STUDY AND REVIEW OF HOT TEARING BEHAVIOR AND QUANTIFICATION TECHNIQUES

A Internship Report

Submitted by

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A Report Submitted in Partial Fulfillment of the Requirements for the Completion of Internship

in

Department of Mechanical Engineering

National Institute Of Technology, Tiruchirappalli - 620015

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BONAFIDE CERTIFICATE

This is to certify that **Mr. Sundara Mahalingam M**, a student of the **Department of Mechanical Engineering, Karpagam Institute of Technology, Coimbatore**, has successfully completed his internship titled **“Study and Review of Hot Tearing Behavior and Quantification Techniques” at the National Institute of Technology (NIT), Tiruchirappalli**, during the period from 02nd June 2025 to 30th June 2025. The internship focused on the study and evaluation of various experimental techniques and assessment standards related to hot tearing phenomena in metal casting. During the course of this internship, the student demonstrated keen interest, technical competence, and commitment in reviewing and analyzing experimental findings from past literature and industrial practices. This work was carried out under the guidance of **Dr.-Ing. N. Ashok Kumar Nallathambi, Assistant Professor, Department of Mechanical Engineering, NIT Tiruchirappalli**, in partial fulfillment of the academic requirements of the internship programme. We wish him continued success in all his future academic and professional endeavors.

26/06/2025

Signature of the Guide

ABSTRACT

This internship report summarizes the work carried out at the Department of Mechanical Engineering, National Institute of Technology, Tiruchirappalli, focusing on the review of hot tearing experiments and evaluation criteria. Hot tearing is a significant casting defect that occurs during the final stages of solidification, often leading to internal cracks in metallic components. The internship involved a detailed study of various experimental techniques used to reproduce and analyze hot tearing, along with an assessment of the criteria employed to predict and measure its occurrence. Key aspects such as alloy composition, mold design, thermal gradients, and strain-induced conditions were explored through the lens of previous research and case studies. The review also covered theoretical models like strain rate-based and thermal contraction criteria, as well as hot tearing susceptibility indexes. This work provided valuable insights into the metallurgical and mechanical factors influencing hot tearing and emphasized the importance of combining experimental observations with simulation-based analysis for better prediction and control of casting defects.

INTRODUCTION:

- Internships play a crucial role in bridging the gap between academic knowledge and real-world industrial practices.
- As a part of my Mechanical Engineering curriculum, I undertook an internship aimed at exploring the experimental, fabrication, and simulation aspects of Aluminum 7075 (AL 7075).
- AL 7075 is a high-strength, lightweight aluminum alloy extensively used in aerospace, automotive, and structural engineering applications due to its excellent mechanical properties.
- The internship provided hands-on experience and technical exposure in the following areas:
  - Quenching experiments on AL 7075 plates.
  - Casting processes of aluminum alloy components.
  - Simulation and modeling using COMSOL Multiphysics.
  - Crack quantification and severity analysis techniques.
- Through these activities, I developed a deeper understanding of material behavior, manufacturing techniques, and simulation tools, significantly enhancing my technical competency in material processing and analysis.

OBJECTIVES:

- To understand the fundamental causes and mechanisms of hot tearing in metal casting, especially in aluminum and its alloys.
- To review and analyze various experimental approaches used to study hot tearing under controlled laboratory conditions.
- To examine the influence of key parameters such as alloy composition, mold design, cooling rate, and mechanical restraint on the occurrence of hot tearing.
- To gain exposure to current research methodologies and practices used in the field of casting defect analysis.

- To explore and compare different criteria and models used to predict and evaluate hot tearing susceptibility (e.g., strain rate-based, temperature-based, and feeding-based criteria).
- To develop the ability to critically review scientific literature and synthesize findings into meaningful conclusions.
- To strengthen skills in technical documentation, academic writing, and effective communication of engineering research.
- To apply theoretical knowledge from mechanical and materials engineering to real-world research scenarios related to manufacturing defects.

