Post Deposition Surface Treatment of Zn-Ni Coatings: Finding an Optimal Dissolution Method for Zn

Modern Day Oppenheimer: How the Race to Mach 10 Can Result in a New Destroyer of Worlds- Social, Geopolitical, and Environmental Impacts of The War Industry

A Thesis Prospectus
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By
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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.

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Introduction

In this prospectus, the technical problem to be explored is post-deposition surface treatments for Zn-Ni coatings, specifically regarding finding an optimal dissolution method of Zn. This problem is of great importance to the aerospace industry as it will help to solve a stress corrosion cracking problem in commercial aircraft. The STS research topic of this prospectus is the social, geopolitical, and environmental impacts of the war industry, specifically in relation to the hypersonics arms race, with an increased emphasis on how geopolitics and the war industry influence each other. These topics connect as the technical topic could easily be applied to the development of hypersonic technology. Given we are in an arms race, the likelihood it will increases by the day. Therefore, it is important to understand how what I am researching can affect society, geopolitics, and the environment.

My capstone project, which is the technical focus of this report, is a special project provided to the University of Virginia (UVA) by the Rolls Royce Corporation. The initial mission of this project was to develop a +/- 0.25% tolerance band of nickel (Ni) content in a Zn-Ni (Zinc-Nickel) electroplated deposit on steel panel substrates with the intention of mitigating stress corrosion cracking in high-stress field conditions. Stress-corrosion cracking (SCC) is an artifact characterized by the presence of a corrosive environment and mechanical stress that, when combined, cause spontaneous failure in metals. We intend to determine the optimal Zn-Ni concentration to achieve balanced properties within a range of 12-15 weight percent (wt%) Ni. While the aim of this project remains to reduce stress corrosion cracking behavior in a Zn-Ni electroplated deposit on steel panel substrates in high stress field conditions, the direction of the project has shifted to optimizing the composition of the Zn-Ni coating within a range of 12-15 wt% Ni. We intend to ensure that the Zn-Ni coating potential will fall within the immunity

region by tailoring the Ni content through Zn dissolution. The potential of the coating is a measure of the coating's tendency to corrode and Zn dissolution is a term to describe how and at what rate Zn atoms dissolve out of the coating. Thus, in a nutshell, the technical objective is to optimize the composition of the Zn-Ni coating within a specific range, 12-15 wt% Ni, by dissolving the appropriate amount of zinc from the coating.

The STS research topic is a critical review of the war industry, specifically in regard to hypersonic technology, and the social, geopolitical, and environmental ramifications of research for war. There will be a special interest placed on geopolitics, as geopolitics influences the war industry just as the war industry influences geopolitics. A critical aspect of the United States' foreign relationships and position as a global superpower is their technical and militaristic advantage over other countries. Our current technological disadvantage to countries the United States government consider a possible threat to our national security has led to a new arms race-hypersonic weapons. The social ramifications to escalation include civil unease and discontent, historical evidence of which is provided by the social sphere during the Vietnam War. Environmental issues related to hypersonics range from materials development to manufacturing to flight tests. This STS research aims to provide an understanding of how developing hypersonic weapons for the war industry can cause social, geopolitical, and environmental effects as well as a map of how each of those subtopics impact each other.

Technical Topic

Post Deposition Surface Treatment of Zn-Ni Coatings: Finding an Optimal Dissolution Method for Zn

Establishing Technological Need

Cadmium coatings have been used to protect steel from corrosion for decades due to its numerous protective properties. The element boasts exceptional corrosion resistance, increased lubricity, better chemical resistance, improved ductility, excellent solderability, and high electrical conductivity (Technologies, C. S. 2023). Most notably, cadmium is highly resistant to corrosion from salt water, a characteristic of great interest to the aerospace and defense industries. Despite its many benefits, cadmium is beginning to be phased out due to its toxicity and high cost. It has been banned by the European Union and heavily limited to certain applications in the United States (Technologies, C. S. 2023). There is an increased interest in implementing electrodeposited Zn-Ni sacrificial anodic coatings in its place because they are non-toxic and have a very similar degree of corrosion protection. Sacrificial anodic coatings are used to protect metal structures from corrosion. They work by oxidizing more quickly than the metal they are protecting and are considered “sacrificial” as they are consumed completely before the metal substrate can interact with the electrolyte, a common example of which is seawater. As a cadmium replacement, Zn-Ni provides many of the other same benefits. As well as providing excellent corrosion protection, Zn-Ni also provides excellent coverage and thicknesses in comparable ranges. It also boasts high hardness and is resistant to high temperatures, both of which are considerable improvements over soft and much less heat resistant cadmium.

