The Effect of Carbon Nanotubes on Tensile Strength of Aluminum in Automobile Industry

Thousand Oaks High School
AP Research STEM

Rollovers

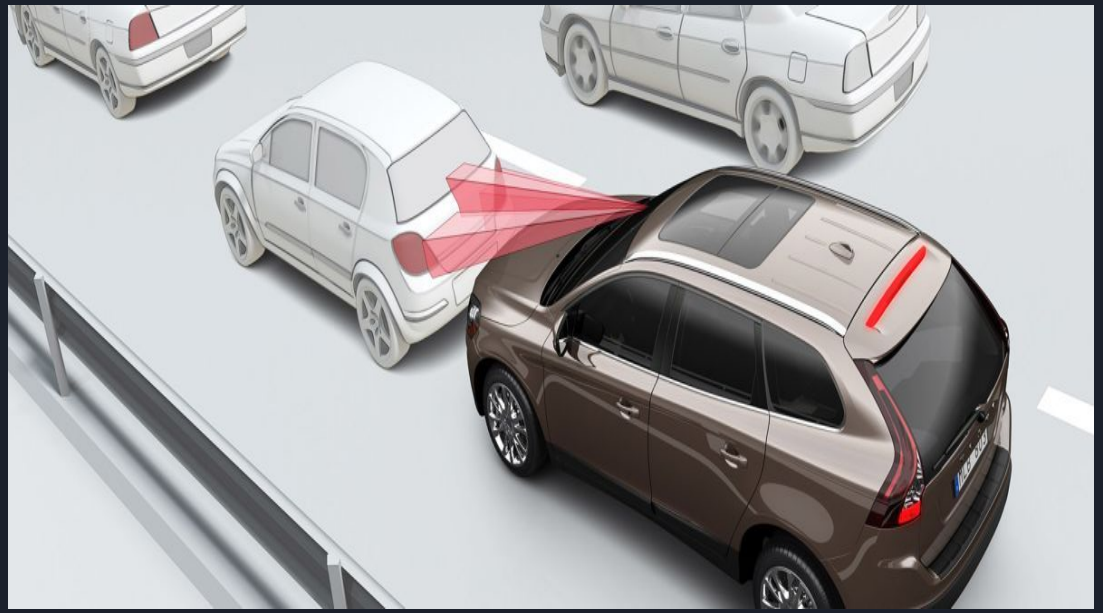
- Overturning of a vehicle
- Direct impact on roof
- Enclosure on passengers

Rollover Fatalities

- 3% of car accidents involve a rollover
  - cause 30% of fatalities
  - 7,600 in 2010
- Higher than 1990's

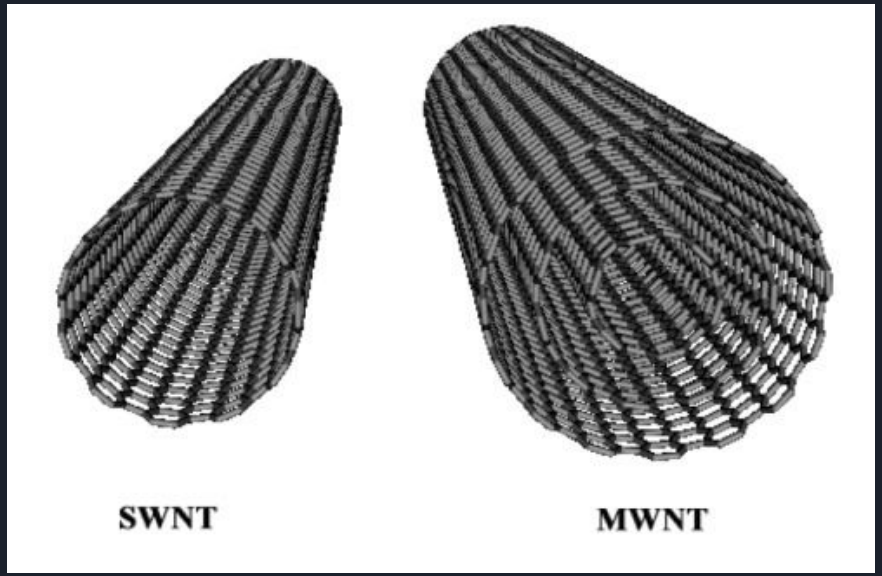
New Safety Feature Attempts

- New Safety Features
  - Side airbags
  - Electronic Stability Control
  - Crash Avoidance Technology



