Brazing Composites for Nuclear Reactors

(Technical Paper)

Fossil Fuels and the Need to Switch to Nuclear Energy

(STS Paper)

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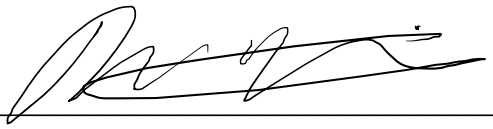
On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Signature  Date 10/31/2022
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Introduction

Fossil fuels such as coal, oil, and gas play a dominant role in energy systems throughout the world. The Industrial Revolution that began in the 1760s expanded the overall use of coal since the English determined that it could produce fuel that burned hotter and cleaner than wood charcoal which was commonly used (Ritchie 2020). Through the expanded use of coal and other fossil fuels during the Industrial Revolution, multiple developments were made in technology which led to improving the economic status of the workforce. Having influenced human development and advancement for the past several centuries, it has become increasingly apparent that carbon dioxide, produced when fossil fuels are burned, is the largest contributor to climate change across the globe. As lower carbon dioxide emitting sources of energy become readily available such as nuclear or renewable energy, the world must transition away from the fossil fuels that have supported the development of humankind for hundreds of years.

Fossil fuel use is unsustainable in the long term which is why humans must identify an alternative renewable or pseudo-renewable energy source as quickly as possible. Nuclear power has a high energetic potential in the world to be a main source of energy due to the enormous supply of uranium on Earth. My technical work will be supporting the development of a brazing process for composite tubes that serve as fuel rods for nuclear reactors. My STS work will examine the importance of moving away from fossil fuels and presenting a compelling argument for transitioning to a more sustainable primary source of energy in the world.

Technical Discussion

A key reason for how this research project on brazing composites for nuclear fuel reactors came about is that fossil fuel use is unsustainable in the long term and requires the need to identify an alternative primary renewable or pseudo-renewable energy source. Nuclear energy is a popular source of clean energy given that it has a high energetic potential because of the abundance of uranium on Earth. Uranium's energy density per mass is extremely high because uranium can potentially last tens of thousands of years.

The extensive research that has been done on feasible alternative energy sources shows that nuclear energy is a vital means to transition to a cleaner energy system (IEA 2019). With that, however, comes problems that exist in the nuclear sector that must be addressed and solved so that any potential incidents can be avoided in the future such as Chernobyl, Three Mile Island, and Fukushima. Current nuclear fuel rod containment systems contain zircaloy which is an excellent material for current operating conditions. However, if there is an accident at a nuclear fuel reactor, wherein overall temperatures and pressures skyrocket that causes the zircaloy to catastrophically melt and fail; this failure did occur at the reactor in Fukushima (Yook 2022).

Researchers are currently developing a different material to be used for nuclear fuel rod containment systems such as the research group under Dr. Li at the University of Virginia. Graceful failure and slow pressure release are highly desired properties of the material as well as extremely elevated temperature and pressure resistant materials such as Silicon Carbide (Si-C) or Silicon Carbide Ceramic Matrix Composite (CMC) fuel rod tubes. These CMC tubes have the capability of operating up to 1200-1300°C, which is higher than zircaloy's temperatures.

Currently, the manufacturing of the fuel rod tubes is being optimized but the main problem that I am supporting in Dr. Li's research group is sealing the ends to seal (close) the cylinder. How this fuel additive process works is that fuel pellets are loaded into the cylinder and then the ends will be closed. It is impossible to do matrix infiltration with uranium already inside the tubes since radiation would be exhibited and spread. High temperatures and specialized gas precursors are required to do infiltration which is another reason this would not work well given the presence of uranium.

The main project I am working on with Ph.D. students is discovering a way to weld the Si-C parts together by brazing so that the tubes can be effectively plugged ex-situ using matrix deposition. Currently, we are developing varied materials and heat-treating them using high-temperature furnaces (up to 1800°C) to be brazed to the ends of the tube to plug them up. This will require the use of brazing materials in the lab, a Scanning Electron Microscope (SEM) in Wilsdorf Hall to observe microstructural behavior. We will be continuing the use of high-temperature furnaces for our materials.

