FATIGUE STUDY OF ALUMINIUM ALLOY AT DIFFERENT TEMPERATURES IN FACULTY OF MECHANICAL ENGINEERING, UNIVERSITI TEKNIKAL MALAYSIA MELAKA.

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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged."

Signature: ....
Author: ....
Date: ....

ABSTRACT

The aim of this research project is to determine the effects on fatigue life of AA6061-T6 aluminium alloy at different temperatures, room and elevated temperatures. The method done was by using constant amplitude tension-tension fatigue test, and while doing so, manipulated the working environment temperature for the specimen. The results of this study include the S-N curves for the three different temperatures in order to determine the effects of high temperature on aluminium alloy and analyzing the reasoning for this cause.

ABSTRAK

Tujuan projek penyelidikan ini adalah untuk menentukan kesan-kesan jangka hidup kelesuan logam aluminium AA6061-T6 pada suhu berbeza, iaitu pada suhu bilik dan suhu yang ditingkatkan. Antara kaedah yang dilakukan adalah dengan menggunakan ujian kelesuan kekuatan malar, dan sambil memanipulasi suhu kerja spesimen aluminium. Keputusan yang dicapai dari kajian ini merangkumi lengkuk S-N untuk tiga suhu yang berbeza demi untuk menentukan apakah kesannya ke atas logam aluminium dan mengkaji sebab di sebaliknya.

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CHAPTER 1

INTRODUCTION

1.1 Background

Aluminium is one if not the rarest of metal present in our lives; it is highly sought after in many industrial application in which the metal provide desirable characteristics and therefore a reasonable choice over other metals, because the atomic weight of an aluminium is 26.98 and has a specific gravity of 2.70; one-third of the weight of commonly used metal. Weight is important for all applications involving motion. Saving weight results in more payload or greater economy of operation and also saves energy and reduces vibration forces. These properties include a relatively high specific strength in tension, compression and shear, a greater strength to density ratio, high corrosion resistance, toughness, and the material is cheap to acquire and relatively easy to use. No matter how good some metals are, it is still susceptible to fatigue failure, and aluminium is one of them.

Fatigue is a condition whereby a material cracks or fails as a result of repeated (cyclic) stresses applied below the ultimate strength of the material; in this case, aluminium. It generally involves three stages : crack initiation, crack propagation and fast fracture. In worst cases of fatigue failure, catastrophic events occurred, for example in 1998, the Germans high speed train ICE derailed due to fatigue fracture of vibration-proof tire and in 2007, a roller coaster of an amusement park in Japan also derailed due to fatigue failure of an axle.

From back then until now, continuous researches have been done so that kind of accidents did not happen again. It is important to know the reliability of the design by conducting study of the fatigue strength of certain material.

1.2 Problem statement

Fatigue failure is a major mode of failure where cyclic load is applied to the machine element. Therefore it is essential in knowing what effects elevated temperatures could have on aluminium alloy fatigue development, which is excessively used in industries like aerospace and automobile industries because of its non-corrosive properties and light in weight. Theoretically, aluminium tensile behavior increases as temperature increases; as the atomic bonds are energized from the change in temperature.

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1.3 Objectives

i. To determine the effects of elevated temperatures on AA6061-T6 aluminium alloy.
ii. To study cyclic fatigue life trend of AA6061-T6 aluminium alloy in different temperatures(room temperature, 27^0C; 70^0C; and 150^0C)
iii. To estimate the approximate value of ultimate tensile strength and tensile stress based on tensile and fatigue tests.

1.4 Scope of study

The main scope will be to establish the effects of three elevated temperatures (27^0C; 70^0C; and 150^0C) on the cyclic fatigue of a AA6061-T6 aluminium alloy.