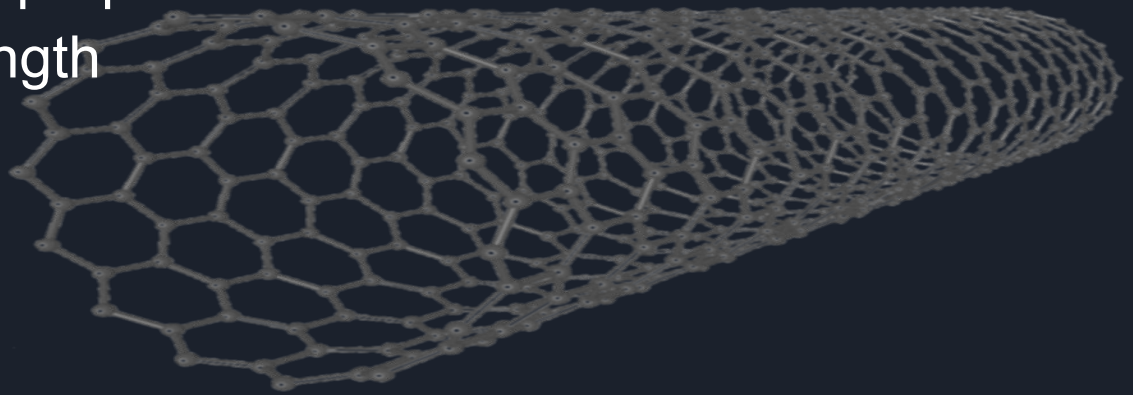
Introduction to Carbon Nanotubes

- Tube-shaped nano-materials made of carbon with complex, cage-like structure
- Two Families: SWNT and MWNT



CNT Characteristics

- Reinforce plastic materials and metals
- Favorable alternatives:
  - Cheap and lightweight
  - mechanical properties
  - tensile strength



CNT Applications

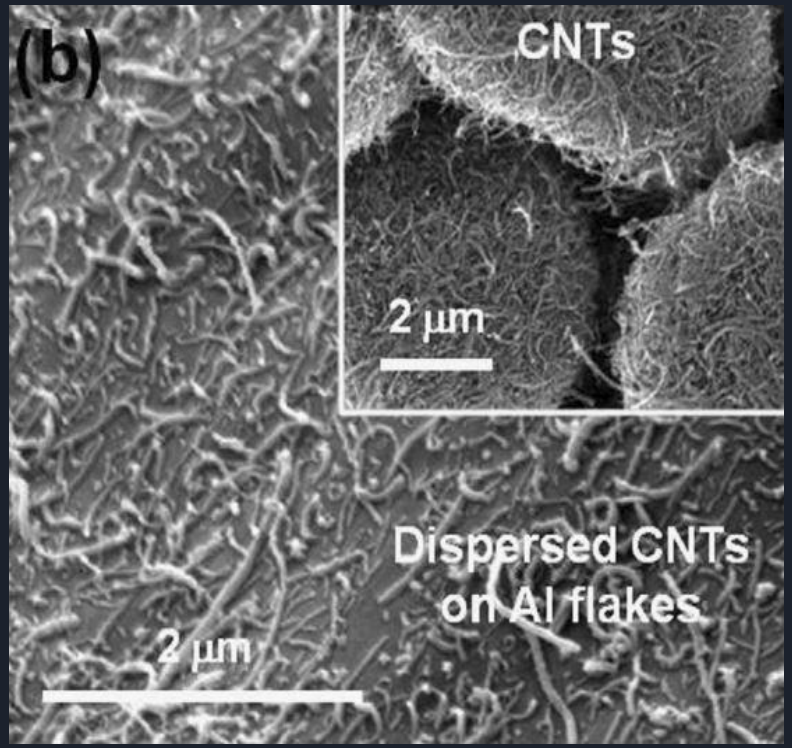
- Aerospace Engineering
- Plastics
- Iron products

