LIQUID FUELED HIGH VELOCITY OXY-FUEL THERMAL SPRAYING TECHNIQUE FOR DURABLE COATING

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Liquid Fueled High Velocity Oxy-Fuel Thermal Spraying Technique for Durable Coating
Introduction

- **Thermal spraying techniques**: are coating processes in which melted (or heated) materials are sprayed onto a surface.

- Thermal spraying can provide thick coatings (approx. thickness range is 20 micrometers to several mm, depending on the process and feedstock).

- Coating materials available for thermal spraying include metals, alloys, ceramics, plastics and composites.

- They are fed in powder form, heated to a molten or semi-molten state and accelerated towards substrates in the form of micrometer-size particles.
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**Introduction**

- The flame and powder are accelerated by a *converging / diverging nozzle* to produce *supersonic* gas and particle velocities, which propel the powder particles toward the substrate to be coated.

- The powder particles flatten plastically upon impact with the substrate; cooling and solidifying to form the coating.

- High particle velocities, uniform heating and low dwell time combine to produce coatings that are very dense and tightly bonded to the substrate.
The HVOF thermal spraying technique is widely applicable to high-temperature coating materials including iron, nickel, and cobalt-based alloys.

High Velocity Oxy Fuel (HVOF) thermal spraying system is a highly promising technique for applying durable coatings on structural materials for corrosive/harsh and high temperature environments in advanced ultra-supercritical coal-fired (AUSC) boilers, steam turbines and gas turbines.
Nevertheless, most commercially available HVOF thermal spraying systems use gas-fuelled spray guns, there is recent interest/trend in using liquid fuel such as kerosene due to its lower operational cost, superior combustion gas acceleration, and higher tendency to promote momentum output of powder particles compared to gas-fuelled systems.
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Liquid fuel HVOF Gun

Oxygen
Kerosene
Ignition
Kerosene
Oxygen

Powder & Carrier gas

Cooling Water

Spray Stream

Substrate

The HVOF (High Velocity Oxy Fuel) Spray process
Objectives

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- The overarching aim of the research team is to develop a comprehensive understanding of the physical and thermo-chemical processes of a LHVOF thermal spraying system and intricate interactions with coating materials.
  - combustion chamber design,
  - fuel-oxygen injector configurations,
  - nozzle design,
  - oxygen/fuel ratio,
  - gas flow rate,
  - combustion chamber pressure,
  - particle size, and
  - position of substrate.
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Objectives

- Inconel 718, Fe-Al, Fe-Ti-Al and Fe-Zr-Al will be systematically studied.
  - Microstructure analysis and Mechanical Characterization
  - Thermo-mechanical and Thermo-chemical
  - A high-pressure combustor rig will be utilized to determine how thermal stress cycling, oxidation degradation (and their complex interactions) can cause coating failures.
## Objectives

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<table>
<thead>
<tr>
<th>Oxidizer</th>
<th>Fuel</th>
<th>Coating Particles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaseous Oxygen</td>
<td>Kerosene / RP-1</td>
<td>Fe-Al</td>
</tr>
<tr>
<td></td>
<td>Jet-A</td>
<td>Inconel 718</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fe-Ti-Al</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fe-Zr-Al</td>
</tr>
</tbody>
</table>
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Plan

Year 1
- Modular and Reconfigurable LHVOF Gun Design
- Experimental Set-up Development

Year 2
- Coatings
- Characterization and Analysis
- Design Optimization

Year 3
- Combustion Rig Testing
- Design Optimization
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- Deep Throttle Capability
- Maximum Exit Mach Number: 4
- Maximum Exit Temperature: 3000 K
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Requirement Overview

- **Five Modular** Sections:
  - Injection system
  - Combustion chamber section
  - Converging-Diverging Nozzle
  - Barrel section
  - Cooling jacket
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System Layout

Oxidizer line
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System Layout

[Diagram of system layout including components such as Gaseous N2 Tank, Pressure gauge, Relief valve, Flow regulator, Kerosene Pressure Vessel, Flow meter, Pressure transducer, Injector, LHVOF Gun, Liquid Fuel line, and various other elements connected by arrows indicating flow direction.]
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Seeding particles/coatings powder line
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System Layout

Flow meter
Flow Direction

Pump
Flow regulator

Dynelene Tank

Heat Exchanger

LHVOF Gun

Coolant line
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Year 2 Plan

- Hot Firing: July 1
- Coatings and Characterization: August 1
### Hazards overview

#### Liquid Fueled High Velocity Oxy-Fuel Thermal Spraying Technique for Durable Coating

<table>
<thead>
<tr>
<th>HA #</th>
<th>System</th>
<th>Hazard</th>
<th>Severity</th>
<th>Likelihood</th>
<th>HA Index</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HVOF</td>
<td>Fire</td>
<td>3-Significant</td>
<td>2-Infrequent</td>
<td>2</td>
<td>Separation of propellants</td>
</tr>
<tr>
<td>2</td>
<td>HVOF</td>
<td>Asphyxiation</td>
<td>3-Significant</td>
<td>2-Infrequent</td>
<td>2</td>
<td>Proper ventilation system</td>
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<tr>
<td>3</td>
<td>HVOF</td>
<td>Over Pressure</td>
<td>2-Moderate</td>
<td>1-Unlikely</td>
<td>1</td>
<td>Installing pressure relief valves</td>
</tr>
<tr>
<td>4</td>
<td>HVOF</td>
<td>Kerosene spill</td>
<td>2-Moderate</td>
<td>1-Unlikely</td>
<td>1</td>
<td>Proper ventilation and diking system</td>
</tr>
</tbody>
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- **Students**
  - Luisa Cabrera (MS Student)
  - Diaaeldin M (PhD Student)

- **Publications**
Liquid Fueled High Velocity Oxy-Fuel Thermal Spraying Technique for Durable Coating

Thank you