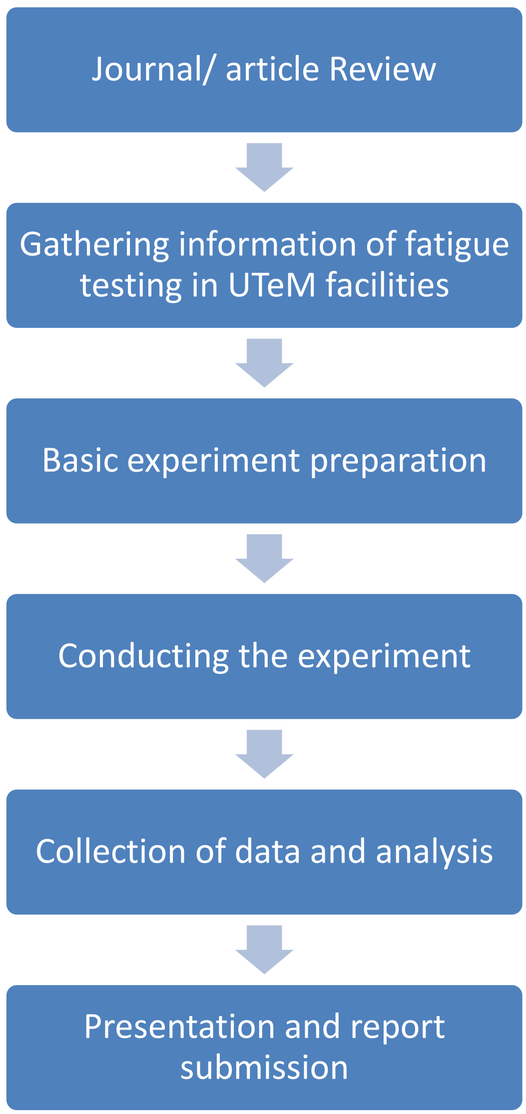
1.5 Research outline

Overall, the study will be done over the course of two semesters, and the work outline is summarized into five chapters.

Chapter 1	Introduction on general project background, objectives, problem statement and research outline.
Chapter 2	Review on aluminium properties, studies related to fatigue testing conducted on aluminium alloy
Chapter 3	Methodology on basically how to proceed with the experiment, specimen preparation and conducting the experiment.
Chapter 4	Data mining from previous researches.
Chapter 5	Conclusion and recommendations based on research result.

1.6 Project planning

1.6.1 Flow chart



CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The fatigue life (N_f) of a material is defined by the total number of stress cycles require to cause failure. Fatigue life can be separated into three stages where

$$\mathbf{N_f = N_i + N_p}$$

1. Crack initiation (N_i) – Cycles required to initiate a crack. Generally results from dislocation pile-ups and/or imperfections such as surface scratches, voids, etc.
2. Crack growth (N_p) – Cycles required to grow the crack in a stable manner to a critical size. Generally controlled by stress level. Since most material contains flaws, the prediction of crack growth is most studied aspect of fatigue.
3. Rapid fracture – Very rapid critical crack growth occurs when the crack length reaches a critical value, a_c

(S-N_f) curve

Most fatigue tests are conducted at what is referred to as “Constant Amplitude” which merely refers to the fact that maximum and minimum stresses are constant for each test cycle. **S-N_f** refers to a plot Constant Amplitude Stress Level(**S**) versus the Number of Cycles to Failure (**N_f**).

A prediction of failure for various stress levels can be made by studying the material’s S-N_f curve

