Undergraduate Thesis Prospectus

Novel Machining Process for Regenerative Cooling in Aerospace

(technical research project in Electrical Engineering)

The Three Mile Island Disaster's Legacy in Nuclear Energy Safety

(sociotechnical research project)

By

Hadrian Sneed

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Technical project collaborators:

Henry Nester

Nathaniel Hersel

Stephen Klem

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.

Hadrian Sneed

Technical Advisor: Adam Barnes, Department of Electrical and Computer Engineering

STS Advisor: Peter Norton, Department of Engineering and Society

General Research Problem

How can the safety of devices in high temperature applications be improved?

High temperature devices are commonly designed in aerospace, aeronautical, and nuclear engineering. Devices in these fields such as planes, rockets, and nuclear reactors respectively can pose great risk to public safety in the event of failure. Along with the risks involved with these devices, failure often involves a high-profile incident that has psychological effects beyond its physical impact. For example, "radiation exposure could spawn persistent fears about developing cancer and long-term depression, regardless of the actual dose of radiation exposure received" (Bromet, 2011). As a result, it is necessary that the safety of devices in these fields be held to a high standard beyond even the requirements in other fields.

Novel Machining Process for Regenerative Cooling in Aerospace

How can electrical discharge machining be used to manufacture regenerative cooling ducts in nozzles for aerospace applications?

This problem will be addressed by our capstone group under the advisement of Mr. Adam Barnes, which consists of myself, Henry Nester, Nathaniel Hershel, and Stephen Klem.

Parts designed for aerospace and aeronautical applications often contact combusted fuel that reaches temperatures around 3500 °C (Percival, 2022). Since Tungsten has the highest melting point of any metal at 3422 °C, heat must be continuously removed from the surfaces of these parts that are in contact with the combusted fuel. There are many ways to do this, but one popular method is the use of regenerative cooling channels that flow coolant beneath the surface of the part. Regenerative cooling channels are traditionally machined in one of two ways. The first method is to use tightly packed tubes to conduct the fluid (Huzel and Huang, 1992). The second method is to carve grooves into the surface of the part and then electroplate an outer shell on top to close off the channel, which results in a channel wall cross section similar to figure 1 (Huzel and Huang, 1992). Today, this method is largely favored since it allows for thicker walls to "permit 'smoothing' of any localized extremely-high-heat-flux regions" and it allows the use of "high conductivity materials for wall construction" (Huzel and Huang, 1992). This project hopes to replicate this channel wall regenerative cooling configuration using electrical discharge machining (EDM). In addition, we hope to machine the regenerative cooling channels from a single solid conductive metal block called a "workpiece" thereby forgoing the need for electrodepositing an outer shell to close out the channel.

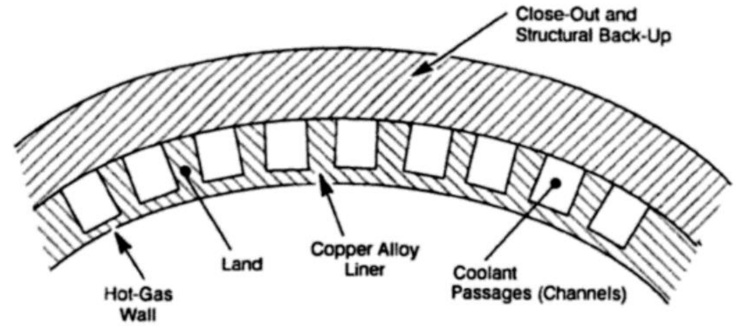

Figure 1. Typical Channel Wall Regenerative Cooling Configuration (Huzel and Huang, 1992)

EDM is a niche type of machining that uses the arcing of sparks in a dielectric to erode a workpiece into a usable part. There are two main advantages to using EDM for this application. EDM allows us to carve extremely long, thin, and precise channels out of a single workpiece. Also, EDM does not cause significant changes to the mechanical properties of the workpiece during machining nor will it introduce any new stresses (Kuriachen, 2022). By creating the channels from a single workpiece, we hope to avoid mechanical weaknesses that arise at the interface between the inner and outer shells of the channel wall configuration. Additionally, the EDM process should not change the crystal structure of the workpiece past a few tens of microns as seen in figure 2, which results in the finished part avoiding the need for additional hardness treatment after manufacturing (Kuriachen, 2022). These factors will result in a manufacturing process that creates more reliable parts for high temperature applications.

