Imprinted Glass Fiber-Reinforced Epoxy Nanocomposites Vascular Self-Healing Wind Turbine Blades

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Introduction

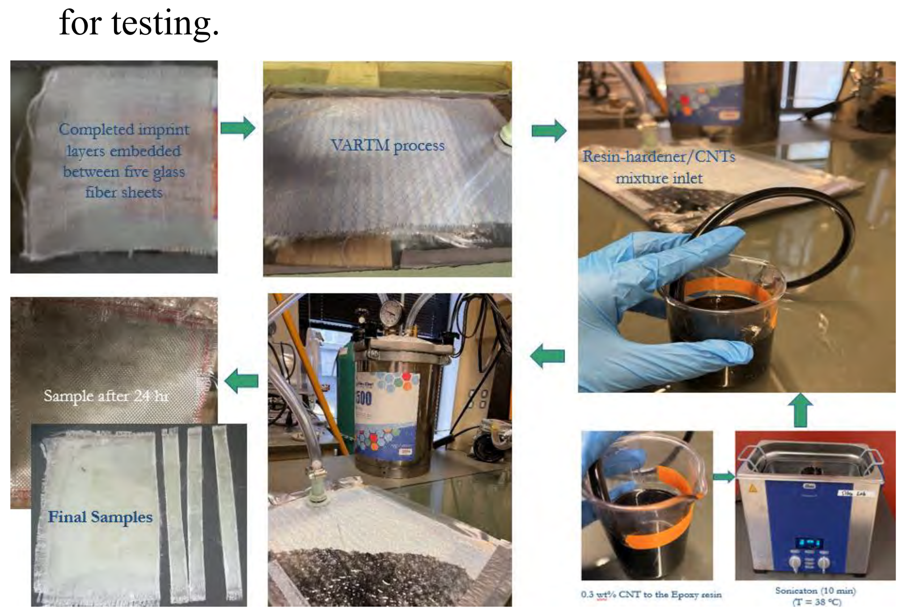
Wind energy is one of the main renewable energy sources, and it has been one of the most promising sources of clean, long-term energy. Self-healing is the ability to sustain and recover from failure autonomously.

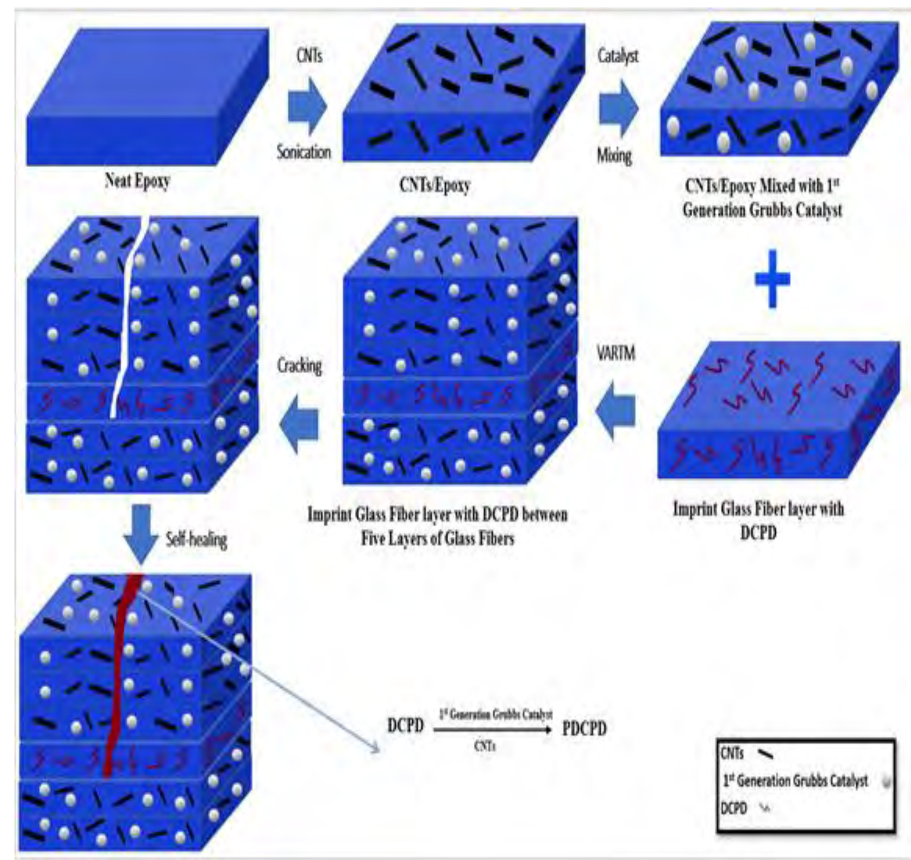
Self-healing material systems in wind turbine blades can reduce costs associated with maintenance, repair, and energy compensation.

