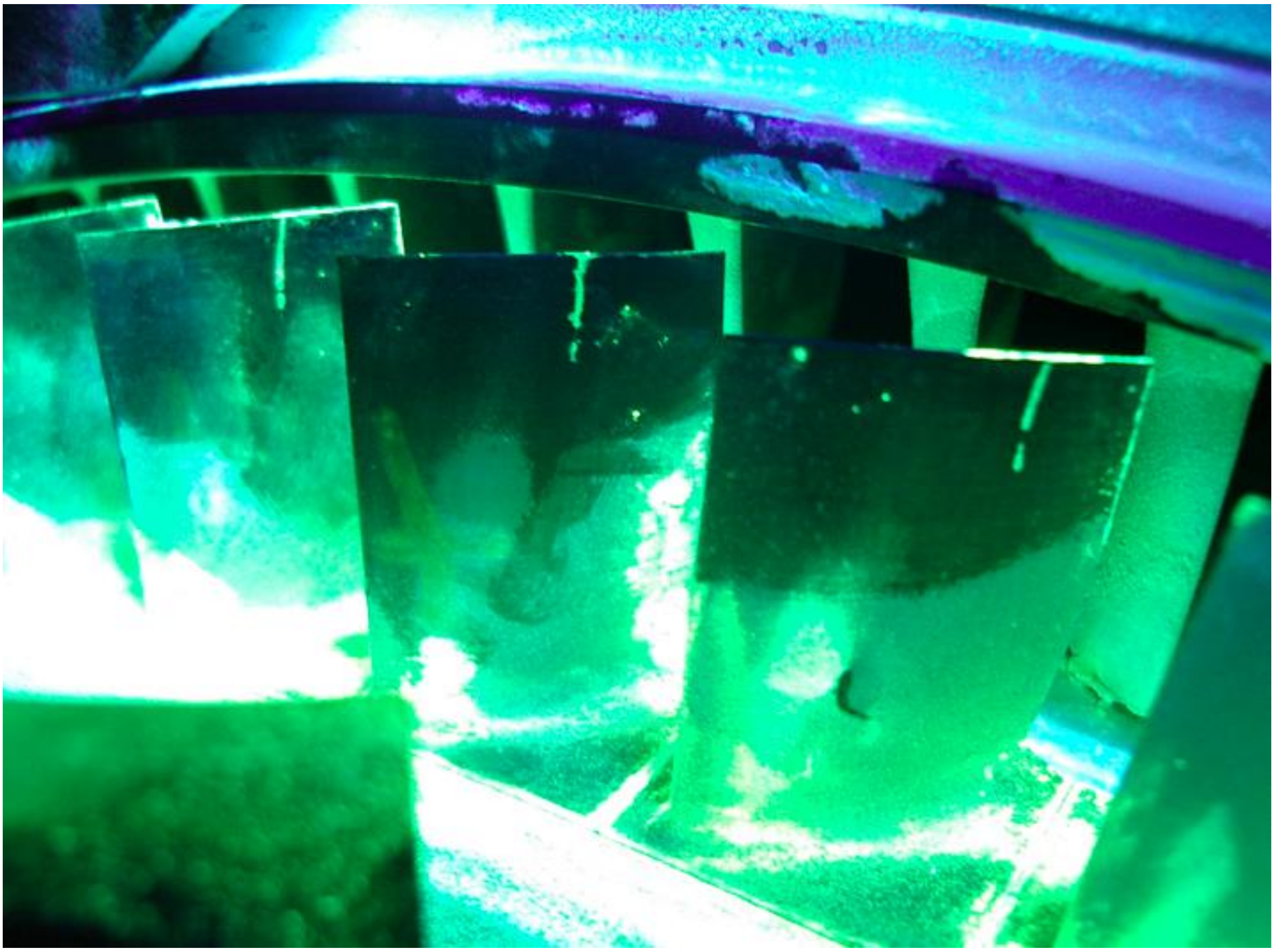
Fluorescent Liquid Penetration Method for Surface Crack Detection



Project Author:

Name: Davutgeldi Altayev
Degree Program: BSc in Mechatronics Engineering
University: Obuda University
Email: dawud.altayev@gmail.com
LinkedIn: Davutgeldi Altayev
Full Portfolio on GitHub: Davutgeldi Altayev

Project Overview:

In this project, I simulated the Fluorescent Liquid Penetrant Testing (FLPT) method using MATLAB to detect surface cracks in titanium alloys. The objective was to model how a fluorescent penetrant interacts with the surface of the material, and how ultraviolet (UV) light exposure reveals cracks by causing the penetrant to fluoresce. Using a 3D simulation, I modeled the surface of a material, applied a crack region, and visualized the changes in fluorescence intensity. This simulation was enhanced with a more realistic geometry, providing a detailed view of the material surface and the crack, which is a key aspect of non-destructive testing (NDT). By adjusting various parameters like crack dimensions and fluorescence intensity, I visualized the detection of fine surface cracks in a material, demonstrating the effectiveness of FLPT in real-world applications.

Introduction

Fluorescent Liquid Penetrant Testing (FLPT) is a non-destructive testing (NDT) technique commonly used to detect surface-breaking cracks, porosity, or other flaws in materials. This method involves applying a fluorescent liquid penetrant to the material surface. After removing excess penetrant, the remaining liquid inside the cracks fluoresces when exposed to ultraviolet (UV) light, making defects visible to the inspector.

In this project, I used MATLAB to simulate the FLPT method on a titanium alloy surface. The primary goals of the simulation were:

1. To model the interaction between the penetrant and material surface.
2. To simulate the effect of surface cracks on fluorescence intensity.
3. To visualize the cracks and their surrounding fluorescence under UV light.
4. To analyze the crack detection ability of FLPT using simulated titanium alloy material.

Technical parameters used in the FLPT simulation:

The tables below summarize the key parameters and values used in the simulation to model a realistic application of FLPT for detecting surface cracks in titanium alloys.

Material Properties of Titanium Alloy:

Parameter	Value	Description
Density	4420 kg/m^3	Density of titanium alloy
Conductivity **(σ)**	2.38e6 S/m	Electrical conductivity of titanium
Permeability **(μ)**	$4\pi \times 10^{-7}$ H/m	Permeability of free space (constant)
Fluorescence Intensity (Base)	100 units	Base fluorescence intensity in material
Fluorescence Intensity (Crack)	150 units	Fluorescence intensity in the crack region

Crack Dimensions:

Parameter	Value	Description
Crack Length	10 units	Length of the simulated crack
Crack Width	3 units	Width of the simulated crack

Geometry of Material:

Parameter	Value	Description
Material Geometry	Curved surface	Simulated using sine and cosine functions to create a smooth, curved surface

Simulation Parameters:

Parameter	Value	Description
Penetrant Exposure Time	10 seconds	Time to apply and remove excess penetrant
UV Light Intensity	5 units	Intensity of ultraviolet light used for fluorescence visualization

Results and Visualization:

3D Surface Visualization (Material with and without Crack):