Description of Proposed Problem Solution: Post-Processing

Post-processing is any processing done to an electrodeposited substrate after its been electrodeposited. Post-processing is often done to either ensure or improve the integrity of the deposit, which in this case is the Zn-Ni coating. In this case, the Zn-Ni coating is being developed in hopes of mitigating stress corrosion cracking (SCC). SCC is significant because it compromises structural integrity of components used in corrosive environments, such as in aerospace applications, for one, while the components are already experiencing a high tensile stress, from applications or residual stress (Jones, R. H. (2017)). SCC is particularly problematic because of its unpredictable failure behavior and difficulty in detecting. Prior work indicates that injecting Zn as a post-processing treatment onto steel has mitigated SCC. In the experimentation performed by *Chen et al.*, it was discovered that addition of Zn in a post-processing treatment improves the stress-threshold for SCC in multiple corrosive environments (Chen et al., 2023).

Our capstone project has been defined and redefined multiple times since the beginning of the semester, thus the changes in title between various "stepping stone" assignments up to this prospectus. The finalized objective as set by Rolls Royce is as follows: Find optimal dissolution method to produce a sufficiently high surface Ni content to immediately put the energy of corrosion(E_{Corr}) of Zn-Ni in the immunity zone of potential. Some constraints on the solution include the need to be measurable after processing, the need to be repeatable, the ability to estimate the loss in protection lifetime, and compatibility with room temperature conditions due to part size and geometry. We are currently drafting our preliminary and detailed designs for our post-processing experiment in my capstone class.

STS Topic

Modern Day Oppenheimer: How the Race to Mach 10 Will Result in a New Destroyer of Worlds- Social, Geopolitical, and Environmental Impacts of The War Industry

Introduction

In the wake of the last couple of years, ridden with political unrest and the ripple effects of a global pandemic, there have been shifts in American society's relationship with technology. While society's dependence on technology has only increased, many have lost faith: faith in their media outlets controlled by politics (Brenan, 2023b), their politicians and government controlled by money (Bell, 2023b), and their money controlled by relations with foreign entities as well as the very government they mistrust (Lu, 2023).

