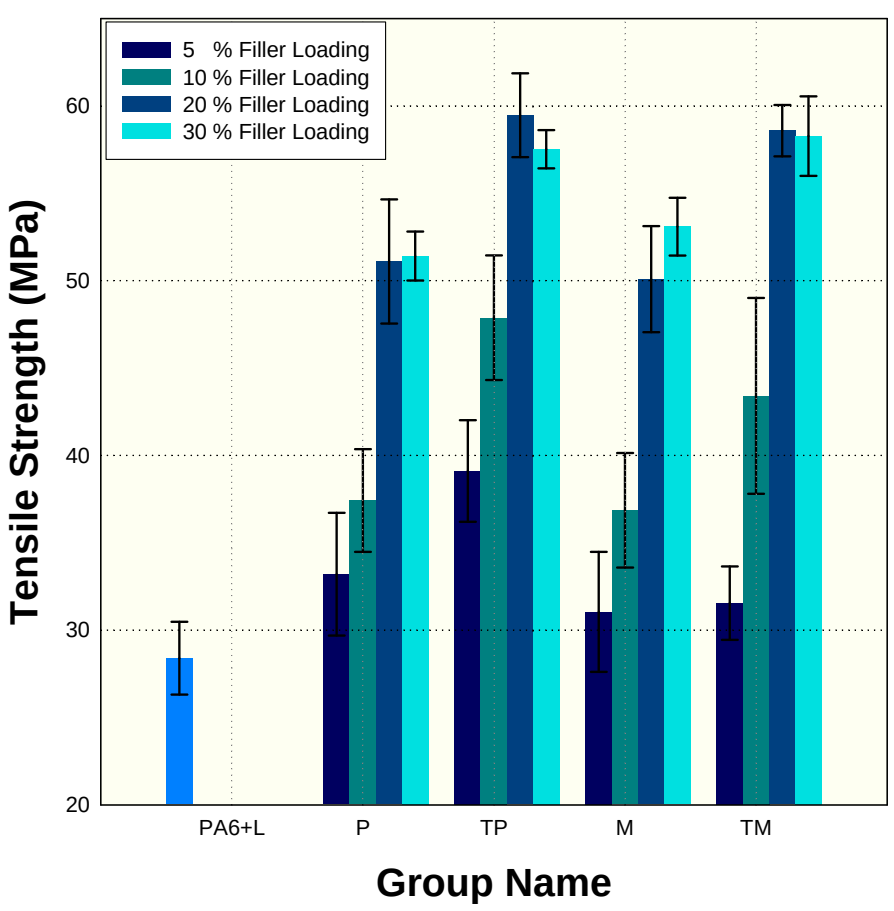
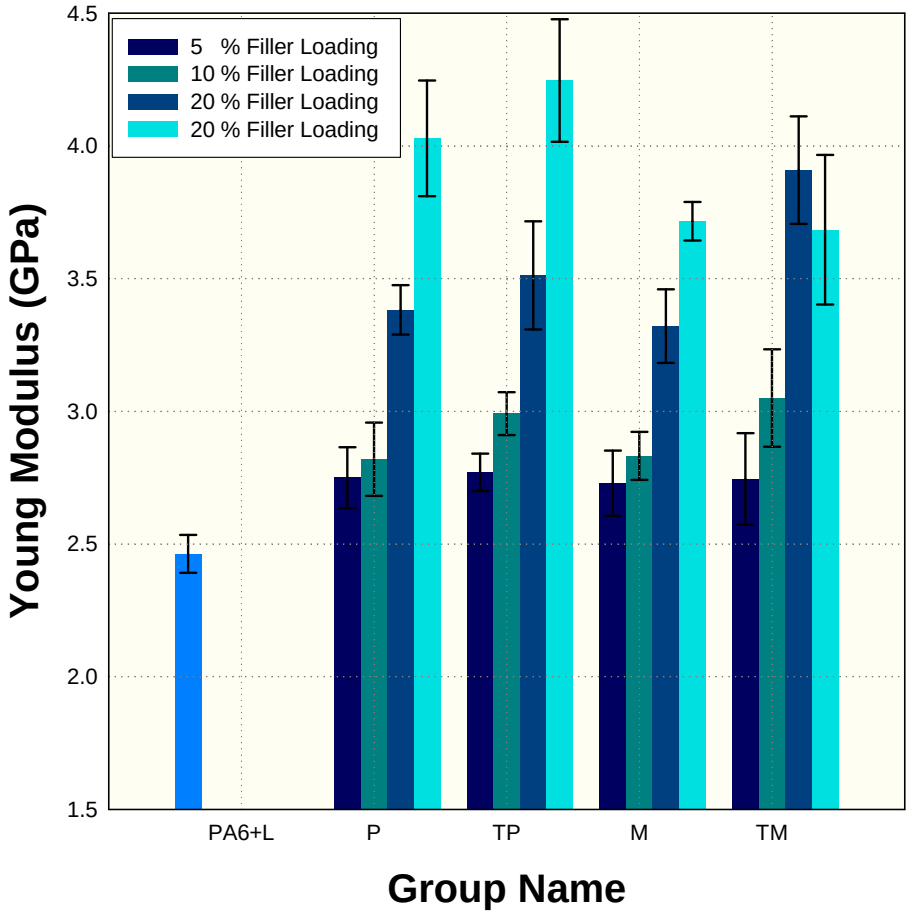
TENSILE PROPERTIES OF THE COMP.