DETAILED WORK DESCRIPTION:

LITERATURE STUDY:

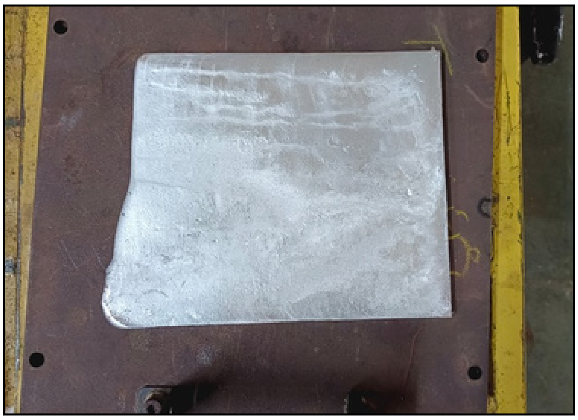
- At the beginning of the internship, my primary task was to study research papers and technical literature related to hot tearing in metal casting.
- I focused on understanding the causes and mechanisms of hot tearing, especially in aluminum alloys.
- I also read about various crack quantification techniques, including how cracks are measured and analyzed using image processing and mathematical models.
- Additionally, I studied literature related to experimental methods and quenching techniques used to simulate and control hot tearing behavior during solidification.
- This initial phase helped me build a strong foundation and prepared me for understanding more advanced topics later in the internship.
- It also gave me clarity on how these defects impact the quality of cast components in real-world industrial applications, especially in the automotive and aerospace sectors.

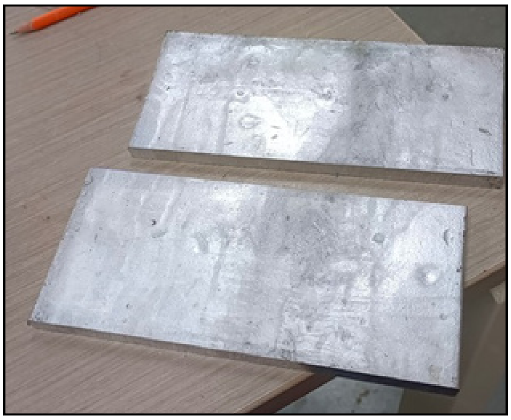
CASTING OF AL 7075 PLATES:

Before proceeding with quenching experiments, I was involved in the casting of AL 7075 alloy plates to produce test samples for further analysis.

OBJECTIVE:

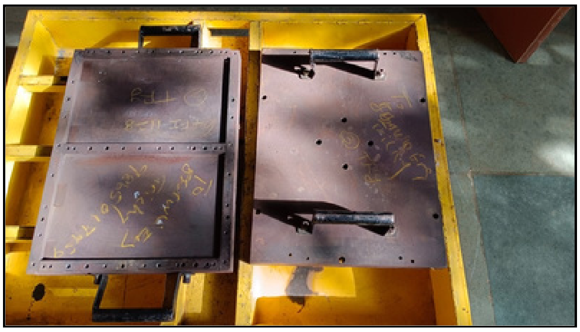
To prepare cast aluminum plates using AL 7075 alloy under controlled conditions for use in subsequent thermal and structural analysis experiments.

