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Effect of wood heat treatment on the dynamic mechanical and impact properties of injection moulded wood/LDPE composites

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Introduction

Wood thermoplastic composites (WTC) are any composites that contains wood and a plastic

Why use wood in thermoplastic composites?

•Abundantly available
•Renewable
•Environmentally friendly
•Relatively cheap
•Low density/good strength to weight ratio
•Good tribological properties

However, wood is …….

•Polar
•Hygroscopic

Wood modification methods

- Chemical
  - Coupling agent
  - Benzylation
  - Alkanization
  - Alkylation
  - Silanization
- Physical
  - Corona or Plasma treatment
  - Densification
- Biological
  - Enzymatic modification
- Thermal Treatment

Thermal treatment

Thermal treatment changes the chemistry of wood:

•Hemicelluloses are degraded

•Lignin softens, flows and blocks the cell pores, thereby contributing to reduction in moisture absorption

•Cross-linking takes place between carbohydrate polymers or between lignin and carbohydrate polymers

•Increased crystallinity of amorphous cellulose

•Improved dimensional stability

•Polarity is reduced, resulting in reduced hydrophilicity

Motivation

- PE possesses desirable processing characteristics such as low melting temperature, high melt strength and relatively low viscosity

- Excellent toughness, exhibited in the puncture resistance of its films, drop strength of blown bottles and impact resistance of moulded items

- The ability of composites from PE to withstand sudden impact is of great importance for any practical application of the material

- Heat treatment presents an environmentally friendly method of modifying wood as no chemicals are used and no effluent generated

- Composites from Red Balau waste and LDPE will extend the applications of LDPE beyond the traditional use in films and packaging

Objectives

- To modify red balau saw dust using heat treatment for use as fillers in WTC

- To assess the effect of heat treatment on the chemical changes in the wood flour

- Investigate the effects of heat treatment of wood flour on the dynamic mechanical and impact properties of the composites

General applications of WTC

EXPERIMENTAL

➢Materials – Red balau wood flour 40-100 mesh (400-150 μm)

LDPE - (Titanlen LDI300YY), Density : 920 kg/m^3,
MFI : 20 g/10 min, Molecular mass : 350,000 – 380,000 g/mol

➢Wood pretreatment - Wood flour was subjected to 180°C and 200°C in an oven for 1 hour effective treatment time

➢FTIR-ATR

- Instrument - Spotlight 400, Perkin Elmer, USA combined with a universal ATR accessory
- Resolution - 4 cm^{-1} for 64 scans in the range of 650-4,000 cm^{-1}

➢Processing

Compounding

- Wood flour applied at 20% and 37% by weight
- Instrument - Brabender KETSE 20/40, twin screw extruder
- Screw speed : 250 rpm
- Barrel temperature : 150°C-155°C

Injection molding

- Instrument - BOY 55M injection molding machine
- Barrel temperature : 150°C – 155°C
- Injection pressure : 100 – 120 bars
- Mould temperature : 25°C

➢ Characterization

• DMA

-Instrument – TA Q800 Dynamic mechanical analyzer, TA Instruments
-Testing mode – Three point bending
-Support span – 50 mm
-Specimen dimensions – 60.0 x13.0 x 3.3 mm
-Scan range – -100°C to 100°C
-Scan rate – 2°C/min
-Frequency – 1 Hz
-Amplitude – 15 µm

•Notched charpy impact test

- Instrument - Instron Dynatup 9210, USA
- Sample dimension - 6 mm x 12 mm x 80 mm
- Impactor load - 6.448 kg
- Impactor velocity - 2.9238 m s^{-1}
- Impact energy - 13.95 J

Formulations of the composites

Sample code	Weight of LDPE (%)	Weight of wood flour (%)	Treatment temperature (°C)
LDPE/$W_{UN/9}$	91	9	-
LDPE/$W_{UN/20}$	80	20	-
LDPE/$W_{UN/37}$	63	37	-
LDPE/$W_{180/9}$	91	9	180
LDPE/$W_{180/20}$	80	20	180
LDPE/$W_{180/37}$	63	37	180
LDPE/$W_{200/9}$	91	9	200
LDPE/$W_{200/20}$	80	20	200
LDPE/$W_{200/37}$	63	37	200