➢**TMOE and TMOR increased with the addition of HTWF. The increase in TMOE is only to the reinforcement effect of dispersed HTWF.**

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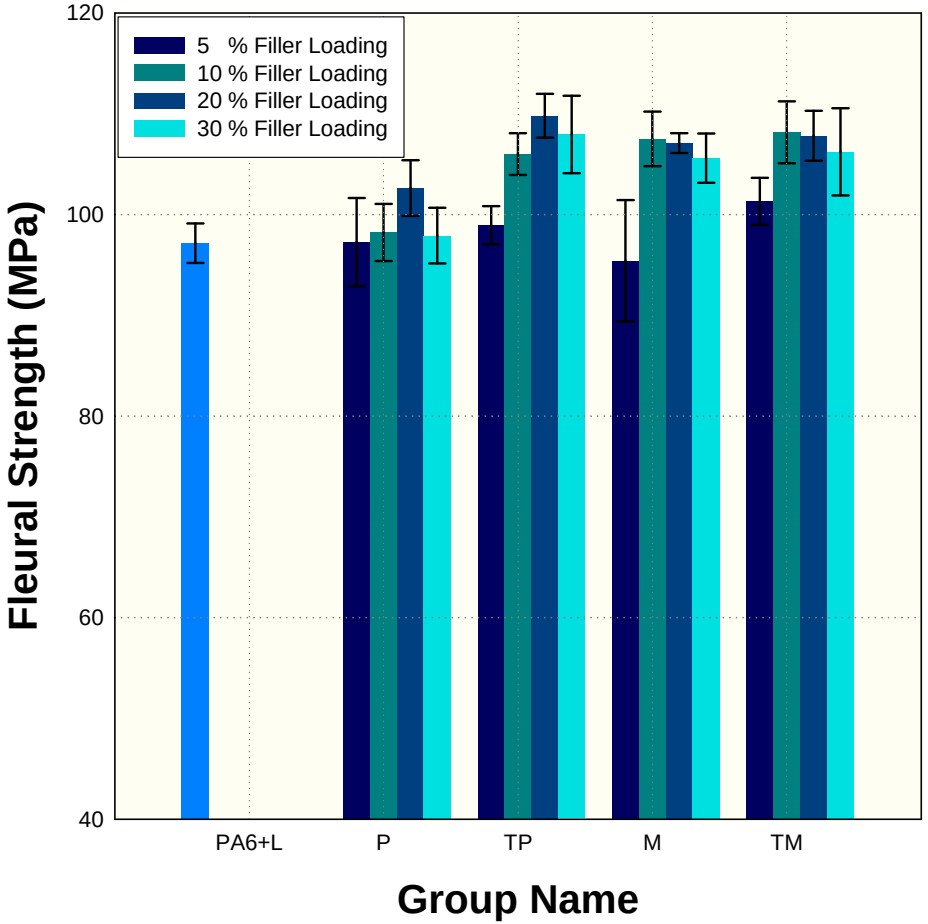