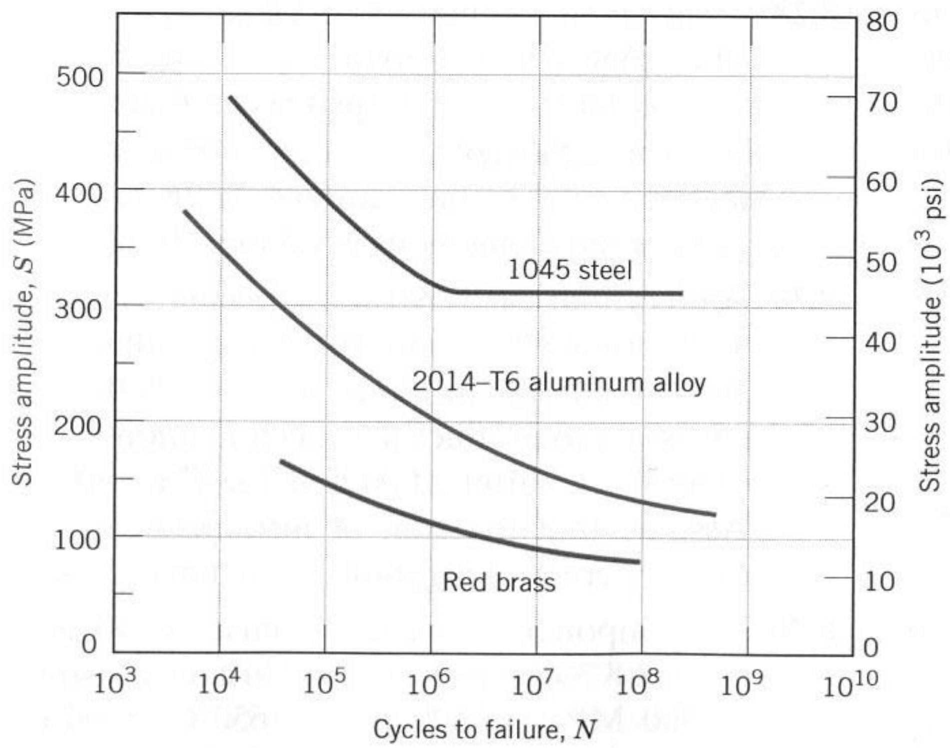


Figure 1: Stress amplitude versus number of cycles to failure curves (Richard A. Flinn, 1995)

2.2 Yield stress

A yield strength, or yield stress or yield point of a material is defined in engineering and materials science as the stress at which a material begins to deform plastically. Prior to the yield point the material will deform elastically and will return to its original shape when the applied stress is remove. Any point further than the yield stress, then the material will deform plastically that means it will not return to its original shape, or break, or fracture in the process (Callister & Kethwisch 2010)

2.3 Ultimate tensile stress

Ultimate tensile stress, or strength (UTS), often shortened to tensile strength (TS) or ultimate strength, is the maximum stress that a material can withstand while being stretched or pulled before failing or breaking. Tensile strength is not the same as compressive strength and the values can be quite different (Black, Ronald & Kohser 2011). Some materials will break sharply, without plastic deformation, in what is called a brittle failure. Others, which are more ductile, including most metal including aluminium, will experience some plastic deformation and possibly necking before fracture.

2.4 Fatigue

2.4.1 Definition

The process of progressive localized permanent structural damage occurring in a material subjected to conditions that produce fluctuating stress and strain at some points and that may culminate in cracks or complete fracture after sufficient number of fluctuations (Liu 2005)

Fatigue is one of the principle damage mechanisms for materials operating at elevated temperatures. Fatigue at elevated temperature produces larger strain deformation, crack initiation and growth for the material under elevated fatigue, there is serious influence on the properties and fatigue life of the material (Mao & Mahadevan 2000)

2.4.2 Nature of Fatigue

Fatigue failure resulted from simultaneous action of cyclic stress, tensile stress and plastic strain. The crack will not initiate and propagates if there is none of these stress and strain.

Fatigue can be stress based, strain based, and fracture mechanics based (Liu 2005). Plastic strain initiates the cracks; while the tensile stress promotes crack growth (propagation).

Fatigue also behaves differently with elevated temperature, as high temperature exposure in services results in a progressive loss of fatigue strength due to the over-aging phenomenon with crack initiation and propagation (Joyce, Styles & Reed 2003)

2.4.3 Fatigue under ambient and elevated temperature

When tested at ambient temperature and an elevated temperature of 190 ^{0}C, aluminium tensile behavior increases as the temperature increases. As the temperature is increased the atomic bonds are weakened as the atoms are energized (Leong 2008). This will result in the nucleation of micro inter-granular voids as shown in Figure 2.