Implementing CNTs into Aluminum

- Improve tensile and yield strength
  - Microstructure
  - Van der Waal forces
- Intake of pressure increases

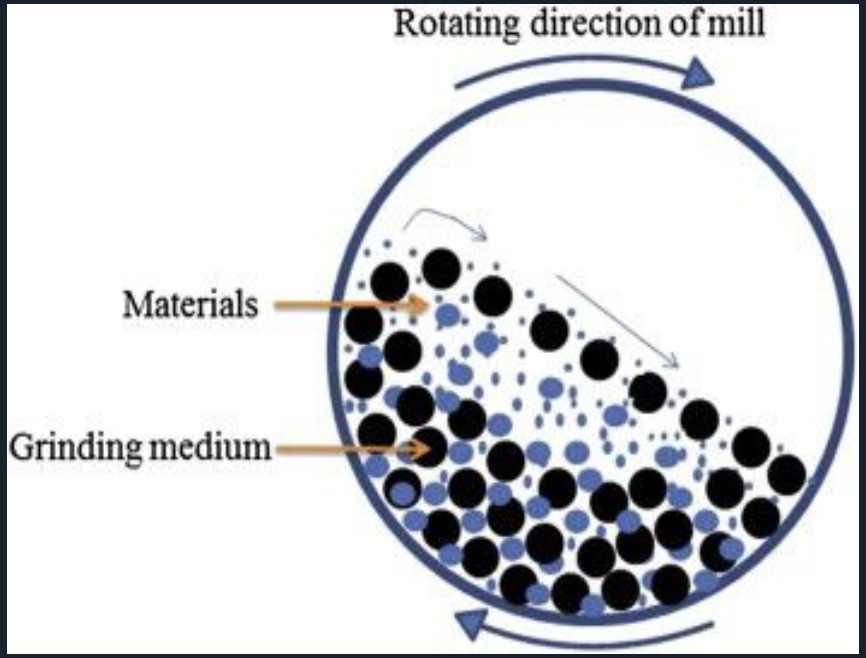
Importance of Dispersion Method

- Control bonding between CNTs and matrix
- Equally distribute the CNTs
- Difficulties
  - Small size
  - Clusters