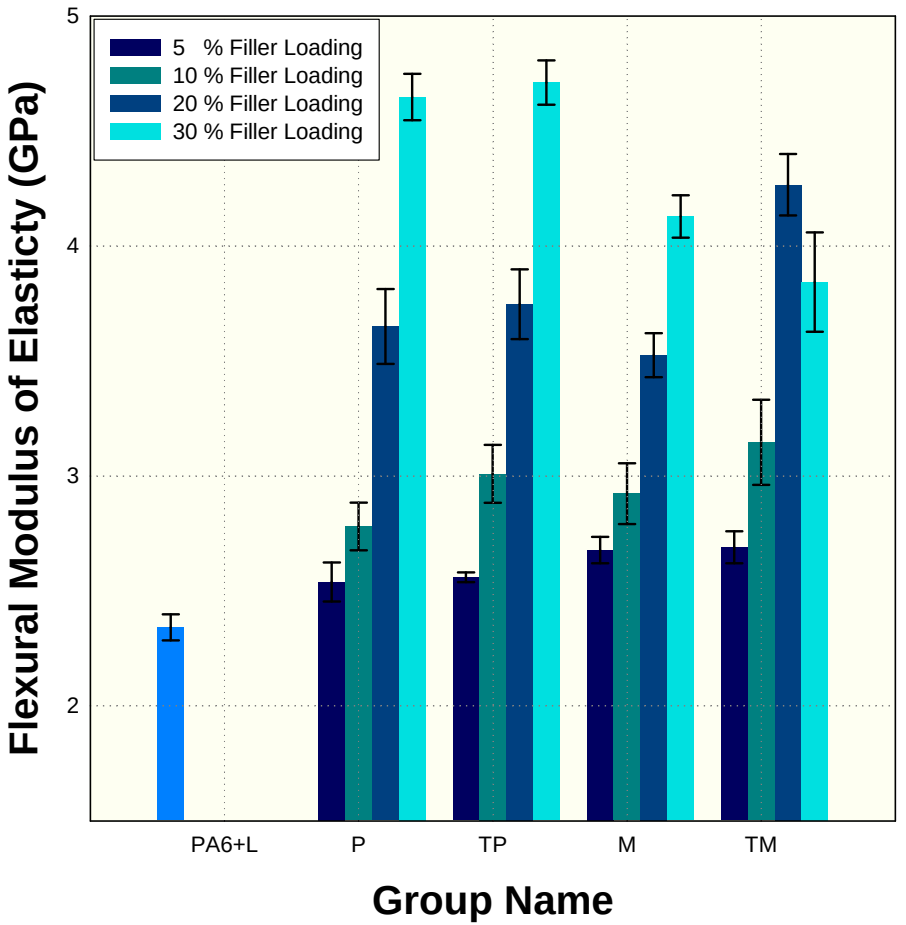
FLEXURAL PROPERTIES OF THE COMP.





➢**FMOE and FMOR increased with the addition of HTWF. The increase in FMOE is only to the reinforcement effect of dispersed HTWF.**