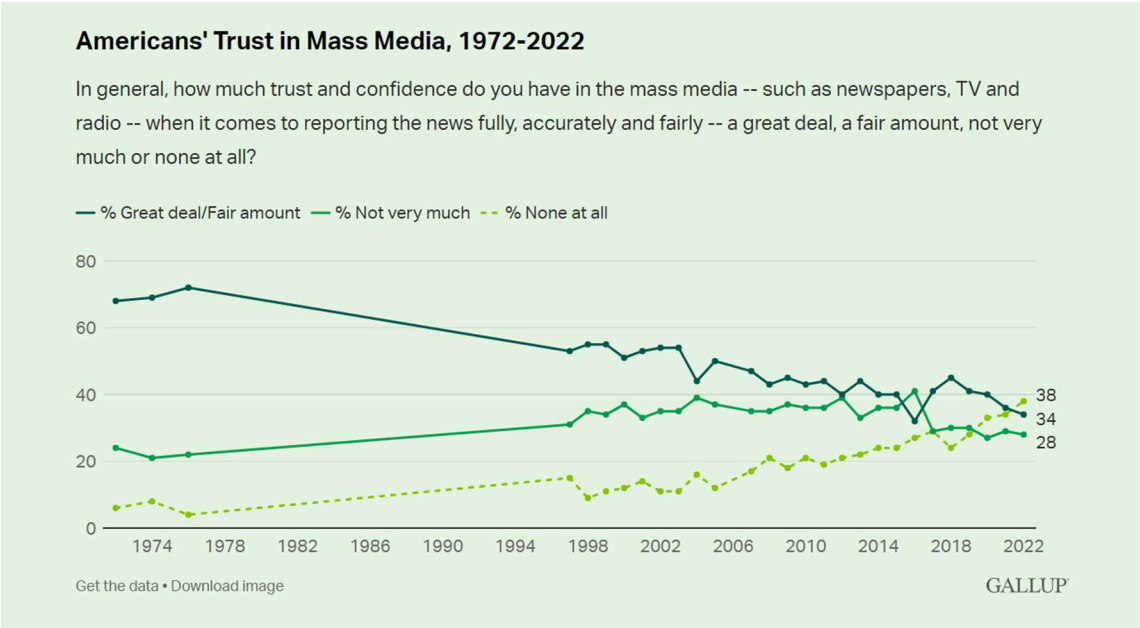

Figure 1: Public Trust in Mass Media, 1972-2022

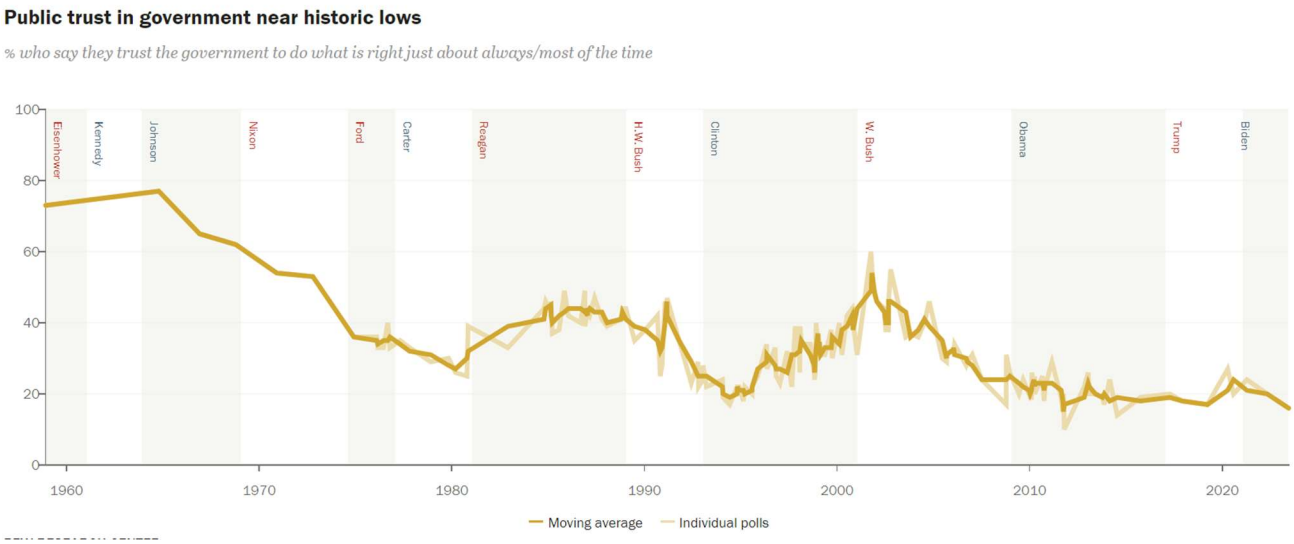

Figure 2: Public Trust in Government, 1959-2023

A critical aspect of the United States' foreign relationships and position as a global superpower is their technical and militaristic advantage over other countries. While the development of weapons technology is a controversial issue among idealists and altruists, those who align themselves with the analytical framework of realism within foreign relations would argue that research and development of these technologies is required to ensure geopolitical stability by maintaining a balance of power. Several beliefs are associated with realism in international relations. Human nature is a starting point for classical political realism (Korab-Karpowicz, 2023). Realists view human beings as inherently egoistic and self-interested to the extent that self-interest overcomes moral principles. Realists, and especially today's neorealists, consider the absence of government, literally anarchy, to be the primary determinant of international political outcomes (Korab-Karpowicz, 2023). The lack of a common rule-making and enforcing authority means, they argue, that the international arena is essentially a self-help system. Each state is responsible for its own survival and is free to define its own interests and to pursue power. Insofar as realists envision the world of states as anarchic, they likewise view security as

a central issue (Korab-Karpowicz, 2023). To attain security, states try to increase their power and engage in power-balancing for the purpose of deterring potential aggressors. This point is, in a nutshell, the heart of the Policy of Mutually Assured Destruction.

Statement of STS Topic

The STS topic of this prospectus is the following: Modern Day Oppenheimer: How the Race to Mach 10 Will Result in a New Destroyer of Worlds- Social, Geopolitical, and Environmental Impacts of The War Industry.

