Effect of carbon nanotubes on the tensile strength of aluminum in the automobile industry

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Introduction

Rollover crashes account for approximately 30% of car fatalities due to their violent nature (Deutermann, 2004). In 2010, it was estimated that about 191,000 passengers were involved in a car rollover, causing more than 7,600 people to die (NHTSA, 2013).

Implementing carbon nanotubes into the composition of aluminum is one way to prevent a car's roof-work from collapsing upon itself. Carbon nanotubes (CNTs) are tube-shaped materials made up of carbon atoms with beneficial mechanical properties due to their complex, cage-like structure. Recently, a group of scientists have blended CNTs with aluminum metal to create a revamped aluminum nanocomposite (Esawi et al, 2010). Given that the addition of CNTs improves mechanical properties of aluminum, the tensile strength of aluminum nanocomposites in cars is experimented in the study. Due to previous success, the purpose of this study is to investigate whether aluminum nanocomposites are favorable alternatives in the automobile industry by testing the effects CNTs have on aluminum products. If the tensile strength of the composite roof increases significantly, then automobile safety will be one step closer to its ideal state.

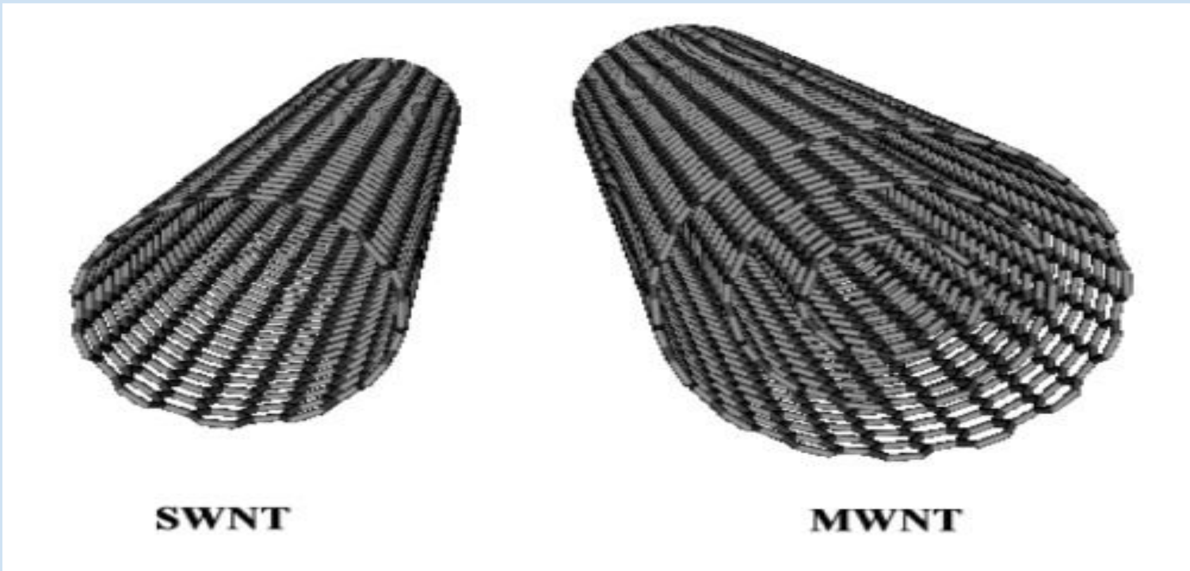

Figure 1: The structure of a single-walled nanotube (SWNT) and multi-walled carbon nanotube (MWNT).

Purpose

Over the past decade, interest in carbon nanotube composites have grown exponentially with potential applications varying from aerospace to sports industries. Nanotechnology could be introduced to the automobile industry to manipulate the car's atoms and molecules to improve their strength. The CNT-reinforced automobile will then theoretically reduce the amount of rollover fatalities.

Hypotheses

Research Question: Would aluminum nanocomposites withstand more damage than pure aluminum used in the automobile industry?

Alternate: Aluminum's tensile strength will increase as CNT concentrations increase.

Null: CNTs have little to no effect on the tensile strength of aluminum.

Methods & Materials

Research was a systematic literature review. Data regarding CNTs and dispersion methods were retrieved from Ebscohost, CSUCI's library database, ScienceDirect, PLOS One or Google Scholar. Rollover statistics came from government organizations such as the NCSA, NHTSA & FARS. Each article had to have significant P-values in order to be taken into consideration. P-values in this study were obtained using a T-Test which resulted in P values less than .05, which were statistically significant.