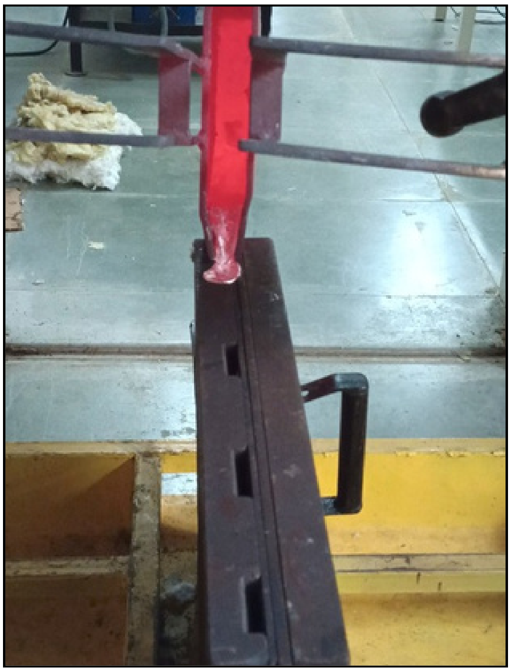


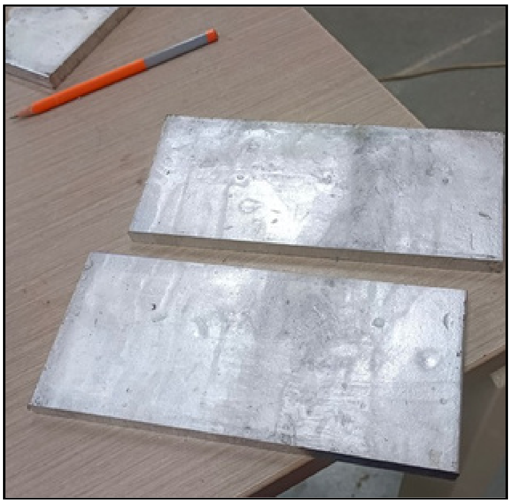


PROCEDURE:

- AL 7075 alloy ingots were first melted in a crucible furnace at the required pouring temperature.
- The molten metal was poured into pre-designed metallic molds to form rectangular plate-shaped castings.
- Special care was taken to maintain mold preheat temperature, pouring rate, and ambient conditions to ensure defect-free casting.
- Once solidified, the plates were allowed to cool at room temperature before removal.





KEY PARAMETERS CONTROLLED:

- Pouring temperature
- Mold material and geometry
- Cooling rate and solidification time

OBSERVATIONS:

- Some surface irregularities and minor shrinkage defects were observed.
- The casting process helped simulate real industrial conditions where hot tearing can potentially occur due to thermal and mechanical constraints.

OUTCOME:

The cast AL 7075 plates served as a base material for the following quenching experiments and structural evaluation. This activity gave me a clear understanding of how casting parameters directly affect defect formation and alloy behavior.

QUENCHING EXPERIMENTS ON AL 7075:

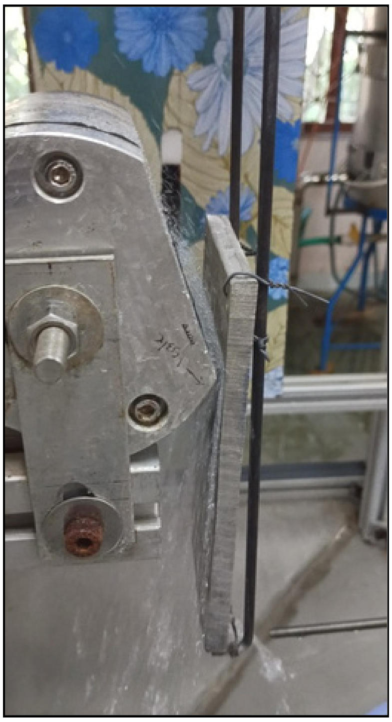
Following the casting process, I performed quenching experiments on AL 7075 alloy plates to investigate the effect of rapid cooling on microstructural behavior and internal stress development.

OBJECTIVE:

To study how water quenching influences the internal structure and cooling characteristics of AL 7075 alloy, which are critical in understanding the conditions leading to hot tearing.

PROCEDURE:

- Each cast plate was individually heated in a muffle furnace to the required solutionizing temperature.
- Only one plate was quenched at a time to ensure better control over timing, handling, and accurate observation of cooling behavior.
- After the holding time, the plate was quickly removed and immersed in a water quenching tank to induce rapid cooling.
- The temperature drop was monitored during the process, and the samples were allowed to reach room temperature before further inspection.



PARAMETERS:

- Furnace Temperature (°C)
- Water Flow Rate (Liters per minute)
- Jet Angle (Degrees)
- Plate Speed (mm/sec)
- Water Temperature (°C)
- Initial Plate Temperature (°C)
- Plate Thickness and Width (mm)

OBSERVATIONS:

- Quenching one plate at a time helped minimize experimental errors and allowed focused study of thermal gradients.
- The rapid cooling produced noticeable hardness variations and zones of thermal stress across the plates.

- Some samples showed fine microstructural variations when viewed under a microscope, suggesting localized transformation effects due to uneven cooling.

OUTCOME:

These experiments provided insights into how quenching influences the residual stress distribution and potential crack formation. Performing the process one plate at a time also helped maintain consistency and ensured more reliable results for microstructural analysis.