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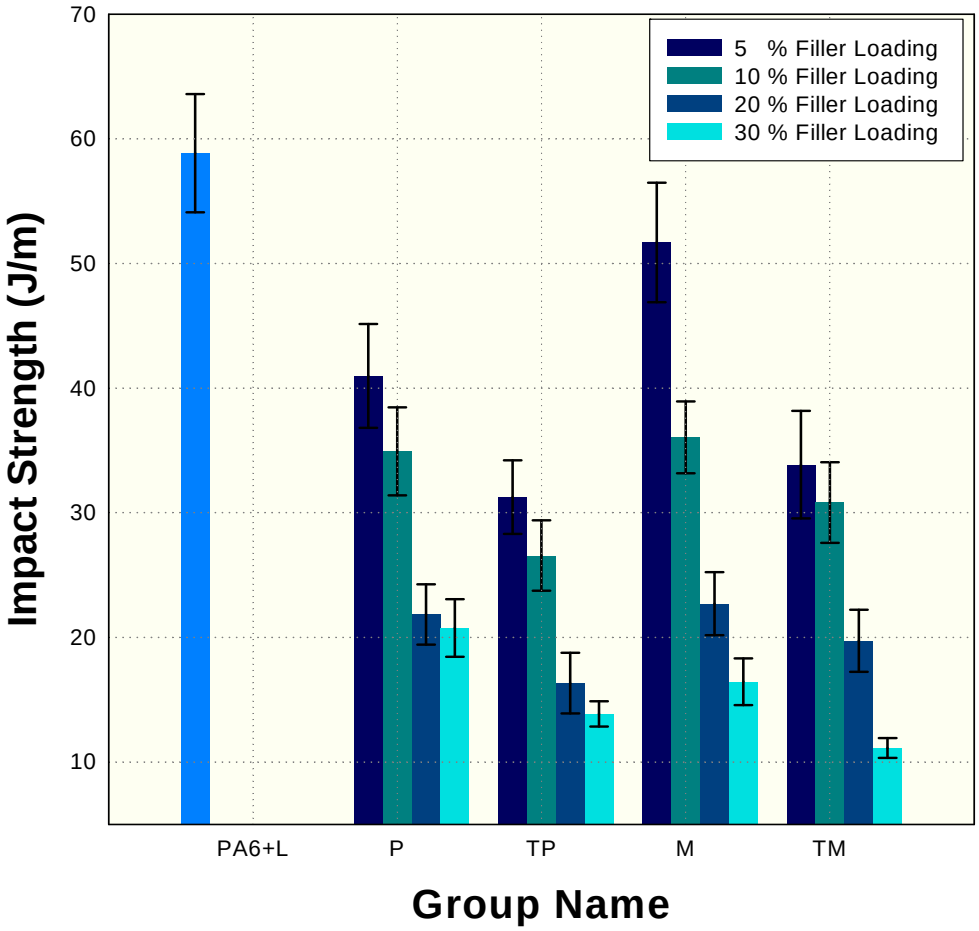
IMPACT STRENGTH OF THE COMPOSITES



➢**Increased HTWF loading has a negative effect on impact strength.** Aydemir et al. 2014

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HEAT TREATMENT-WPC-LITERATURE-CONT.

Polymer	Type of Wood	Characterization Method	Reference
PE	Bamboo	Hygroscopicity and Dimension Stability, FTIR and TGA	Fang et al. 2013
	Maple	TGA	Kaboorani and Faezipour 2009
	Red Balau	TGA, DSC, Mechanical Tests and SEM	Lafia-Araga et al. 2012
	Maple	Mechanical Tests and SEM	Kaboorani et al. 2008
	Spruce and NF	Mechanical Tests, TGA and SEM	Robin and Breton 2001
PP	Poplar	Hygroscopicity, Thickness Swelling, Flexural Test, SEM Stress Relaxation	Luo et al. 2013 Luo et al. 2012
	Norway Spruce	Water sorption, UV laser technique, ,Biological Durability and LV-SEM	Sgerholm 2007
	Birch and Spruce	SEM Hygroscopicity, thickness swelling and Mechanical Tests	Butylina et al. 2011
	Poplar	TGA, DSC	Kaboorani 2009
	Poplar	XPS, Hygroscopicity, DMA, Mechanical Tests, Thickness Swelling and SEM	Luo et al. 2014
	Eucalyptus	Hygroscopicity, thickness swelling and Mechanical Tests	Ayrilmis et al. 2011
CAB	Norway Spruce	Water sorption, UV laser technique, ,Biological Durability and LV-SEM	Segerholm 2007