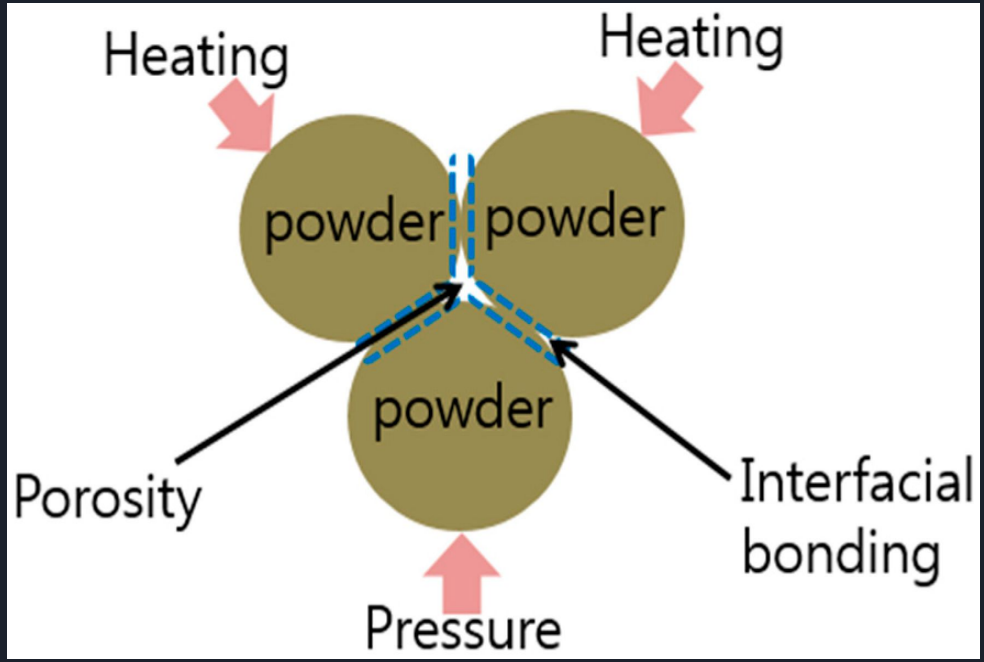
High Energy Ball Milling

- Mixed in ball mill, hit with high energy collisions
  - Proper energy and orientation



Vacuum Sintering

- Formation of solid mass through heat and pressure
- Damage CNTs



Purpose

- Research carbon nanotubes effect on aluminum’s tensile strength in the automobile industry.
- Reduce amount of rollover fatalities

Research Question

Would tensile strength of CNT-reinforced aluminum withstand additional stress than typical aluminum used in the automobile industry?

Hypothesise

- **Alternate:** Aluminum’s tensile strength will increase as CNT concentrations increase

- **Null:** CNTs have little to no effect on aluminum’s tensile strength

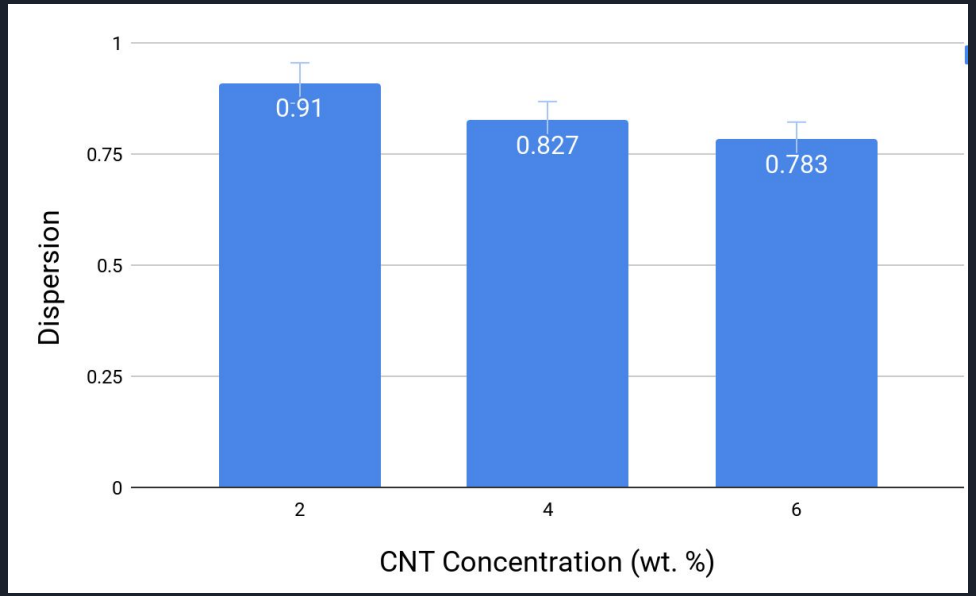
Methods

- Systematic Literature Review
- Data collection from: Ebscohost, CSUCI’s library database, ScienceDirect, PLOS One or Google Scholar

Selection Criteria

1. Strength and dispersion of aluminum
2. Included Ball Milling
3. Rollover values came from government organizations
4. Post 2005