R E S U L T S

A N D

D I S C U S S I O N

Characterisation of wood flour

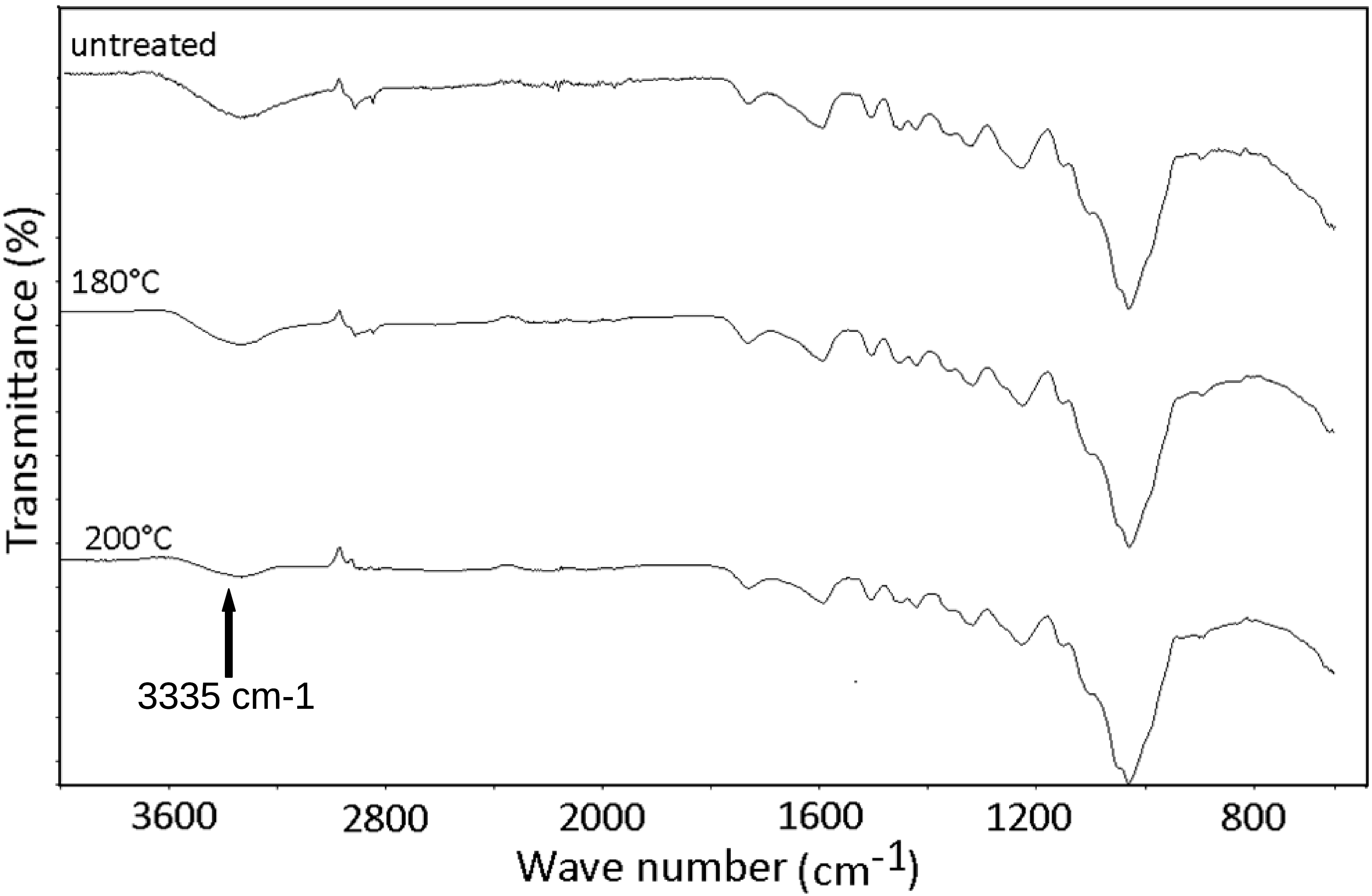
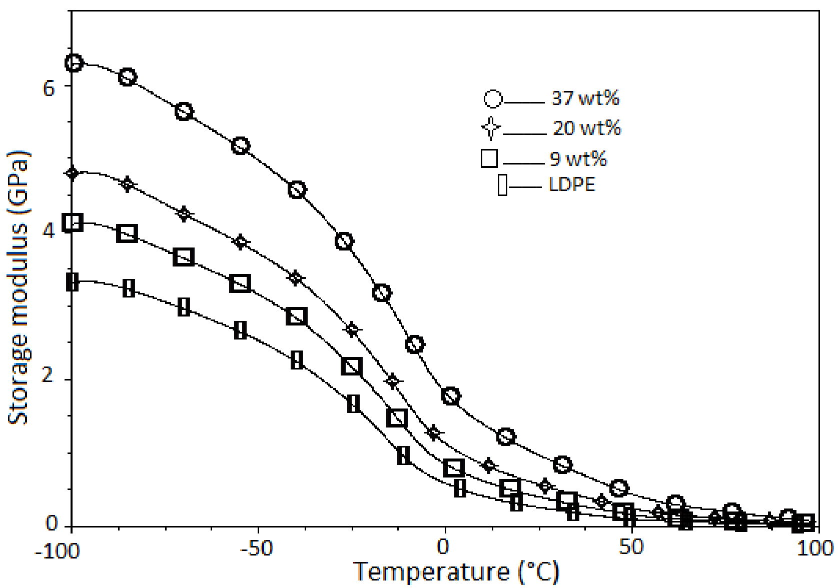


Fig. 2. FTIR spectra of heat treated and untreated red balau saw dust.

Dynamic mechanical behaviour

Storage modulus

a)



b)

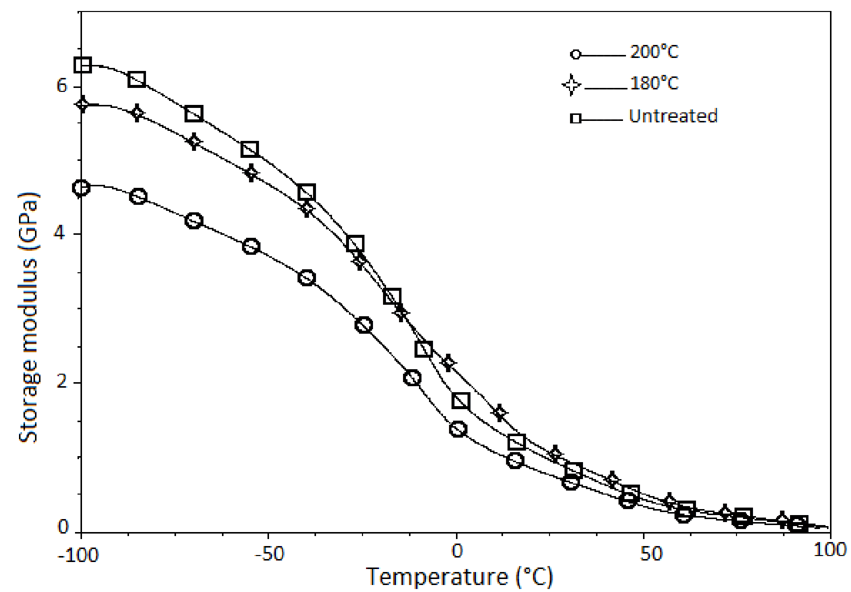


Fig 3: Storage modulus curves of untreated and heat treated WTC as a function of a) wood content and b) heat treatment

Loss modulus

a)

b)