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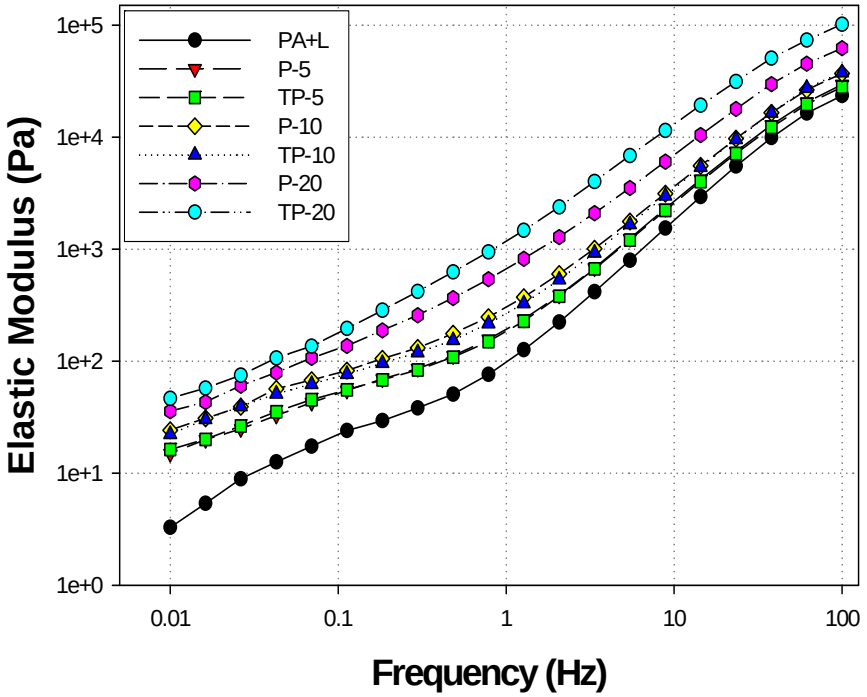
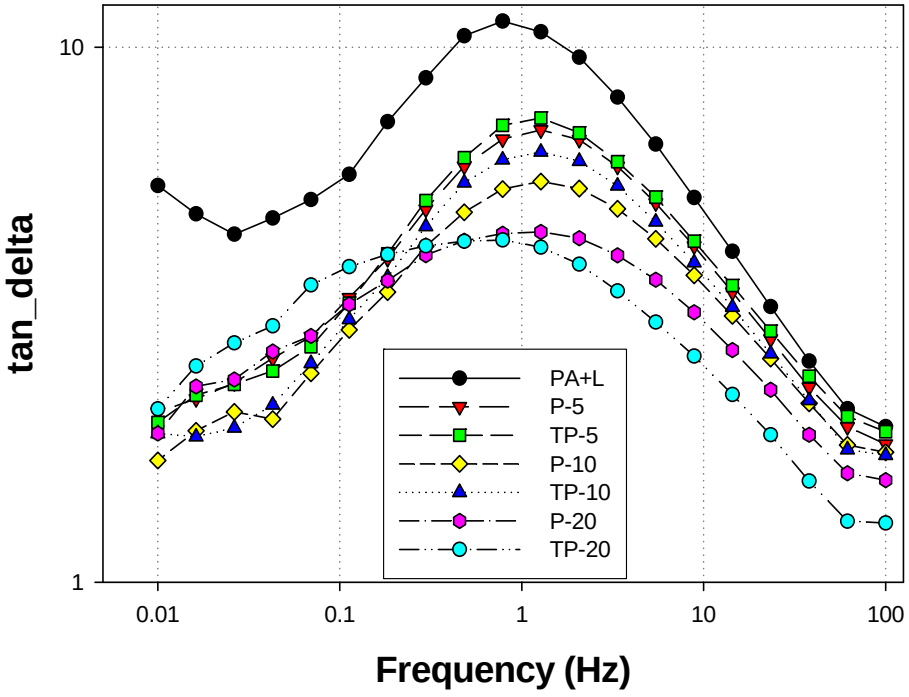
ELASTIC MODULUS AND TAN_DELTA