Establishing Importance and Geopolitics

The social, geopolitical, and environmental impacts of the war industry, especially in relation to hypersonics technologies, are the focus of this STS research prospectus. The urgent importance of understanding this topic is highlighted most eloquently in Jerome Gavin's "Hypersonic Missiles: A New Arms Race" (Pandit, 2022). As geopolitics are affected by the war industry, the war industry is shaped by geopolitics. The article reports and elaborates upon a series of comments made by the commander of U.S. Northern Command and the North American Aerospace Defense Command. Navy Vice Adm. Jon A. Hill, director of the Missile Defense Agency, testified that countering hypersonic weapons is a challenge now and for the future. To strengthen this point, the commander, Gen. Glen D. VanHerck, testified "I believe the greatest risk for the United States stems from our inability to change at the pace required by the changing strategic environment." (Pandit, 2022). The pace of said environment is set by other countries, and the U.S is struggling to keep up due to technological and fiscal limitations. The race is on.

This geopolitical dynamic is the main catalyst for the urgency behind developing hypersonic technologies, and thus the foundation for the social and environmental issues that come with it.

Social and Environmental Issues

During wartime, there is an increased use of toxic materials due to military activity that negatively impact the environment (ConEnvObs, 2023). A history of weak environmental oversight has left many countries with serious environmental legacies linked to military pollution, with impacts on public health and steep costs for environmental remediation. Environmental concerns have become such a prominent sociopolitical topic in the last decade that military and industrial pollution is being increasingly scrutinized, thus resulting in a change in social climate and popular opinion regarding these issues. The public is becoming more sensitive to environmental issues, which makes development for war generally unpopular but especially hypersonics. This is the case as hypersonic flight requires a lot of resources to achieve, including materials that are harmful to the environment to manufacture, and actively harms the environment during flight (Pletzer et al., 2022).

Shifting gears, social unrest is common during and after wartime, historically causing increased discontent and division among society. A notable example is the Vietnam War, which sparked a mass antiwar movement in the United States (Antiwar History: Vietnam, n.d.). Sociological impacts post wartime are explored in Modell and Haggerty's "The Social Impact of War", in which the authors reviewed work written in the United States in the wake of the Vietnam conflict ("The Social Impact of War on JSTOR," n.d.). Their findings are applicable to general discussions regarding the war industry today, ranging from the economic and social issues on developing weapons due to divided opinion to psychological impacts of using said weapons.

This STS topic and all it entails will be analyzed and investigated by extensive literature search. A mixture of technical papers, books, news articles, and statistical information will be used to gather evidence to support the connection between the war industry, society, geopolitics, and the environment in the STS Thesis. Analysis will include both a study of how each aspect is impacted independently as well as a detailed investigation of how they influence each other.

Conclusion

The purpose of this technical research is to find an optimal dissolution method to produce a sufficiently high surface Ni content to immediately put the energy of corrosion(E_{Corr}) of Zn-Ni in the immunity zone of potential. The technical deliverable, as expected by our sponsor and industry partner Rolls Royce, is proof of concept that Zn-Ni coatings can be post-processed by dissolution to display desire properties. By proving the concept is viable, we will enable Rolls Royce's manufacturers to produce Zn-Ni coated parts that meet the buyer's specifications. We will also open the door for further research into applications of this capability, which has the potential to change how we treat metals for extreme environments.

The purpose of this STS research is to establish the effects of the war industry, specifically in relation to the current hypersonics arms race, on society, geopolitics, and the environment. By fully characterizing these issues, we can better understand where they come from and how they influence each other. This would allow us to provide better and more creative solutions to these issues. It is imperative that we as engineers take on a professional responsibility to understand how our inventions impact society. Developing weapons of war impacts society in a number of ways, both directly and indirectly. Development costs money that then isn't going towards other programs, thus impacting society (schools, social programs, etc). Development escalates the already tense geopolitical climate and breeds competition with other countries (the Policy of Mutual Destruction), thus increasing citizen anxieties. Development consumes resources and often produces toxic byproducts (increased carbon footprint), thus polluting land that could be inhabitable and impacting public health.

The expected results of the technical paper are an optimal dissolution method for Zn-Ni to provide the desired properties. The expected result of the STS paper is a detailed analysis of the

sociotechnical system between the war industry, society, geopolitics, and the environment. It is intended to provide a compelling case for the interconnectedness of each aspect of the system, as well as plainly explain how each aspect influences the other.

The race is on.

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