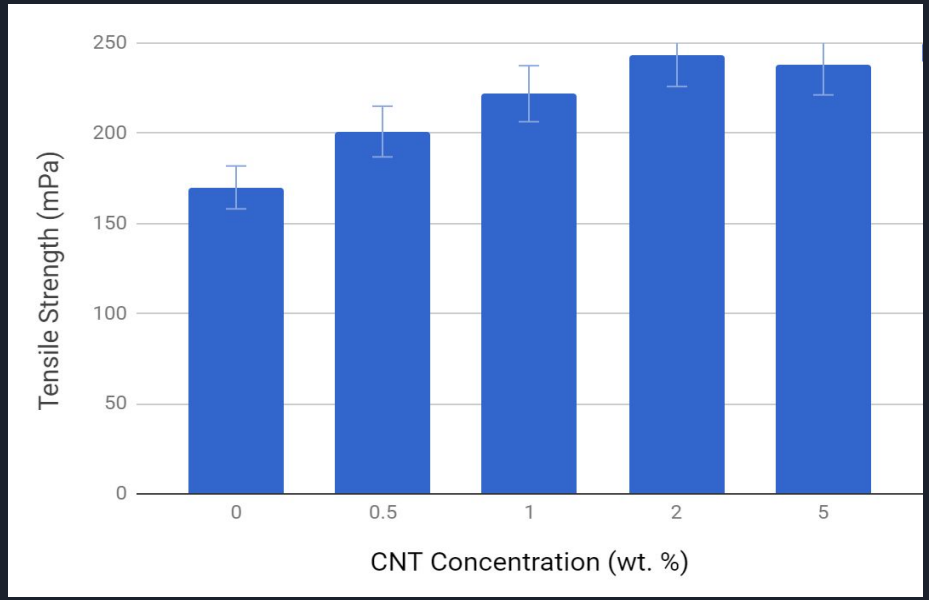
Dispersion of CNT Concentrations



The Effect of CNT Concentration on the Equal Dispersion of the CNTs. The values of fully uniform and non-uniform states of dispersion are 1 and 0 respectively. Retrieved from Carvalho, O, Miranda, G et. al (2016), Yazdanbakhsh et. al (2010), Bakshi et. al (2009), and Luo and Koo (2007).

Tensile Strength

- Tensile strength increases as CNT concentration increases
- 2% concentration is ideal



Effect of Carbon Nanotubes on the Tensile Strength of Aluminum. Shows the predicted tensile strength (mPa) with increasing CNT concentration. Concentration is measured in wt. % which is weight of solute per weight of solvent. Controlled has no CNT concentration. Retrieved from Esawi et al. 2010, Jagannatham et al. 2015, and Carvalho, O., Buciumeanu, M., et al. 2016.

Effect of Ball Mill Time on Strength

Amount of Time Ball Milled (hours)	Tensile Strength (MPa)	Yield Strength (MPa)	Study Experimented by
N/A Pure Aluminum	162	73	Jagannathan et. al
0.5	254	-	Esawi et. al (2010)
1	231	200	Jagannathan et. al
1.5	334	276	Yang et. al
5	252	180	Perez-Bustamante et. al
6	348	-	Esawi et. al (2009)
72	244	-	Carvalho et. al

P Values
TS: 0.0093
YS: 0.0097

Discussion

- HBEM proposes best dispersion
- As CNT concentration increases, tensile and yield strength increase to an extent

Limitations

- Aluminum structure in automobiles
- Dispersion conclusions
- Required tensile strength value

Conclusion

- Tensile and yield strength increase
- HEBM proposes the best dispersion results

Further Work

- Dispersibility
- Consistency
- Outdoor Effects
  - Sun Rays
  - Paint Job

Acknowledgements

- Dr. Nikki Malhotra
- Dr. Philip Costanzo
- Michelle Magnusson

References

Attanasio, A., Ceretti, E., Fassi, I., & Pagano, C. (2017). Experimental study on micro manufacturing of carbon nanotube (CNT) plastic composites. *International Journal Of Advanced Manufacturing Technology*, 92(5-8), 1721-1729. doi:10.1007/s00170-017-0288-z

Bakshi, S., Batista, R., & Agarwal, A. (2009). Quantification of carbon nanotube distribution and property correlation in nanocomposites. *Composites: Part A,* 40 (1311-1318). doi: 10.1016/j.compositesa.2009.06.004