➢**The decrease in the slopes of elastic modulus for the composites compared to nylon 6 can be explained by the microstructural changes of the polymer matrix because of the incorporation of HTWF.**

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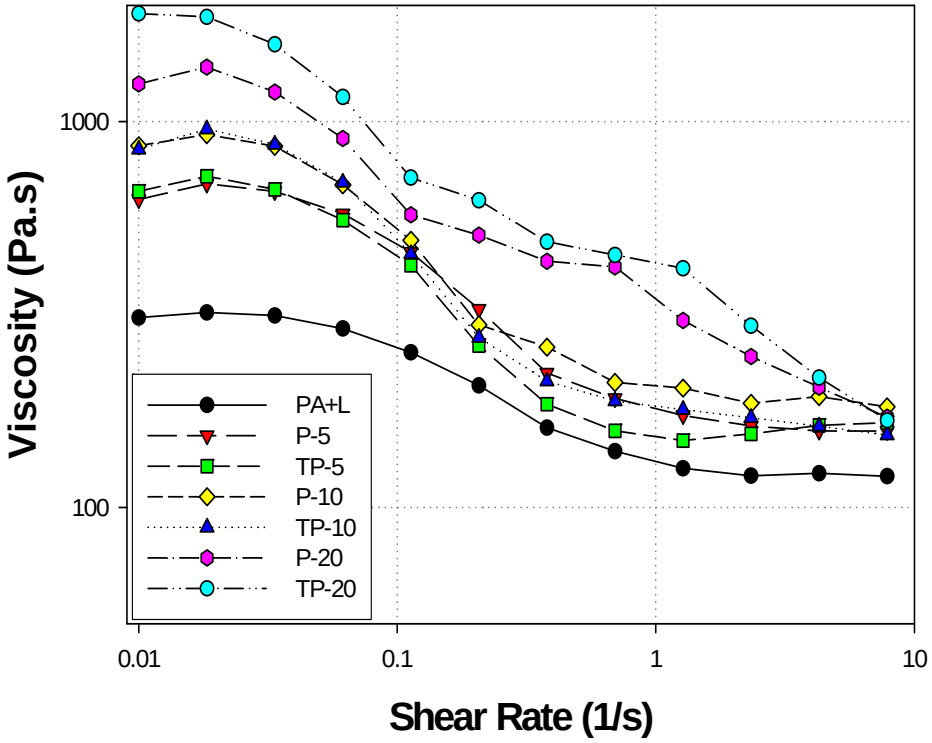
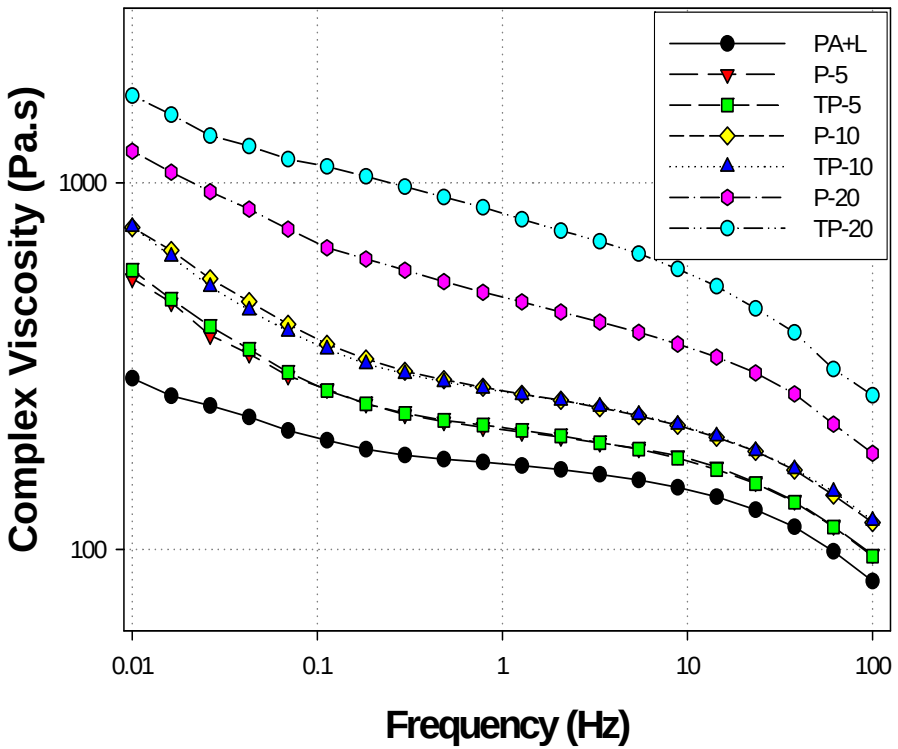
MELT VISCOSITY