During the course of this project, we will observe UVA EH&S standards for high voltage equipment and wear eye protection for the UV light generated during the sparking process. If this project is successful, we will have created at least one regenerative cooling channel of significant length in a block of aluminum.

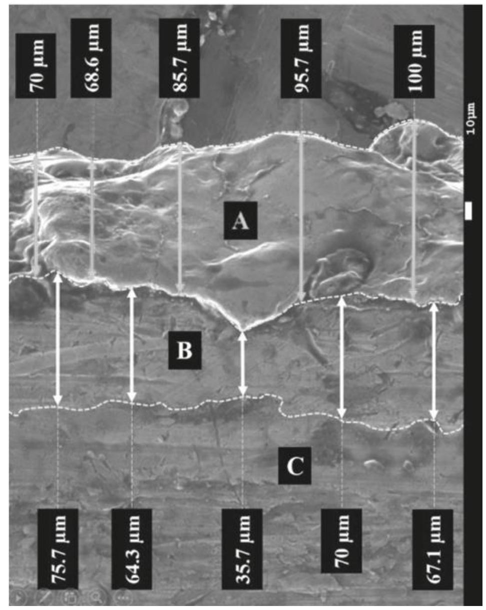

Figure 2. Cross Sectional Image of Electrical Discharge Machined Surface (ETi64). The Sections are divided into the RL crystal (A) Heat Affected Zone (B) and Substrate (C) (Kuriachen, 2022)

The Three Mile Island Disaster's Legacy in Nuclear Energy Safety

How did social groups in the United States work to promote safety in nuclear energy after the Three Mile Island disaster?

In 1979, seven years before the Chernobyl incident, the Unit 2 reactor at the Three Mile Island nuclear power plant in Londonderry Township, Pennsylvania experienced a partial meltdown. In response to the accident, President Jimmy Carter issued an executive order that established a commission of 12 analysts who described the incident as "the worst accident in the history of commercial nuclear power generation" (Kemeny, 1979). The President's commission advocated for "fundamental changes" within the U.S. Nuclear Regulatory Commission (NRC) and insisted that the leading cause of the incident was "people-related problems" (Kemeny, 1979). The NRC, in turn, made a wide range of changes to regulation while focusing on regulation for part suppliers and training for personnel. After responding to the recommendations by the President's commission in NUREG-0737, "TMI Action Plan", the NRC created "13,863 action plan items were applicable when reviewed against each specific licensed nuclear power plant" (NRC, 2016). For example, the "NRC issued a requirement for nuclear power plants to have a simulation facility appropriate to conduct operator licensing tests" (NRC, 2016). Meanwhile, a group called Musicians United for Safe Energy (MUSE) performed an album titled "No Nukes" at the New York Madison Square Garden Protests (MUSE, n.d.). Their message argues that "aside from fossil fuels, nuclear power would be the worst among choices available to us" to fight climate change (MUSE, n.d.). MUSE's music emphasizes the dangers of nuclear energy as in the song "FACE THE FIRE", which has lyrics like "the people are running from what they can't even see".

Interestingly, before the TMI disaster occurred, an almost identical incident resulting from the same faulty valve manufactured by the company B&W, was discovered at the Davis-Besse power plant in Ohio in 1977. However, the plant was at 9% power when the incident occurred and no meltdown occurred (Bushbaum, 2011). The NRC largely ignored the incident, but a regional inspector named James Cresswell would not let it go unnoticed. He tried to raise his concerns about the incident's safety implications through proper channels in vain and eventually broke the chain of command to send a memo to upper management in 1978 (Bushbaum, 2011). Forty-five years later, I had the opportunity to hear a presentation from Mr. Cresswell at my summer internship at BWXT, a splinter company from B&W who manufactured the faulty part in both incidents. I saw a part of the memo he sent to management, which read "Had this event occurred in a reactor at full power… core uncovery and possible fuel damage would have resulted." After the Davis-Besse incident, two years before TMI, despite warnings from investigators, little was done to prevent subsequent failures simply because no damage resulted from the accident.

The incident also inspired Normal Accidents: Living With High-risk Technologies by Charles Perrow, which reimagines risk management when dealing with complex systems (Perrow 1984). The fears surrounding airplane flights analyzed by Margaret Oakes and Robert Bor have direct parallels to the fears surrounding nuclear energy (Oaks and Bor, 2010). Finally, Damico, Conway, and Damico offer insight into how public trust is gained and lost (Damico, 2000).

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