CRACK QUANTIFICATION:

After completing the quenching experiments, the next phase of my internship involved the quantification of cracks that appeared on the surface of the AL 7075 plates. This step was crucial to understanding the severity and characteristics of thermally induced damage that can contribute to hot tearing.

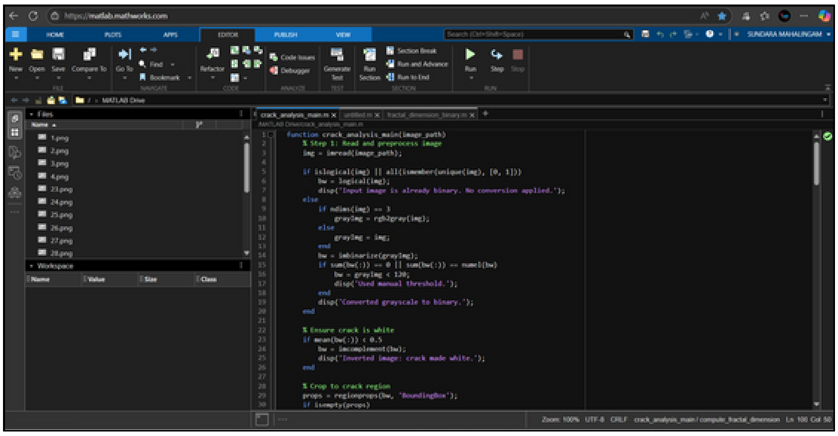
OBJECTIVE:

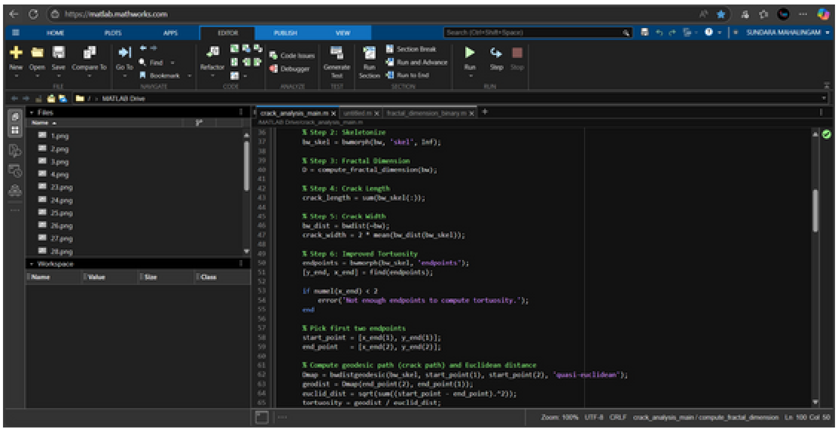
To analyze and measure cracks formed during casting and quenching using image-based methods and quantitative analysis techniques.

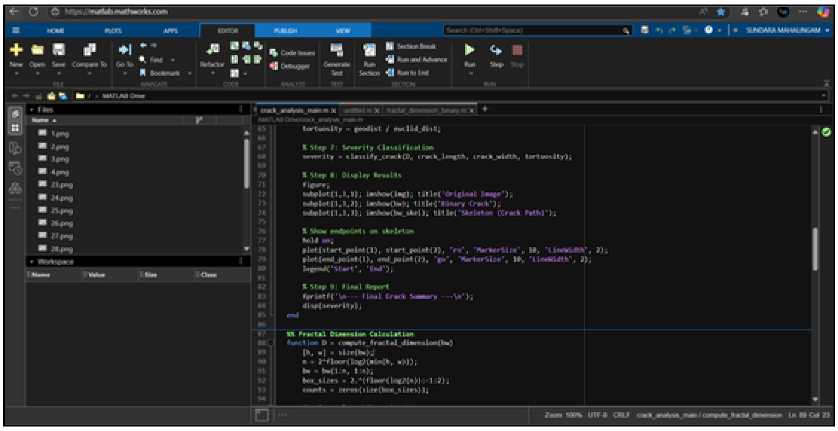
PROCEDURE:

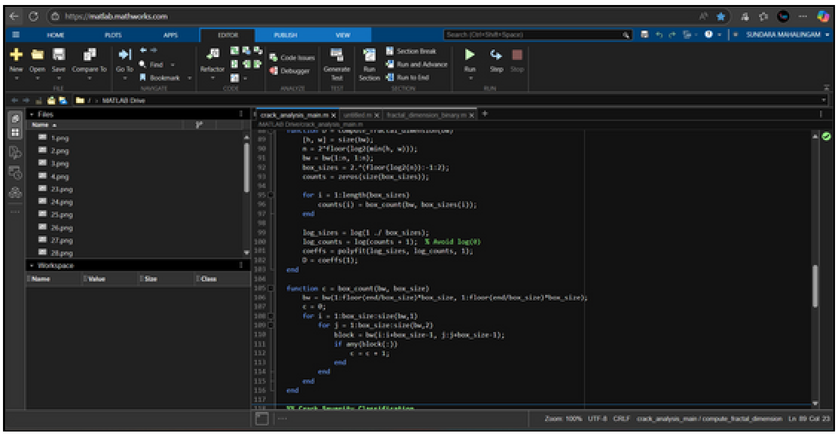
- The surfaces of quenched plates were carefully examined for visible cracks.
- High-resolution images of cracked regions were captured using a camera setup under proper lighting conditions.
- The images were then converted from grayscale to binary to improve crack visibility and enhance contrast.
- Crack features were analyzed using the box-counting method, a technique based on fractal geometry used to estimate crack complexity.

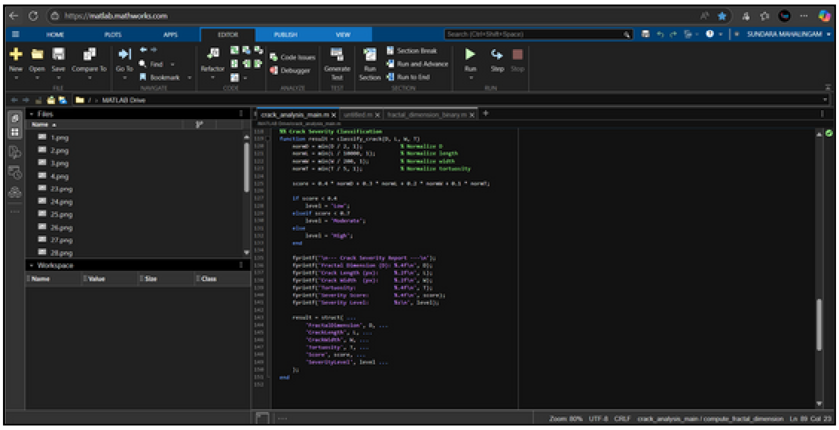
MATLAB WORKSPACE:











PARAMETERS MEASURED:

- Crack Length (in pixels)
- Crack Width (in pixels)
- Tortuosity (the ratio of actual crack path length to the shortest distance between endpoints)
- Fractal Dimension (D) – a measure of crack complexity
- Severity Score – a combined indicator reflecting overall crack intensity

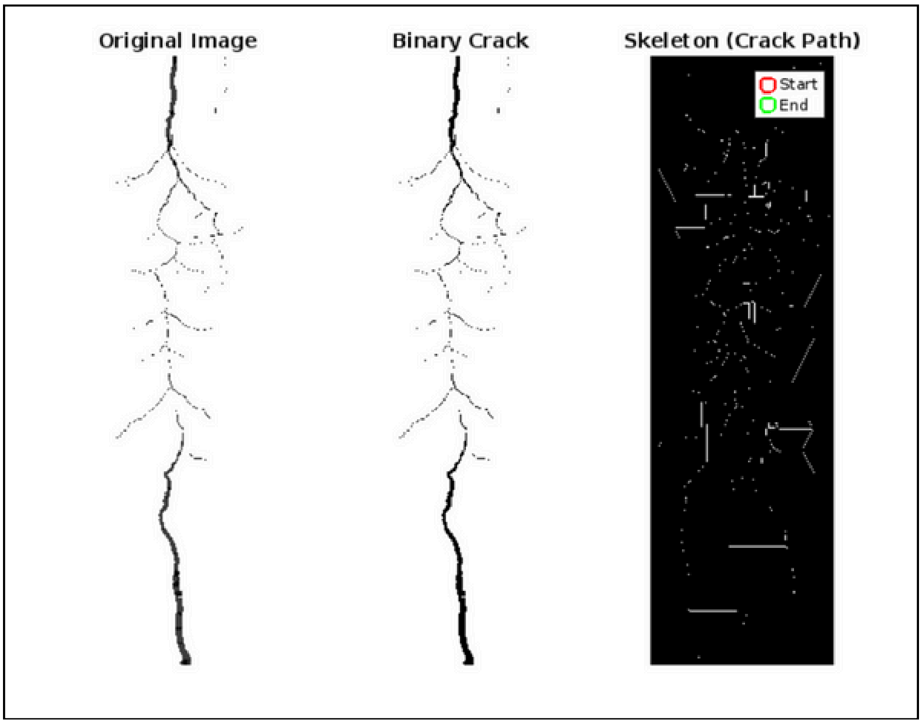
TOOLS USED:

- Image pre-processing and analysis were performed using MATLAB and Python scripting environments.
- Techniques such as thresholding, morphological operations, and edge detection were applied to isolate and measure cracks accurately.

OUTCOME:

Through this phase, I gained practical knowledge in applying image processing and mathematical models for non-destructive evaluation (NDE) of casting defects.

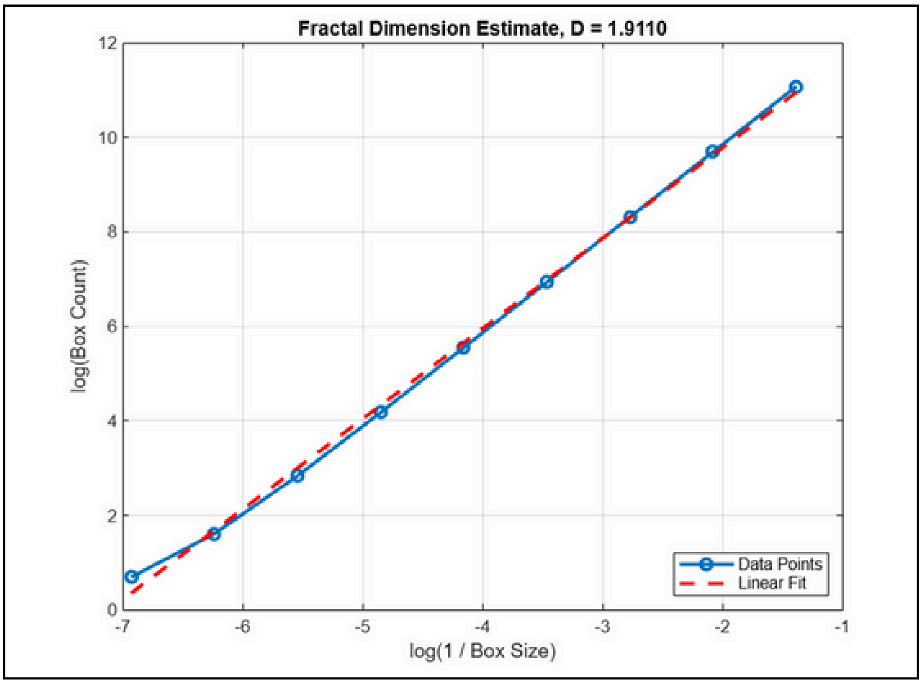
The quantified crack data served as a useful indicator for assessing the influence of quenching and thermal stress on hot tearing susceptibility.




```
>> crack_analysis_main('/MATLAB Drive/crack 1.png');
Converted grayscale to binary.

--- Crack Severity Report ---
Fractal Dimension (D): 1.9110
Crack Length (px):     44327.00
Crack Width  (px):     188.97
Tortuosity:            1.2060
Severity Score:        0.8953
Severity Level:        High

--- Final Crack Summary ---
    FractalDimension: 1.9110
         CrackLength: 44327
          CrackWidth: 188.9670
          Tortuosity: 1.2060
               Score: 0.8953
       SeverityLevel: 'High'
```



CONCLUSION:

- Gained practical experience in casting, quenching, and analyzing AL 7075 alloy plates.
- Understood hot tearing behavior through literature review and experimental work.
- Collected data on key process parameters during quenching for further analysis.
- Used MATLAB to quantify cracks based on length, width, tortuosity, and fractal dimension.
- Improved skills in experimental methods, image processing, and technical reporting.