➢**The higher the HTWF content of the composite, the higher the shear viscosity.**

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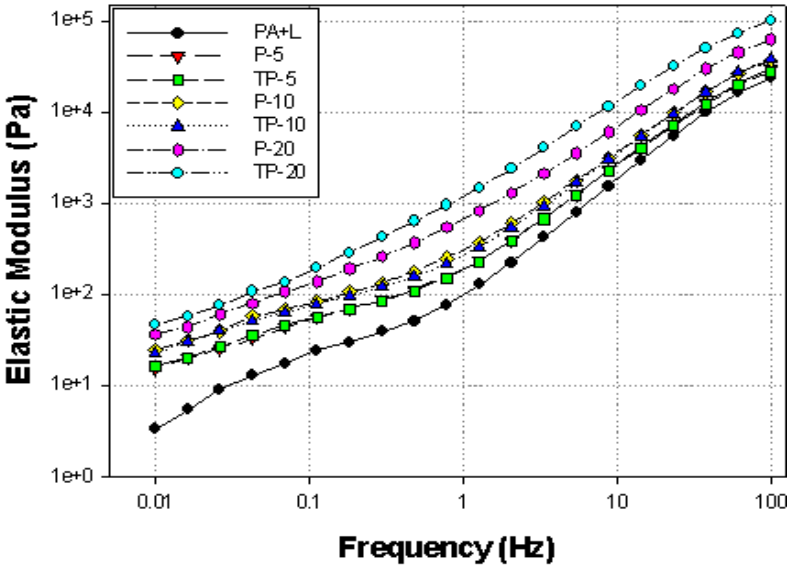
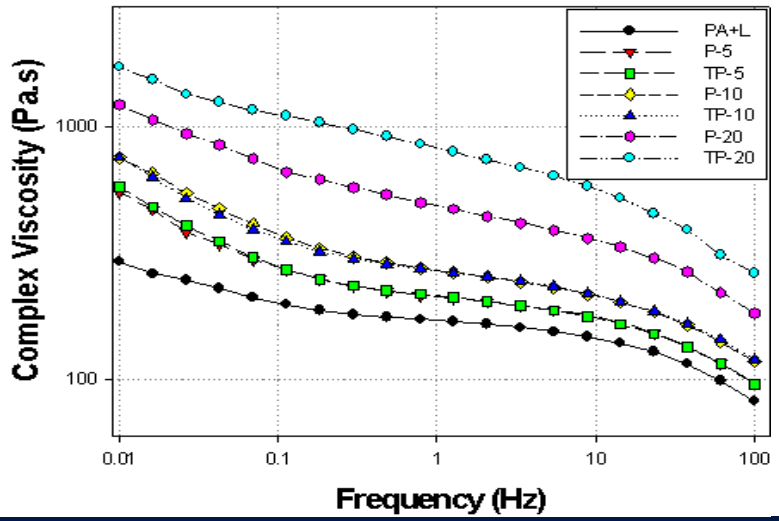
MELT VISCOSITY COMPARISION