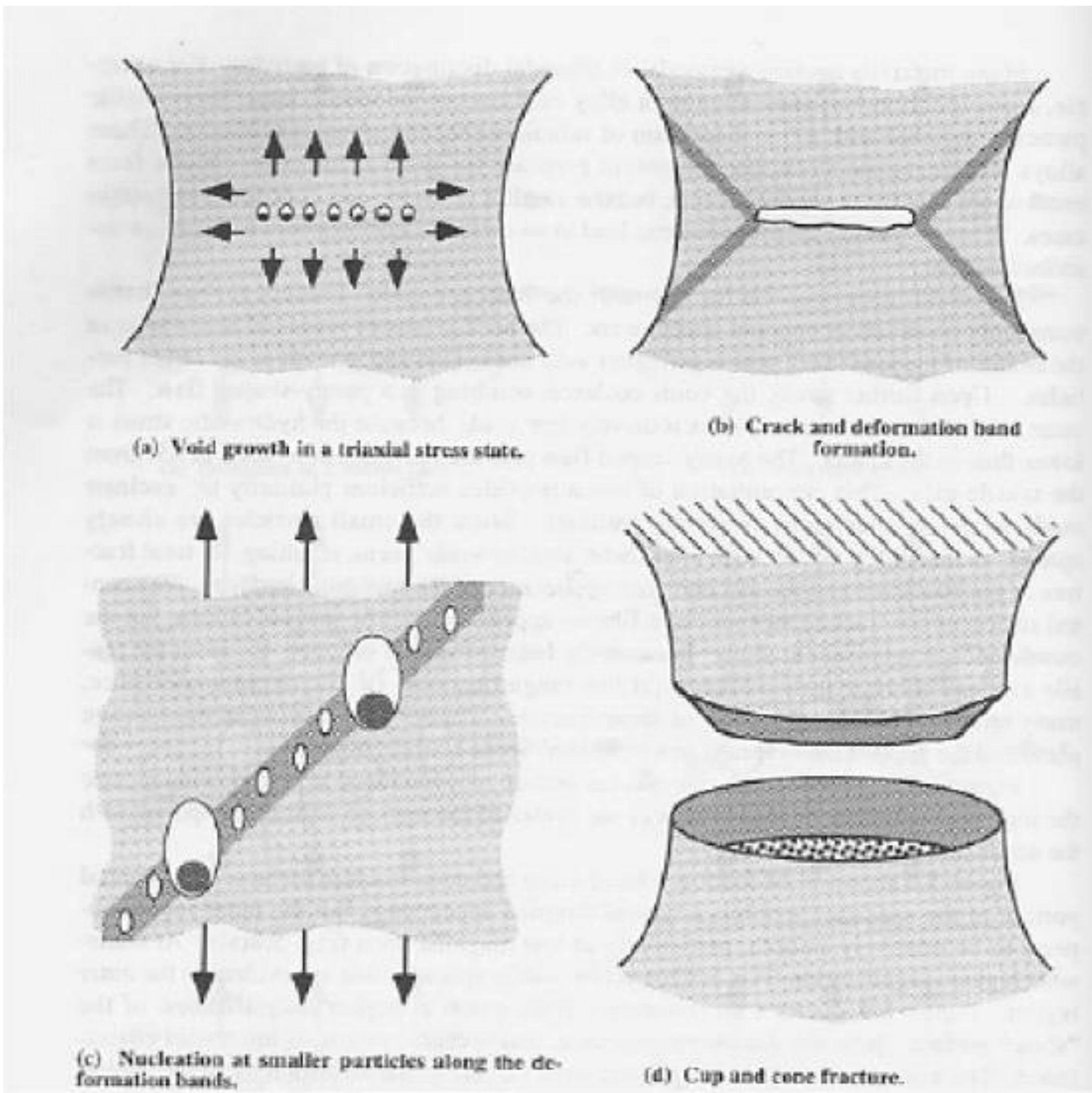


Figure 2 : Micro inter-granular void nucleation to failure process (Anderson, 1995)

At ambient temperature, fracture occurs in a brittle manner. The fine microscopic cracks grow into multiple macroscopic cracks which propagate in the direction parallel to the stress axis. At elevated temperatures, the fracture surface contains both trans granular and inter-granular failure. The quality of alloy (aluminium) that is tested will determine the results obtained. Ultimately, the dominant failure process is due to the bimodal failure of both trans granular and inter-granular failure in which is more susceptible at high temperature.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The course of this research will take about two semesters for completion; the first semester will be focusing mostly on literature review and basic knowledge of fatigue study and aluminium properties as a whole. Meanwhile, the second semester, the appropriate experiment will be conducted which is the fatigue testing in Structural Mechanics Laboratory, using Universal Testing Machine (Instron 8802).