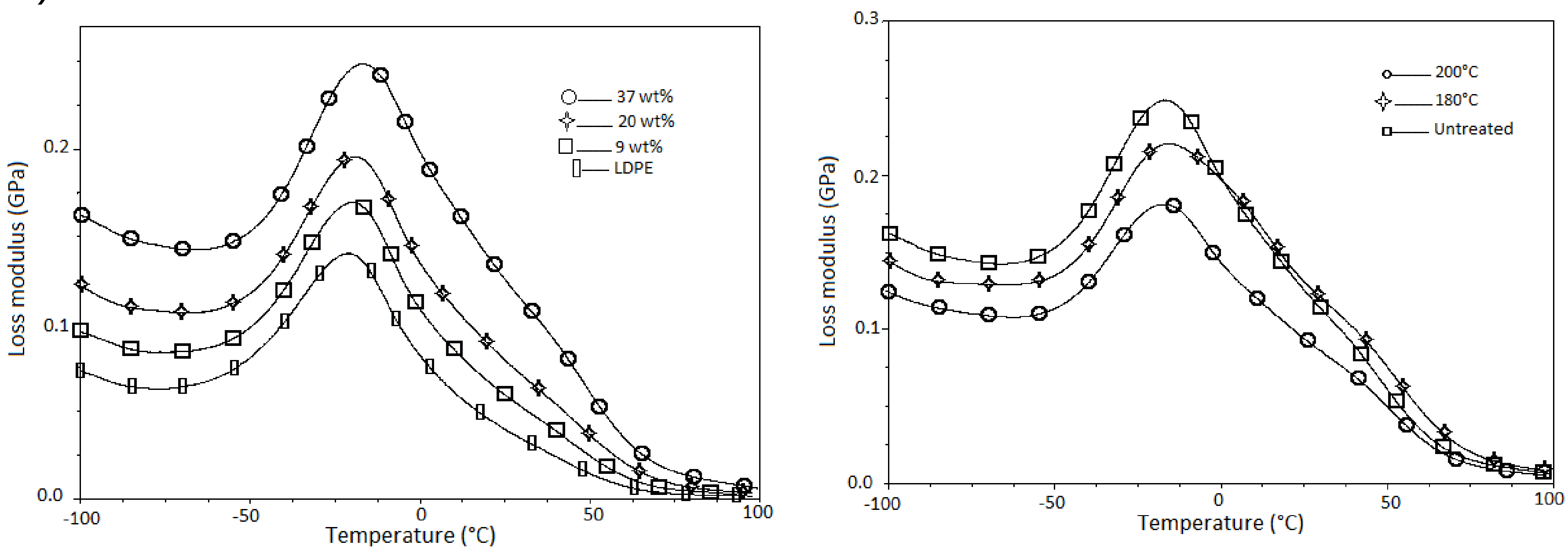
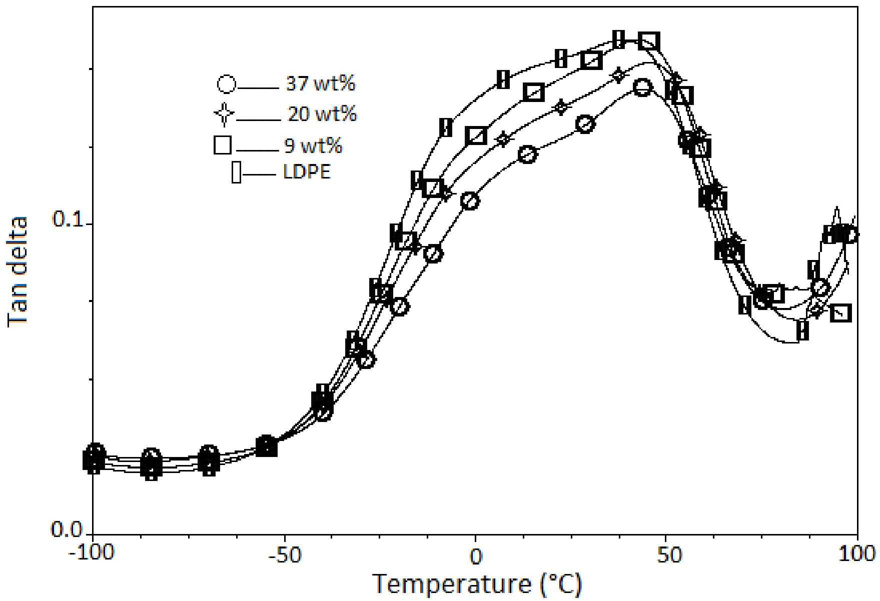


Fig 4: Loss modulus curves of untreated and heat treated WTC as a function of a) wood content and b) heat treatment

Tan delta

a)



b)

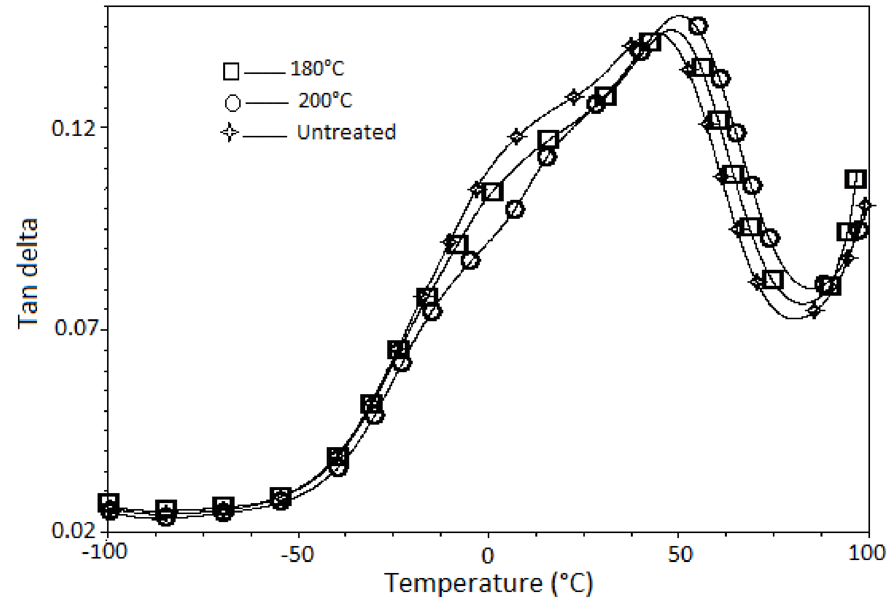


Fig 5: Tan delta curves of untreated and heat treated WTC as a function of a) wood content and b) heat treatment