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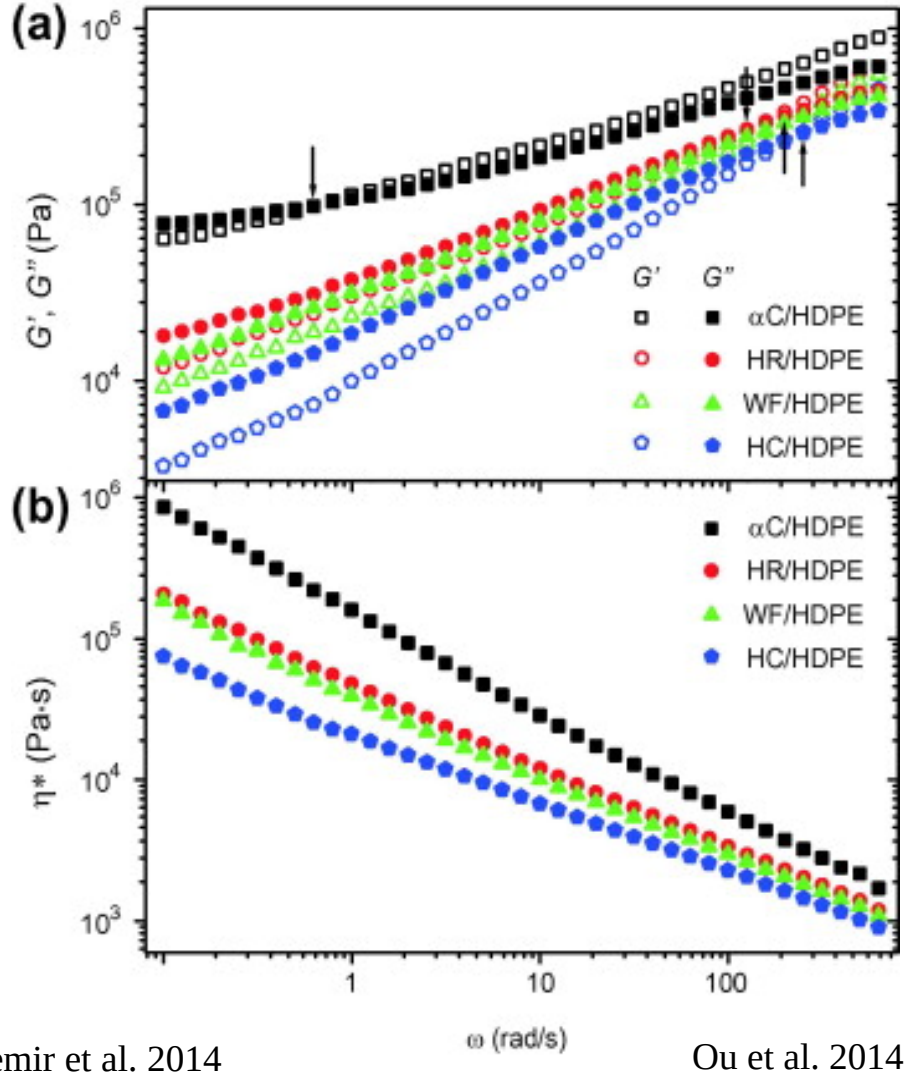

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Conclusions

- **The tensile strength increased and reached an optimum value at 20 wt. % of HTWF loading level.**
- **The TMOE and FMOE increased with the addition of HTWF.**
- **Increased HTWF loading level has a negative effect on impact strength.**
- **The thermal stability and crystallinity increased with heat treatment.**
- **The incorporation of HTWF in a nylon 6 matrix results in higher storage modulus and shear viscosities compared to those of neat nylon 6. The results of TMOE and FMOE are in accordance with the rheological data.**
- **This study laid groundwork for future research on the role of heat modification in WPC processing.**

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Acknowledgements

- **My advisor Dr. Douglas J. Gardner.**
- **The republic of Turkey, TUBITAK for the scholarship. ERDC and USDA cellulose research projects for support.**
- **Chris West and Alex Nash.**
- **University of Bartin.**

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