Results

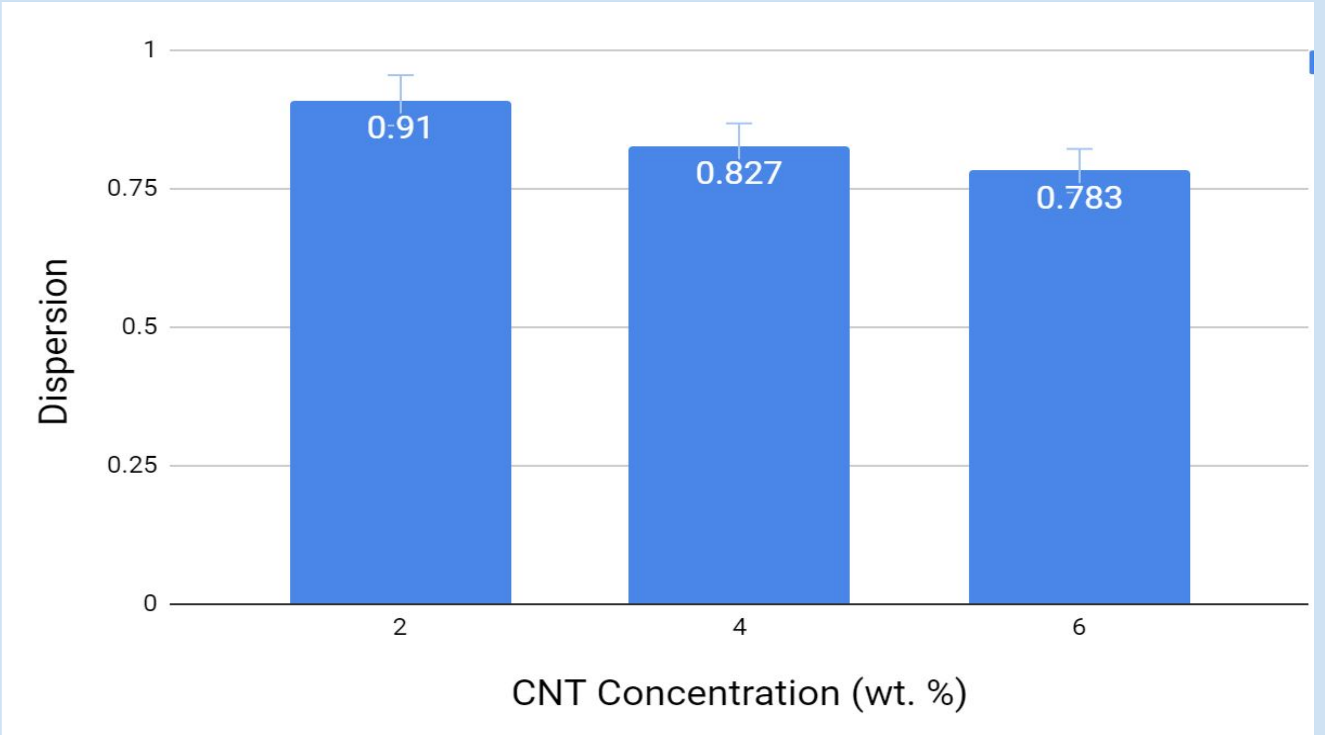

Figure 1: The Effect of CNT Concentration on the Equal Dispersion of the CNTs. The values of fully uniform and non-uniform states of dispersion are 1 and 0 respectively. Retrieved from Carvalho, O, Miranda, G et. al (2016), Yazdanbakhsh et. al (2010), Bakshi et. al (2009), and Luo and Koot (2007).