Table 2: DMA data of red balau/LDPE composites containing untreated and heat treated wood flour

Sample	Treatment temperature (°C)	Tan delta				Storage modulus E'		Loss modulus E"		
		Tan δ_{max}	Temperature at tan δ_{max} (°C)	$W_{\sqrt{2}}$	Tan $\delta_{25°C}$	$E'_{25°C}$ (GPa)	$E'_{-100°C}$ (GPa)	$E''_{25°C}$ (MPa)	$T^{E''}_{\beta}$ (°C)	E''_{Max} (MPa)
LDPE	-	0.16	39.1	74.1	0.15	0.26	3.3	40.0	-25.0	140.1
LDPE/$W_{UN/9/0}$	-	0.16	42.5	72.7	0.15	0.40	4.1	59.2	-19.0	170.3
LDPE/$W_{180/9/0}$	180.0	0.16	43.2	73.4	0.15	0.31	3.1	46.6	-18.1	129.8
LDPE/$W_{200/9/0}$	200.0	0.16	44.1	73.5	0.15	0.31	3.1	46.5	-18.2	130.4
LDPE/$W_{UN/20/0}$	-	0.15	45.9	70.5	0.14	0.57	4.8	80.0	-19.1	195.6
LDPE/$W_{180/20/0}$	180.0	0.16	49.4	66.0	0.13	0.56	3.8	67.0	-19.8	150.4
LDPE/$W_{200/20/0}$	200.0	0.16	49.7	63.1	0.13	0.51	3.8	66.1	-18.1	150.3
LDPE/$W_{UN/37/0}$	-	0.14	43.7	66.0	0.13	0.97	6.3	134.0	-16.4	248.8
LDPE/$W_{180/37/0}$	180.0	0.14	48.1	66.6	0.12	1.07	5.7	130.7	-17.2	220.5
LDPE/$W_{200/37/0}$	200.0	0.15	50.3	58.7	0.12	0.76	4.6	93.8	-15.9	181.2

Impact properties

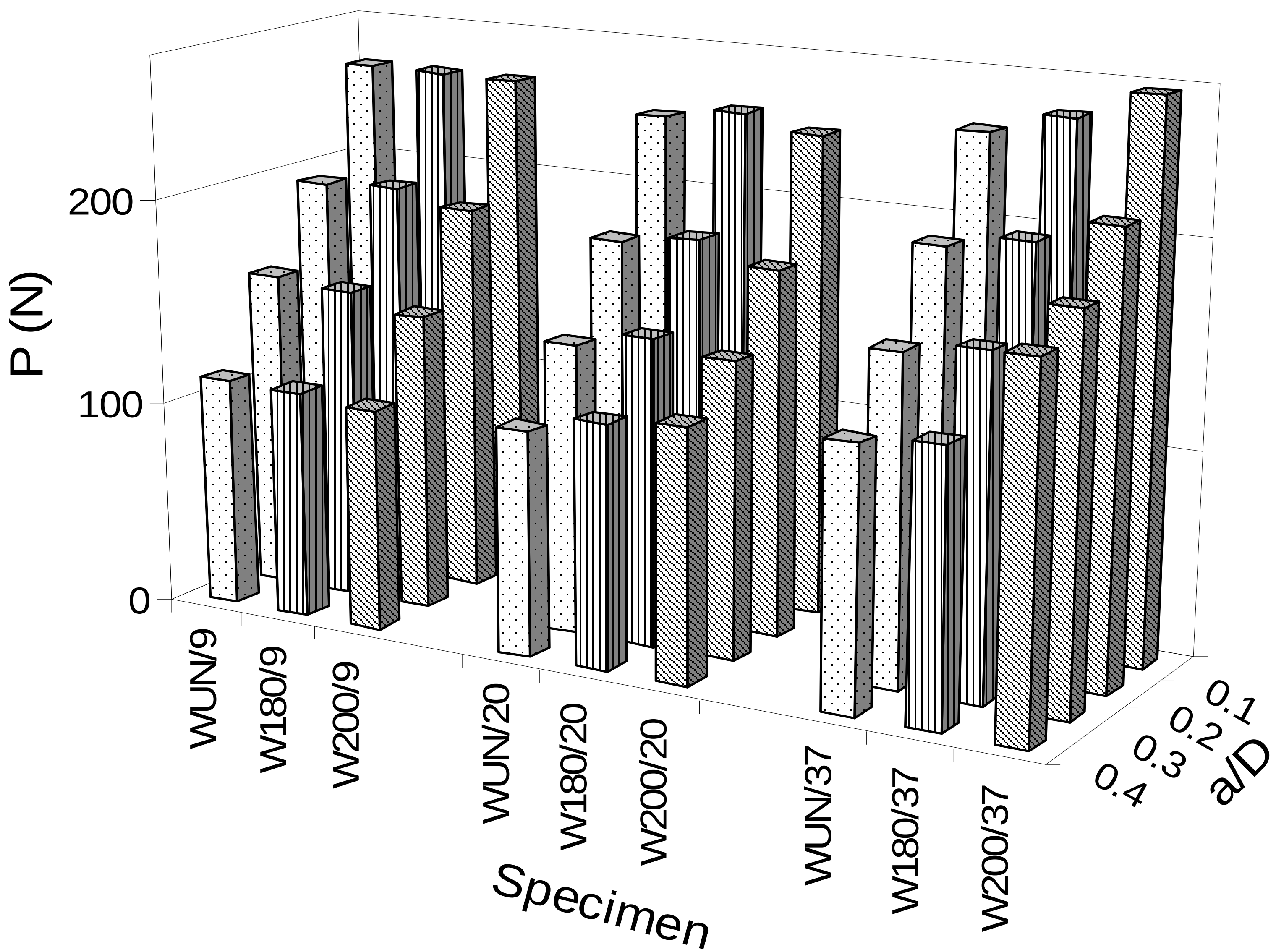


Fig. 6: Peak load as a function of notch dept for different wood content and heat treatment.