Carvalho, O., Buciumeanu, M., Miranda, G., Costa, N., Soares, D., & Silva, F. S. (2016). Mechanisms governing the tensile, fatigue, and wear behavior of carbon nanotube reinforced aluminum alloy. *Mechanics Of Advanced Materials & Structures*, *23*(8), 917-925. doi:10.1080/15376494.2015.1063176

Carvalho, O., Miranda, G., Soares, D., & Silva, F. S. (2016). Carbon nanotube dispersion in aluminum matrix composites—Quantification and influence on strength. *Mechanics Of Advanced Materials & Structures*, *23*(1), 66-73. doi:10.1080/15376494.2014.929766

Chen, B., Kondoh, K., Imai, H., & Umeda, J. (2016). Effect of initial state on dispersion evolution of carbon nanotubes in aluminium matrix composites during a high-energy ball milling process. *Powder Metallurgy*, *59*(3), 216-222. doi:10.1080/00325899.2016.1144375

Deutermann, W. (2004). Characteristics of fatal rollover accidents. *National Center for Statistics and Analysis Research and Development.* 1-52. Retrieved from: https://www.citizen.org/sites/default/files/ncsareport.pdf

Esawi, A., Morsi, K., Sayed, A., Gawad, A. A., & Borah, P. (2009). Fabrication and properties of dispersed carbon nanotube–aluminum composites. *Materials Science & Engineering: A*, *508*(1/2), 167-173. doi:10.1016/j.msea.2009.01.002

Esawi, A., Morsi, K., Sayed, A., Taher, M., & Lanka, S. (2010). Effect of carbon nanotube (CNT) content on the mechanical properties of CNT-reinforced aluminum composites. *Composites Science and Technology.* 70, 2237-2241. doi: 10.1016/j,compscitech.2010.05.00

References

George, R., Kashyap, K., Rahul, R., & Yamdagni, S. (2005). Strengthening in carbon nanotube/ aluminium (CNT/Al) composites. *Scripta Materialia*, *53*(10), 1159-1163. doi:10.1016/j.scriptamat.2005.07.022

Jarolim, T., Labaj, M., Hela, R., & Michnova, K. (2016). Carbon Nanotubes in Cementitious Composites: Dispersion, Implementation, and Influence on Mechanical Characteristics. *Advances In Materials Science & Engineering*, 1-6. doi:10.1155/2016/7508904

Luo, Z. P., & Koot, J. H. (2007). Quantifying the dispersion of mixture microstructures. *Journal Of Microscopy*, *225*(2), 118-125. doi:10.1111/j.1365-2818.2007.01722.x

NHTSA (2013). Rollover Characteristics: Fatalities. Retrieved from: https://www.safercar.gov/Vehicle-Shoppers/Rollover/Fatalities

Nouri, M. (2010). Effect of carbon nanotubes on dynamic mechanical properties, TGA, and crystalline structure of polypropylene. *Journal of Applied Polymer Science.* 124, 2541-2549. doi: 10.1002/app.34484

Pérez-Bustamante, R., Pérez-Bustamante, F., Estrada-Guel, I., Licea-Jiménez, L., Miki-Yoshida, M., & Martínez-Sánchez, R. (2013). Effect of milling time and CNT concentration on hardness of CNT/Al2024 composites produced by mechanical alloying. *Materials Characterization*, *7*513-19. doi:10.1016/j.matchar.2012.09.005

Pötschke, P., Bhattacharyya, A. R., Janke, A., Pegel, S., Leonhardt, A., Täschner, C., & ... Cech, J. (2005). Melt Mixing as Method to Disperse Carbon Nanotubes into Thermoplastic Polymers. *Fullerenes, Nanotubes & Carbon Nanostructures*, *13*211-224. doi:10.1081/FST-200039267

Strashny, A. (2007). An analysis of motor vehicle rollover crashes and injury outcomes. *National Highway Traffic Administration.* 1-89. Retrieved from: https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/810741

Yazdanbakhsh, A., Grasley, Z., Tyson, B., & Al-Rub, A. (2010). Dispersion quantification of inclusions in composites. *Composites: Part A* 42 (75-83). doi: 10.1016/j.compositesa.2010.10.005

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