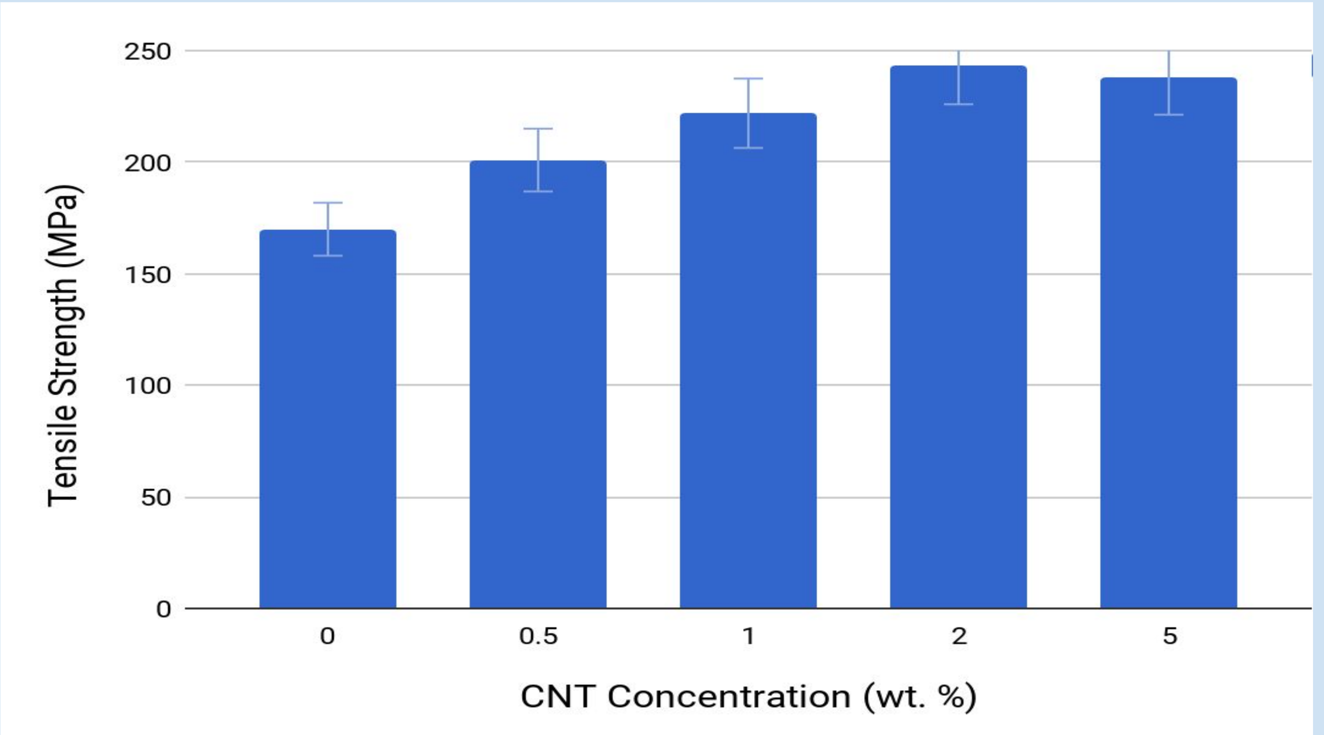

Figure 2: Effect of Carbon Nanotubes on the Tensile Strength of Aluminum. Shows the predicted tensile strength (MPa) with increasing CNT concentration. Controlled has no CNT concentration. Retrieved from Esawi et al. 2010, Jagannatham et al. 2015, and Carvalho et al. 2016.

Discussion

Dispersion: The improvement of mechanical properties depends on the distribution of CNTs throughout its matrix. CNTs tend to form clusters when dispersed in materials due to their Van der Waal forces, affecting the overall strength (Jarolim et al, 2016). Figure 5 shows the decrease of dispersion as the CNT concentrations increase. The 6 wt. % CNT solution has too many CNTs for the ball milling device to disperse, later affecting its tensile strength. It should be noted that every dispersion method is inconsistent which is why the dispersion of CNTs is critical.

Yield Strength: Yield strength of the CNT-reinforced aluminum follows the same trend of tensile strength in which 2 wt.% CNT was concluded to be more effective. The addition of CNTs in mixtures above 2 wt.% CNT reduces the yield strength due to the formation of clusters once again (Jagannathan et al, 2015). Yield strength increases by approximately 300% due to the change in microstructure and crystallization.

Tensile Strength: The tensile strength increased by 50% from the original strength of the pure aluminum. In order to have achieved its peak performance, a small amount of CNTs must have been added to improve the mechanical strength of the nanocomposite (Li, 2017). The 5 wt.% CNT has the potential of having a higher MPa value depending on the ball milling and hot extrusion times.

Conclusion

2 wt.% CNT was the ideal CNT to aluminum ratio as it outperformed other concentrations due to its higher dispersion value. The mechanical properties of aluminum noticeably increased as tensile strength increased by ~50% and yield strength tripled with the addition of CNTs. Aluminum used by the automobile industry can theoretically withstand additional pressure, reducing the amount of rollover fatalities each year.

Further Work

There is still more testing to be done in order to conclude whether or not CNT-reinforced aluminum is a favorable alternative in the automobile industry. To improve the dispersion methods, the correct ball milling and hot extrusion times need to be further tested to conclude which set of times consistently yield similar results. Additional studies on the effects of vacuum sintering and hot extrusion on mechanical properties should be conducted. CNT-reinforced aluminum is also to be tested in outdoor environments and how the CNT structures are going to hold. Heat affects the CNT structure, therefore the effect the sun has on the CNTs and the effect of CNT-reinforced aluminum on the paintjob of a car over long and short terms is to be tested. Consistency of dispersibility and tensile strength values should be obtained before heading into actual implementation into vehicles. Above all, the increase of tensile strength should be tested to determine whether it's going to play a major role in a rollover or any type of crash. In order to determine its efficiency, a CNT-reinforced car would have to go through automobile safety tests.

References

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For rest of the references, see academic paper.

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