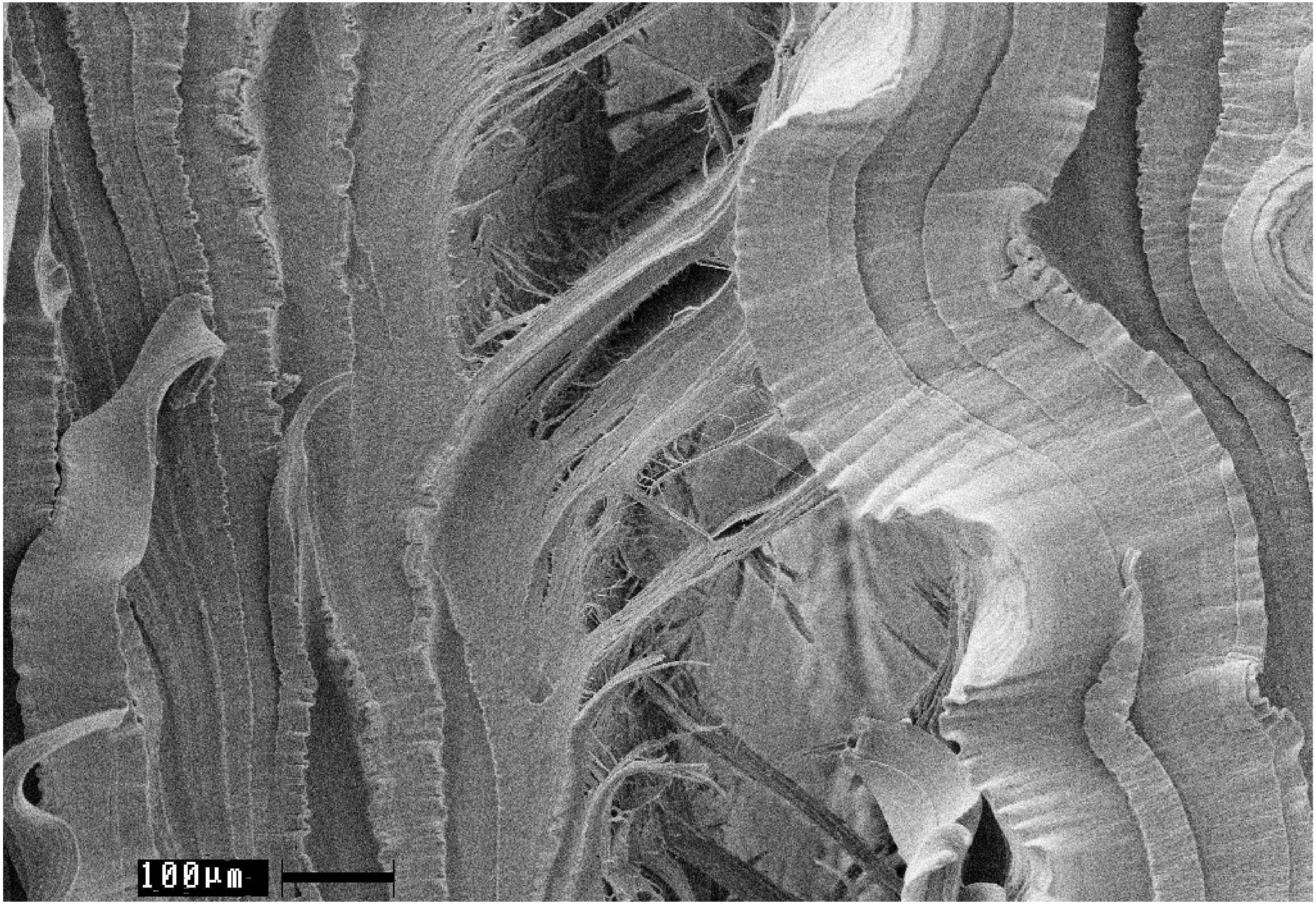


Fig. 7: Impact fractured surface of neat LDPE showing signs of ductility.