The period of this project is to finish all the direct testing in the laboratory by the end of the Fall 2022 semester. My technical advisor who also serves as my research advisor is Dr. Xiaodong Li from the Department of Mechanical & Aerospace Engineering at the University of Virginia.

STS Discussion

Research in Science, Technology, and Society (STS) explores the relationships between engineering and ethical considerations within technology and society. Engineers must consider the potential ethical issues when designing innovative technologies that may impact the world. My

STS research topic covers the importance of developing and utilizing more sustainable sources of energy while rapidly transitioning away from the use of fossil fuels. I expect to describe the harmful effects of nuclear energy should a disaster occur and why research and further development must be done with both care and caution.

Nuclear reactors have numerous safety concerns which can be seen in Chernobyl, Three Mile Island, and Fukushima. On April 26, 1986, a block of the nuclear power plant in Chernobyl exploded which ended up as the "biggest civil nuclear accident ever recorded" (Danzer 2011). There is evidence that the Chernobyl Incident has led to long-term changes in levels of well-being, health, and personal safety among citizens of Ukraine (Danzer 2011). Through my research, I expect to explain the effects that nuclear disasters have on populations of the affected area and why nuclear power must be treated carefully.

The anticipated scope of my research in STS is to discuss the current state of climate change and how switching to more sustainable sources of energy is vital to preserving Earth as well as discussing the impacts of nuclear disasters that can occur when nuclear energy is not treated with immense caution. This STS topic is tightly coupled to my technical research as researchers in the field such as my research advisor and Ph.D. student mentor have discussed the same topics beforehand. Research in this STS topic points to the need for technical research which will be addressed in my paper.

Research in this STS topic is crucial as opinions about various forms of energy have been thrown in the spotlight worldwide. "Environmental activists have shifted their focus in recent years to target fossil fuel projects and companies directly" (Green). In recent years, calls to ban or challenge companies that produce fossil fuels or heavily use fossil fuels in their products. For example, virtually every single automobile company has committed to solely producing electric

vehicles with a deadline of at least by 2035 (Motavalli). There are numerous health impacts that I will address regarding the burning of fossil fuels to produce electricity. Low-income populations "have been found to have a higher prevalence of pre-existing diseases, limited access to medical treatment" since they tend to live closer to fossil-fuel burning power plants (Environmental Protection Agency). As it will be strongly proved through numerous sources of research from the government and various research papers, nuclear energy is the safer and more reliable source of energy for the environment. Being able to explain the various purposes of the technical research I am writing about may help more funding to be invested in the research of nuclear energy.

Research Question and Methods

Given the importance of switching to a more sustainable source of energy, I plan to address the concerns of fossil fuels and why we must gravitate to nuclear energy. My research in STS will also include the need to research and invest in nuclear energy safely so that incidents such as Fukushima and Chernobyl can be avoided in the future. Exploring and analyzing my research questions will involve reading and gathering data from numerous research papers that have studied the harmful effects of fossil fuels and the benefits of nuclear energy. After gathering data and information that answers this first research question, I will analyze the data and reveal the connections between fossil fuels, their harmful impacts on the environment, and how nuclear energy is proven to be cleaner and more dependable than fossil fuels. Upon this part of my STS research, I will gather data and information about past nuclear tragedies and how they can be avoided in the future. I will directly connect my technical research to this part of my STS research, since the research group I am working in at the University of Virginia is working on improvements for nuclear fuel cell storage. The main purpose of my STS research is to justify the work I am doing in Dr. Li's research group and give an overall purpose to the research done in nuclear energy.

Conclusion

The entire world needs to shift to a more sustainable primary source of energy such as that which nuclear offers and transition away from the use of fossil fuels. However, to do this as efficiently and safely as possible, research in composites that will be used to house nuclear energy must be as comprehensive as possible. The project with brazing composites will have a profound positive impact on the use of nuclear reactors once it is fully implemented by the United States Department of Energy. The project I am working on with Dr. Li is one step forward in the development of safer containment methods for nuclear fuel rods. Research in this field has already demonstrated the need for nuclear energy which is where researchers come into the picture of addressing the environmental problems occurring globally.

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