This project is to improve a method of instilling healing capabilities into VARTM molded fiber reinforced plastic (FRP) via vascular networks by using dicyclopentadiene (DCPD)/ Epoxy/ Carbon nanotubes (CNTs) polymer nanocomposites in addition to the Grubbs' first-generation catalyst.

Methods

VARTM process involved the arrangement of six layers of glass fibers over the base plate. Additional layers of peel ply and breather material were placed above the glass fiber sheets, and then they were covered by a vacuum bag for sealing which has inlet and outlet provisions for resin-hardener-nanofiller mixture overflow. High suction pressure was generated using a vacuum pump to infuse the resin/CNTs into the glass fiber layers. After leaving the mold to be cured for 24 hr (exothermic reaction). Finally, the sample has been cut into several sections for testing.



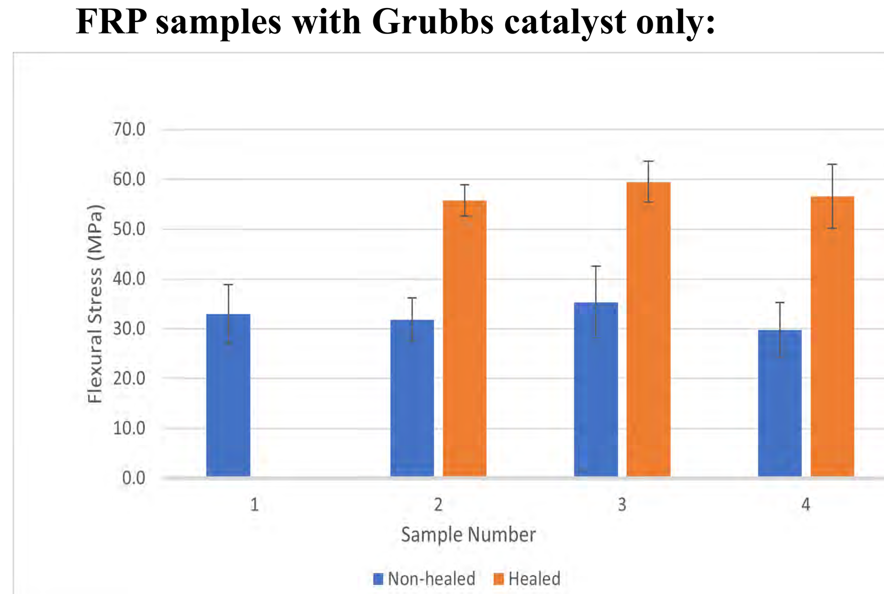