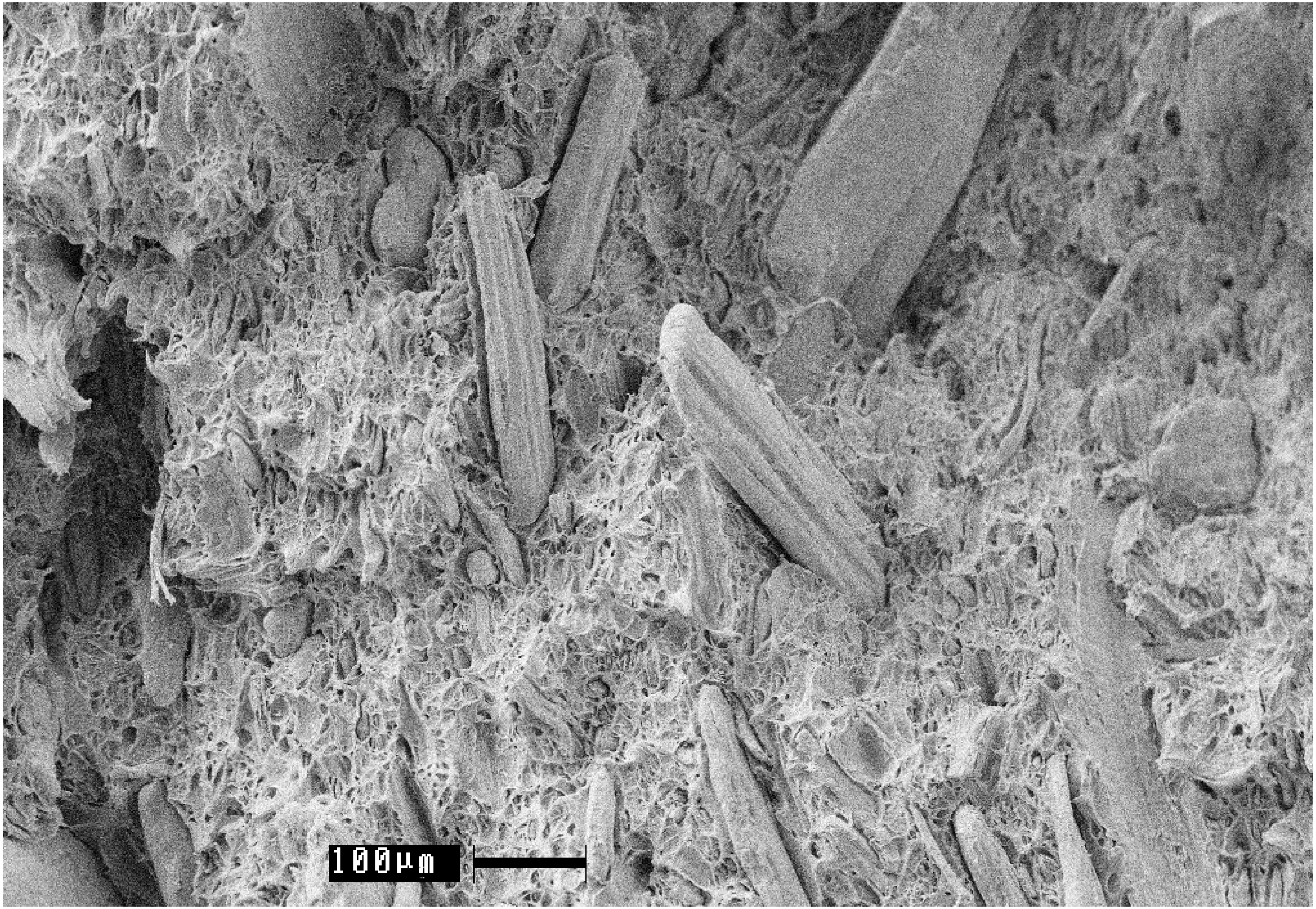


Fig. 8: Impact fractured surface of untreated wood composites at 37 wt%

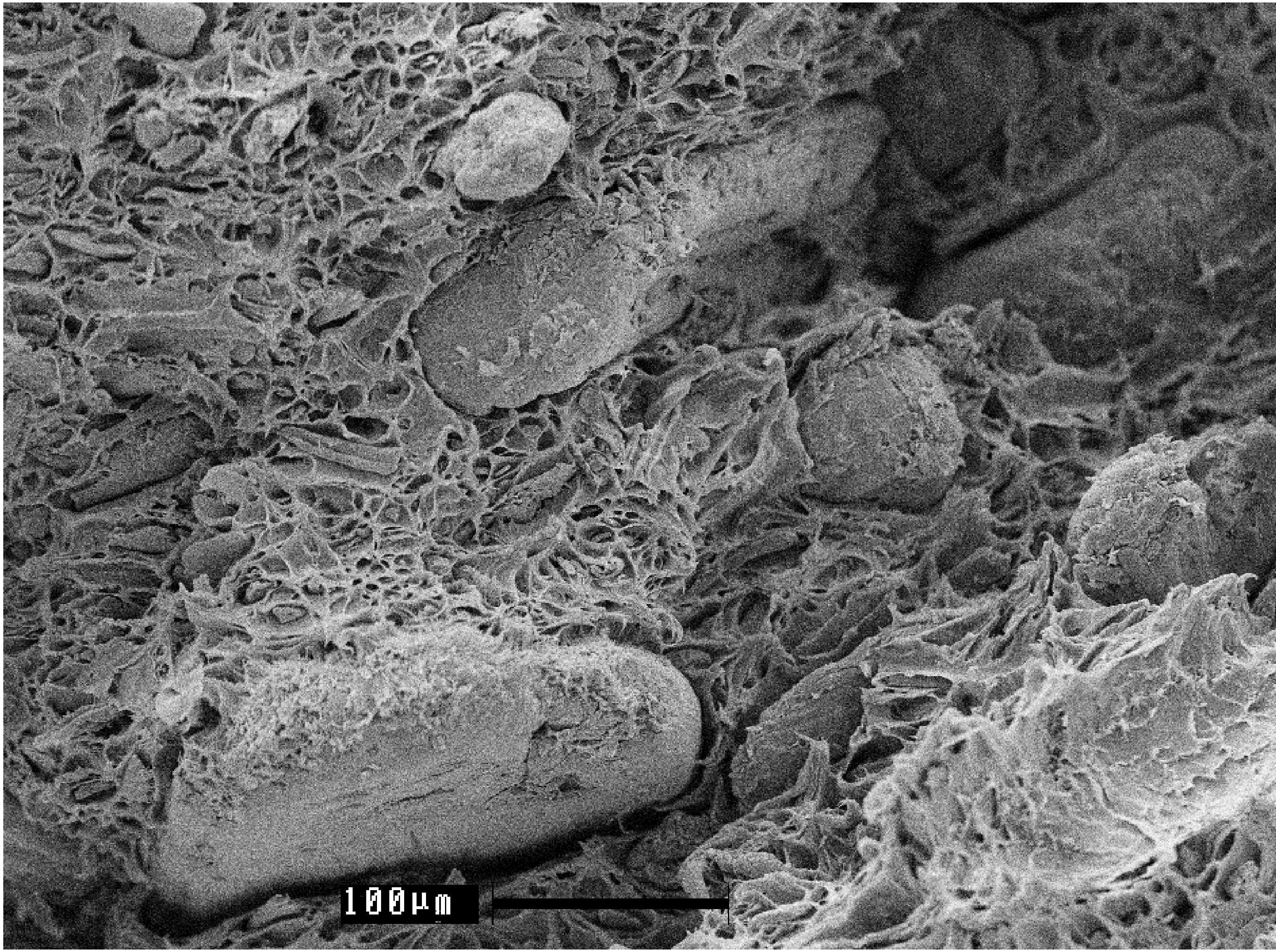


Fig. 9: Impact fractured surface of composites from wood treated at 200°C at 37 wt% filler loading showing no sign of ductility.