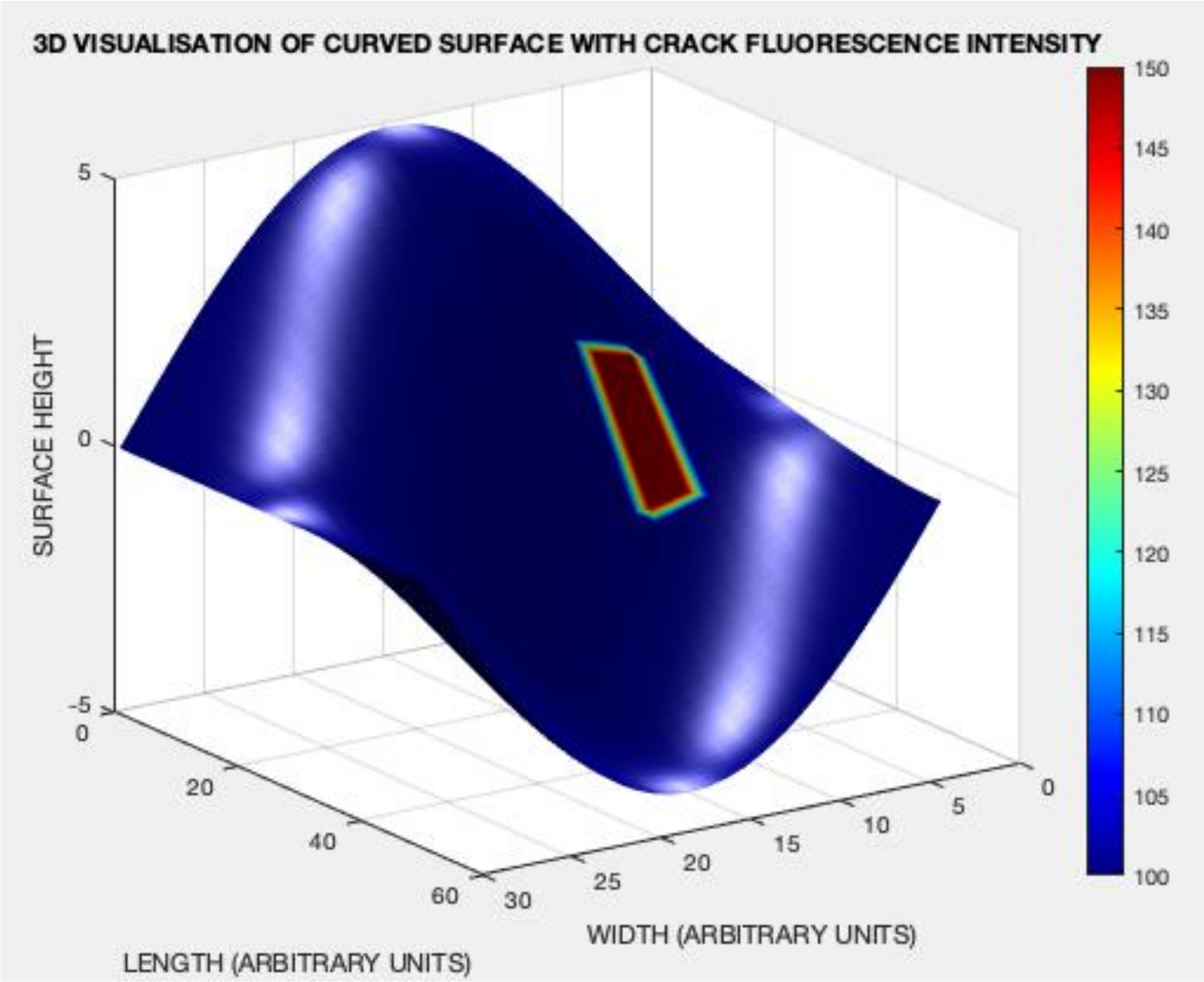


Figure 1: The first plot presents the 3D geometry of the material surface, with color maps indicating fluorescence intensity. The crack is visible, showing areas of higher intensity due to the penetrant.

Zoomed-In Crack Region:

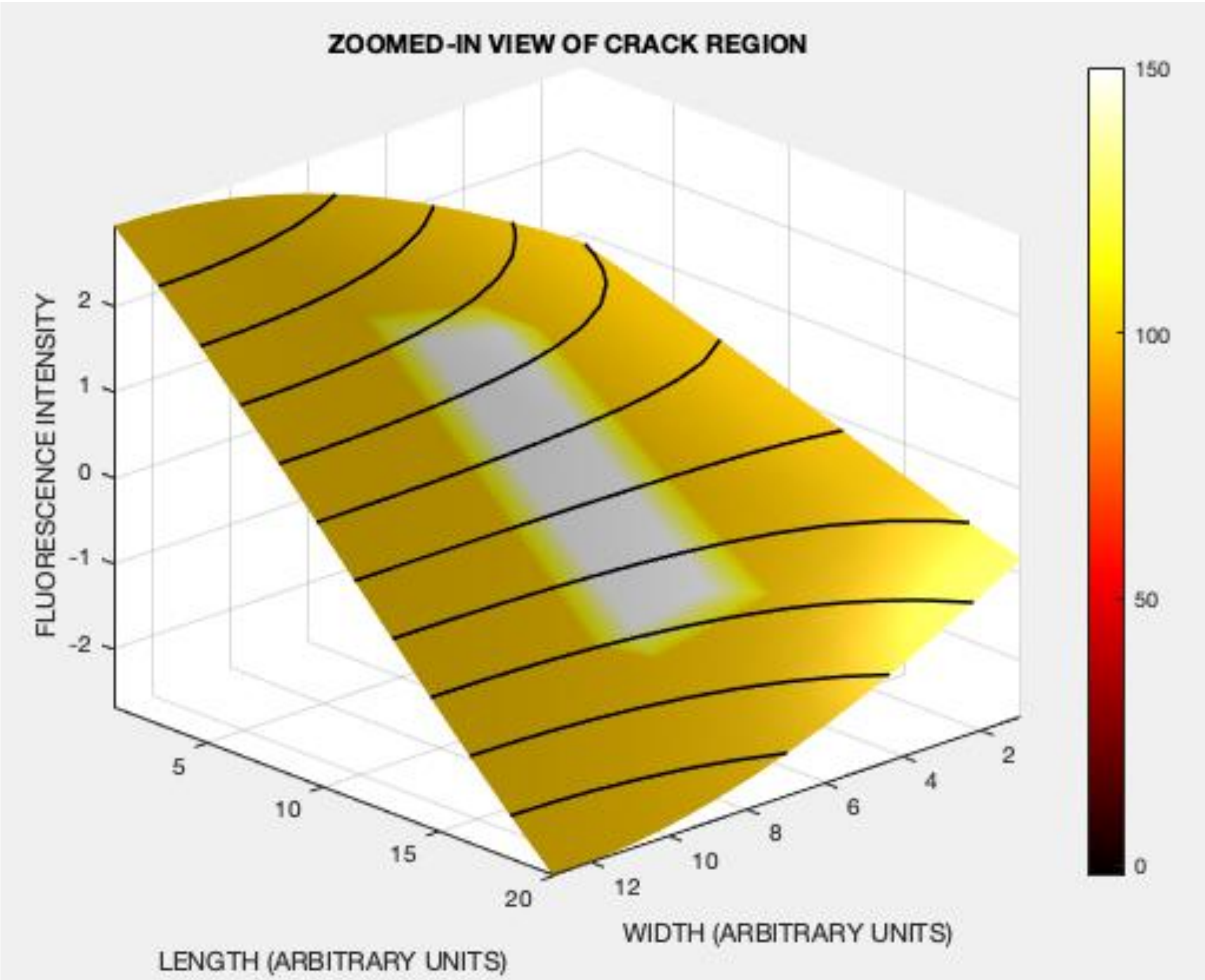


Figure 2: A close-up view of the crack region, where the higher fluorescence intensity is clearly visible, confirming the presence of the crack.

Fluorescence Intensity Profile:

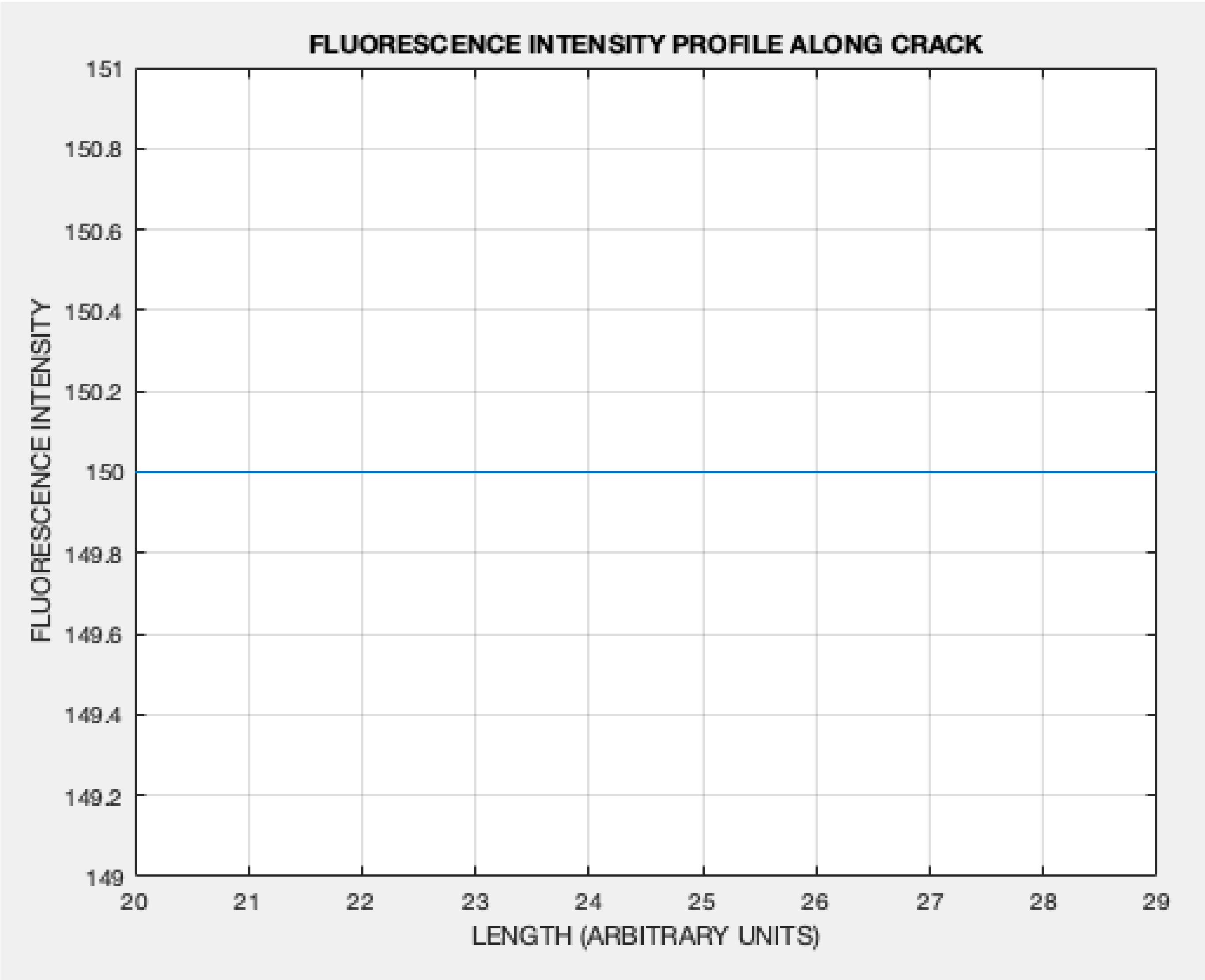


Figure 3: A plot showing the fluorescence intensity across the material surface, with a noticeable increase in intensity at the crack location.

Heatmap of Fluorescence Intensity:

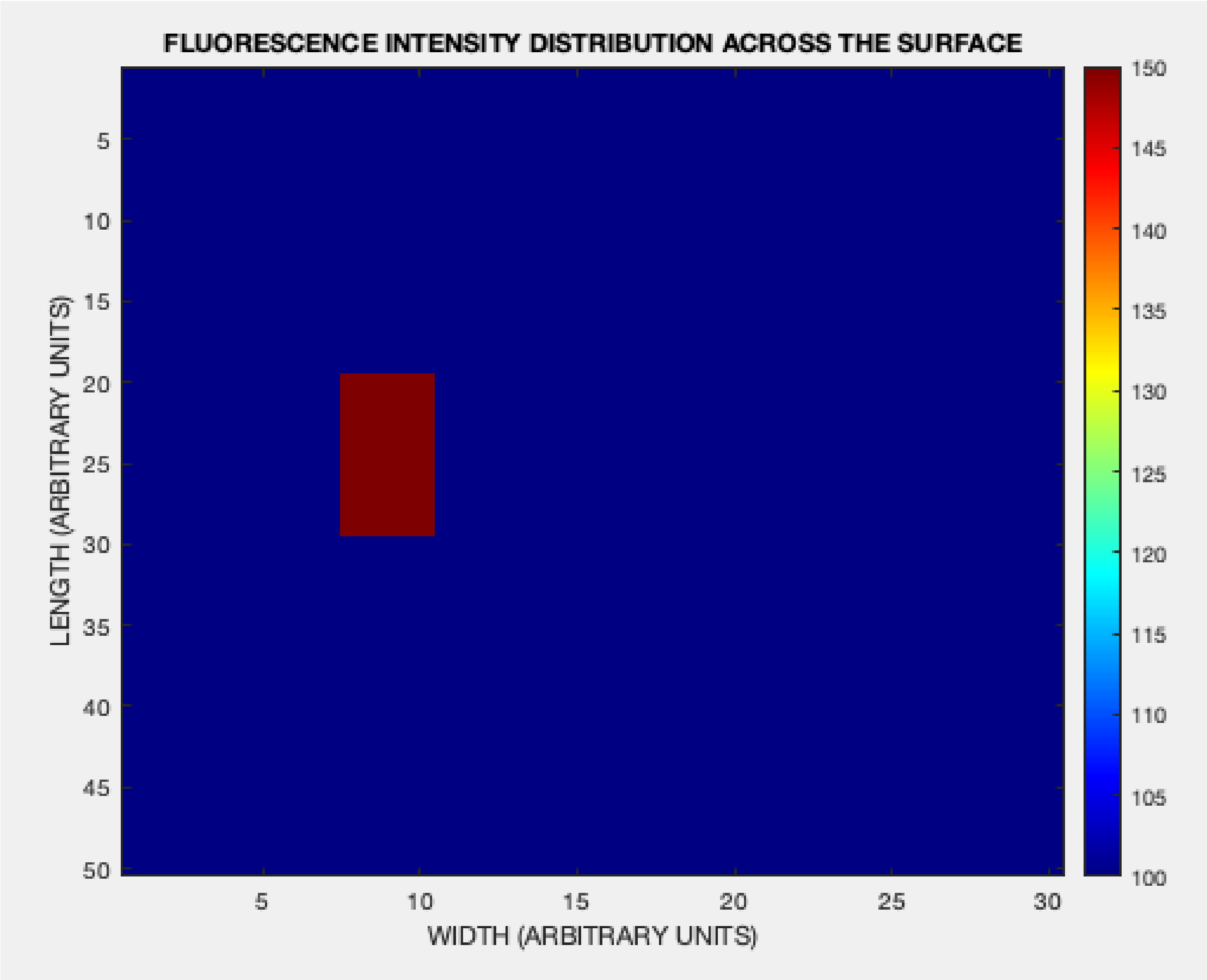


Figure 4: A heatmap visualizing the fluorescence intensity across the entire material surface. The heatmap clearly shows the crack region with significantly higher fluorescence intensity.

Conclusion:

The simulation successfully demonstrates the Fluorescent Liquid Penetrant Testing (FLPT) method's ability to detect surface cracks in titanium alloys. The simulation showed how fluorescence intensity is significantly higher in the crack region, making it detectable under ultraviolet light.

This project highlights the effectiveness of FLPT in non-destructive testing (NDT), particularly for detecting fine surface cracks that are critical in industries like aerospace and automotive, where titanium alloys are commonly used.

Key Findings:

- **Fluorescence Intensity**: The fluorescence intensity in the crack region is significantly higher (by 50%) compared to the surrounding material.
- **Crack Detection**: The crack region is clearly identifiable in both the 3D surface plot and fluorescence intensity profile.
- **Crack Dimensions**: The simulated crack length of 10 units and width of 3 units is effectively detected through increased fluorescence intensity.

Additional Notes:

- **Tools Used**: MATLAB for simulation and visualization.
- **Challenges**: Modeling realistic material geometry and simulating fluorescence accurately.
- **Future Improvements**: In future iterations, more advanced crack geometries and penetrant behaviors could be simulated for better real-world applicability.