Results

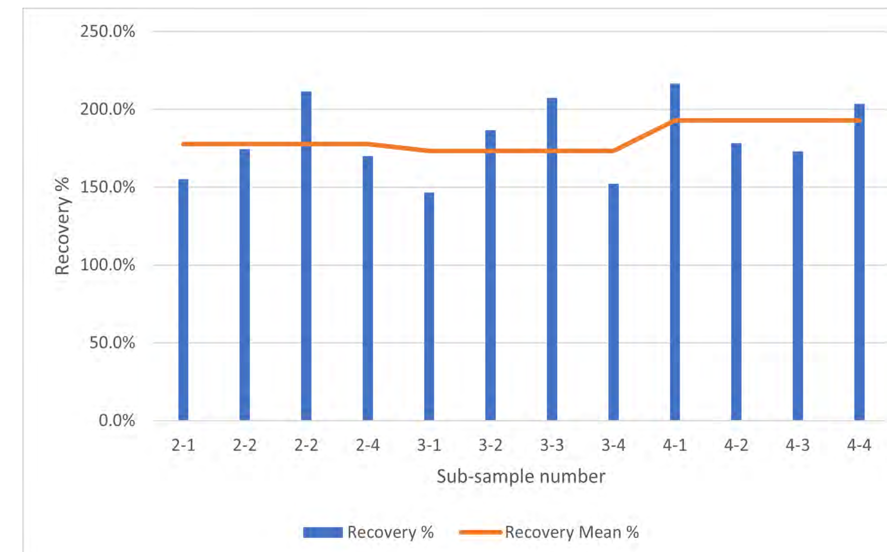
The overall effectiveness of the CNTs /DCPD/ imprinted glass-fiber-reinforced epoxy nanocomposites samples was examined to prove the self-healing capabilities. Three-point bending testing with Instron Corporation's tensile testing machine was performed to calculate the percent of strength recovered after the self-healing of the samples after cracking occurs.

Only two types of sample configurations were tested; samples were containing Grubbs catalyst and CNTs, and samples containing only Grubbs catalyst without CNTs.

- **Three-point bending average flexural stress readings for healed and non-healed imprint FRP samples with Grubbs catalyst only:**



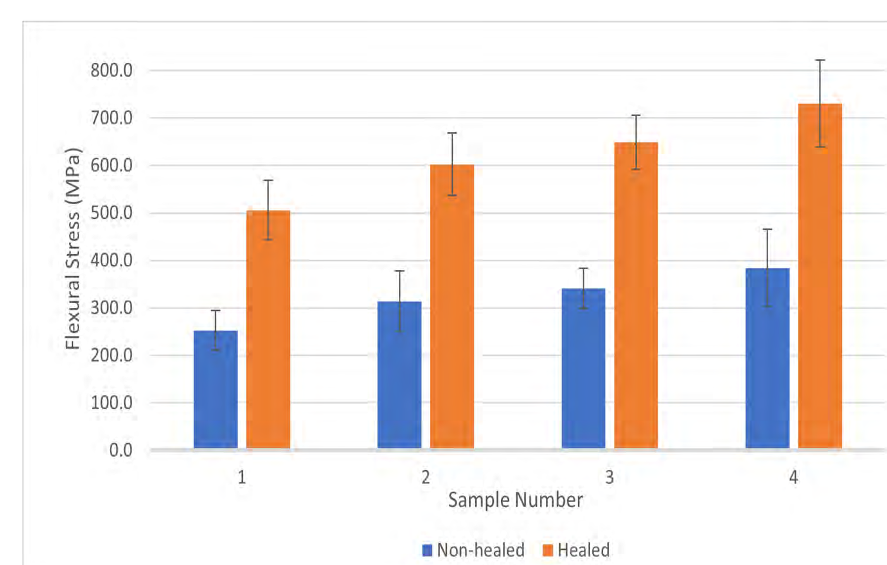
- **Self-Healing imprint method FRP average flexural test recovery comparison for samples with Grubbs catalyst only:**