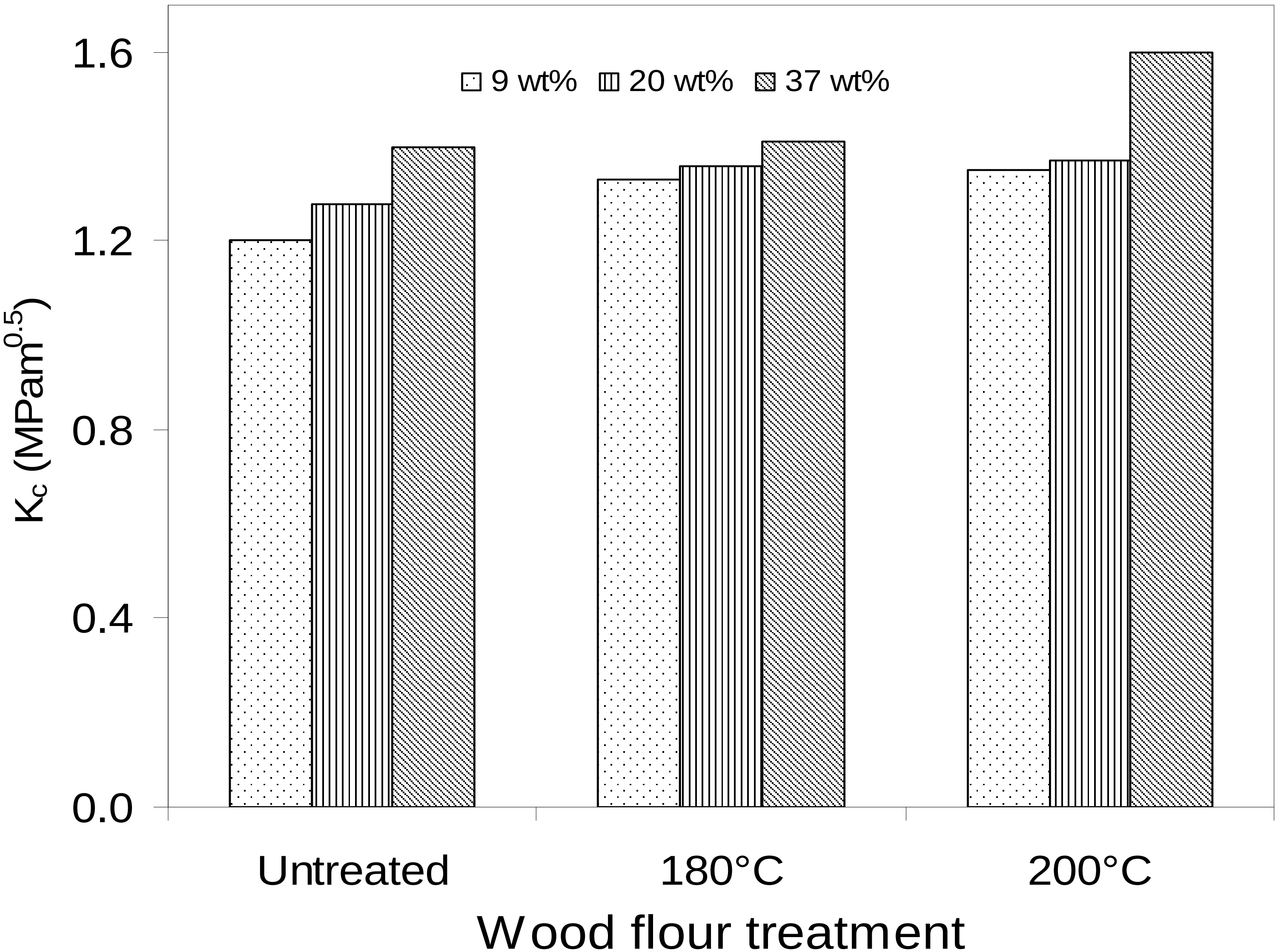


Fig. 10: Changes in K_c of composites as a function of wood content and treatment temperature.

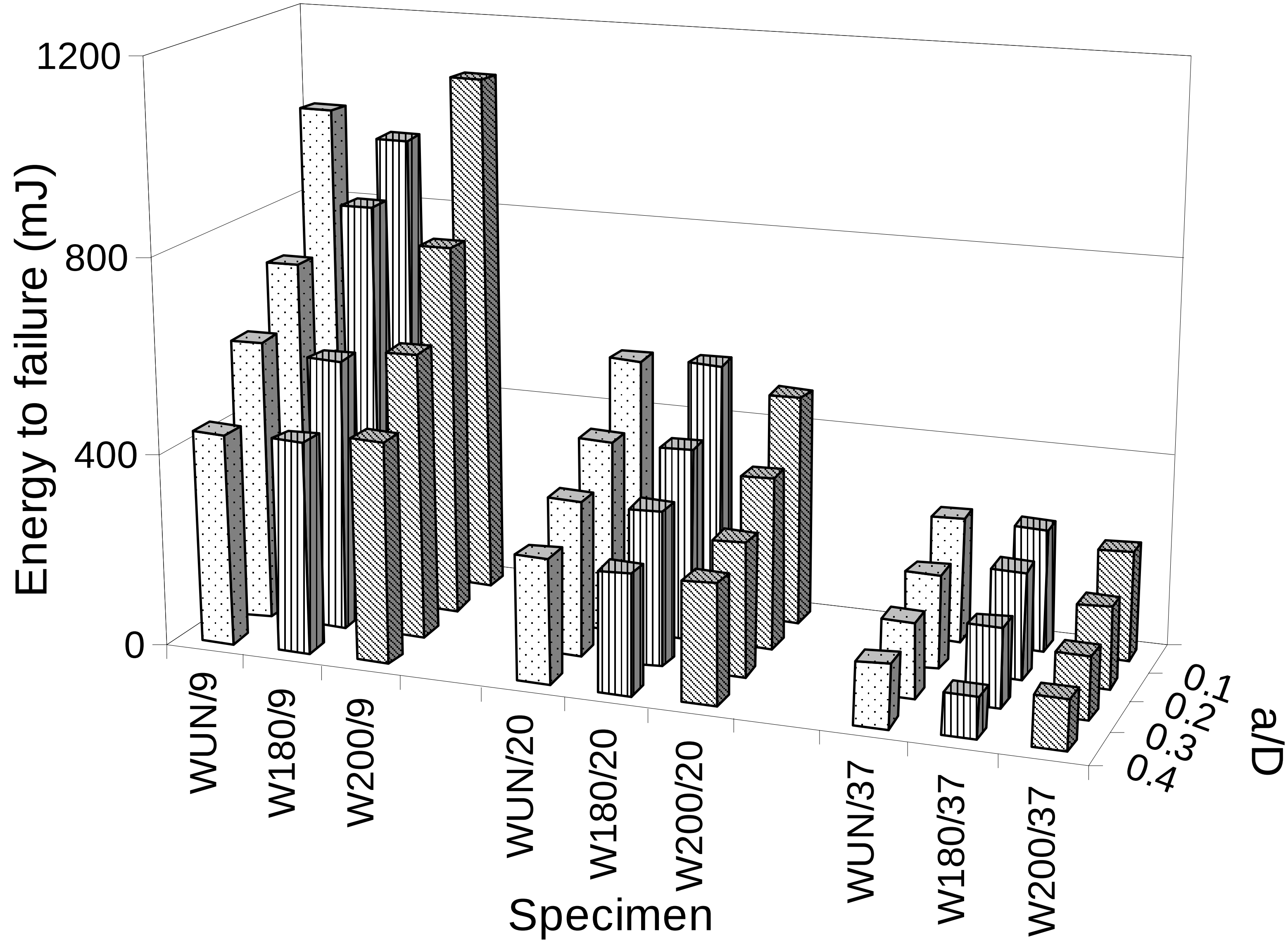


Fig. 11: Energy to failure as a function of wood content and treatment temperature for different a/D ratios.

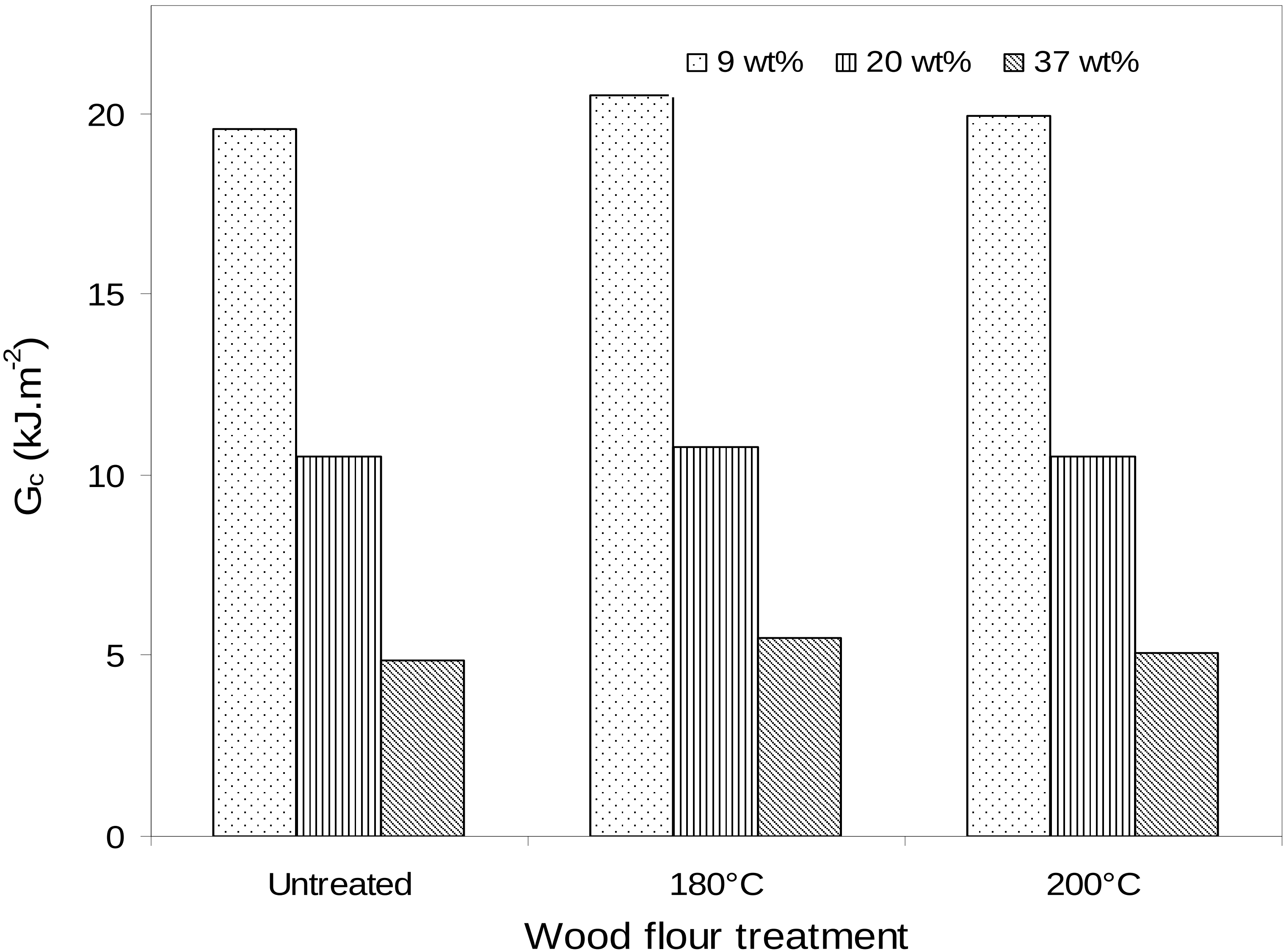


Fig. 12: G_c of composites as a function of wood content and treatment temperature

Conclusion

- Composites containing untreated wood flour exhibited higher storage and loss modulus than those made from heat treated wood flour
- The tan delta width decreased generally with wood content and heat treatment, indicating reduced damping
- Tan delta maximum decreased with wood content but increased marginally with heat treatment
- P and K_c decreased with both wood content and treatment temperature
- W and G_c decreased with wood content but the G_c is highest in composites made from wood flour treated at 180°C, and reduced in 200°C heat treated wood composites
- Heat treatment of wood flour at appropriate treatment temperature produced composites with better compatibility and improved dynamic mechanical and impact performance

Acknowledgments

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