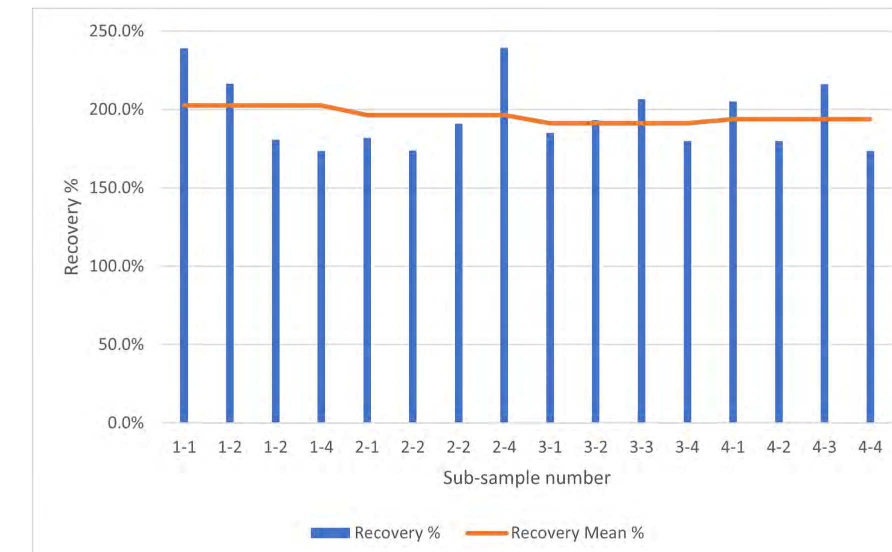
- **The calculated ultimate stress and recovery for healed and non-healed samples that include Grubbs catalyst only:**

Samples	Non-healed (MPa)	Healed (MPa)	Recovery Percentage (%)	Non-healed Mean (MPa)	Healed Mean (MPa)	Recovery Mean Percentage (%)
1	41 25 36 31	N/A	N/A	32.9 ± 5.93	N/A	N/A
2	38 33 26 30	59 58 55 51	155.3% 174.5% 211.5% 170.0%	31.8 ± 4.4	55.8 ± 3.1	177.8 ± 20.7
3	45 30 27 39	66 56 56 60	146.7% 186.7% 207.4% 152.3%	35.3 ± 7.2	59.5 ± 4.1	173.3 ± 25.0
4	22 37 32 28	48 66 55 57	216.7% 178.4% 173.1% 203.6%	29.8 ± 5.4	56.6 ± 6.4	192.9 ± 17.9

- **Three-point bending average flexural stress readings for samples with Grubbs catalyst and CNTs:**



- **Self-Healing imprint method FRP average flexural test recovery comparison for samples with CNTs:**



- **The calculated ultimate stress for non-healed samples (Grubb's catalyst & CNTs):**

Samples	Non-healed (MPa)	Healed (MPa)	Recovery Percentage (%)	Non-healed Mean (MPa)	Healed Mean (MPa)	Recovery Mean Percentage (%)
1	220 250 220 321	526 541 398 557	239.1% 216.4% 180.9% 173.5%	252.8 ±41.3	505.5 ± 63.0	202.5± 27
2	320 411 290 233	582 715 554 558	181.9% 174.0% 191.0% 239.5%	313.5 ± 64.4	602.3 ± 66.0	196.6 ± 25.5
3	401 317 289 357	743 613 597 642	185.3% 193.4% 206.6% 179.8%	341.0 ± 56.8	648.8 ± 56.8	191.3 ± 10.1
4	311 425 302 498	638 765 653 865	205.1% 180.0% 216.2% 173.7%	384.0 ± 81.7	730.3 ± 92.0	193.8 ± 17.5

Conclusions

- The present work proposed a new improvement for the mechanical properties of the self-healing material by the incorporating CNTs into the DCPD/Epoxy polymer composites with a very low concentration of 0.3 wt% of the epoxy resin mixed with the presence of 1st generation Grubbs catalyst, which will reduce the maintenance frequency for the wind turbine blades since it will be ten times stronger than the blades without CNTs. This reduction in maintenance work will be reflected in the cost reduction of this process.
- Furthermore, Flexural stress measurements show that using CNTs to fabricate wind turbine blades can produce samples with an increased average recovery percentage by two times around 196%.

Literature cited

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