3.2 Specimen preparation

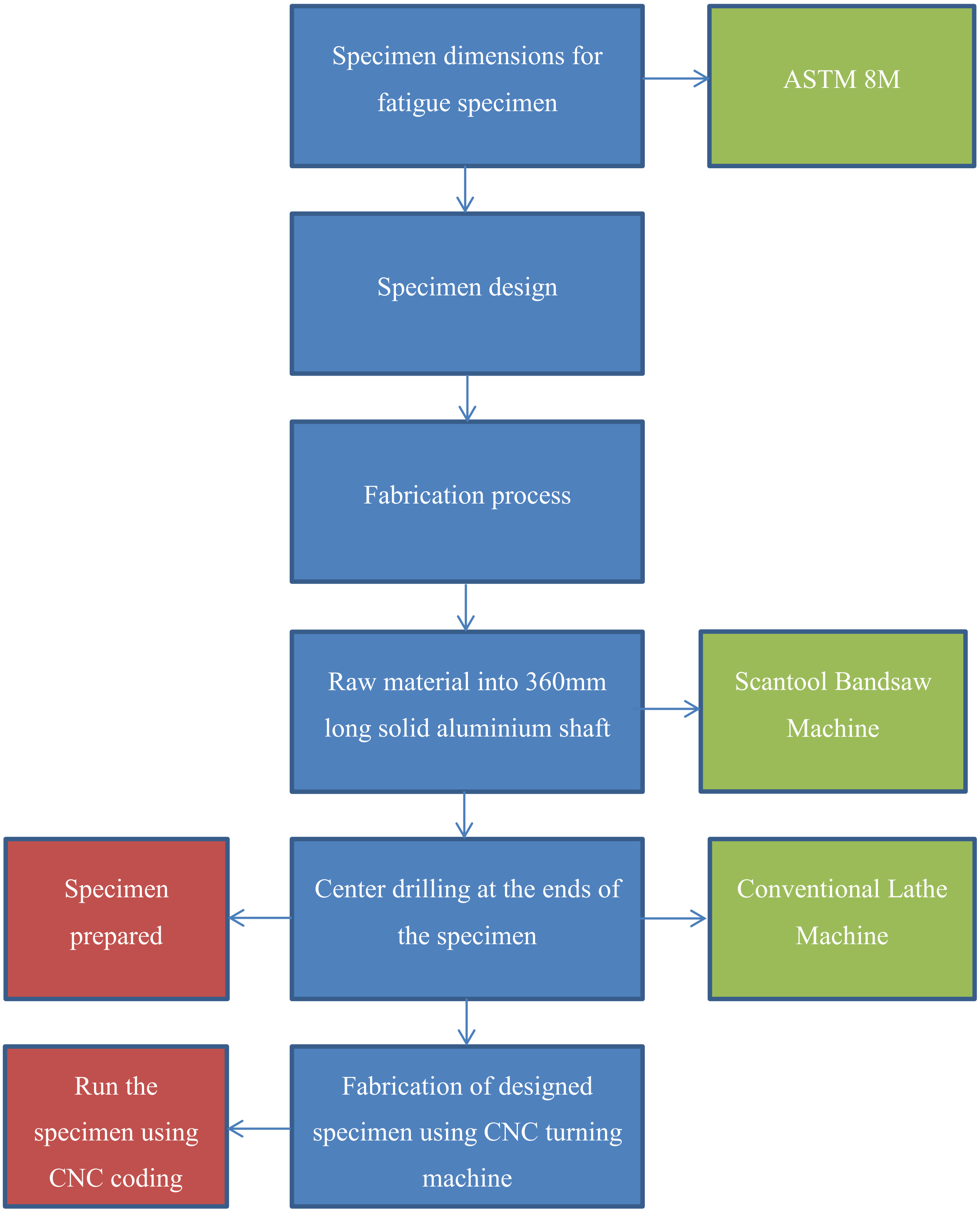


Figure 3 : Flow of specimen preparation

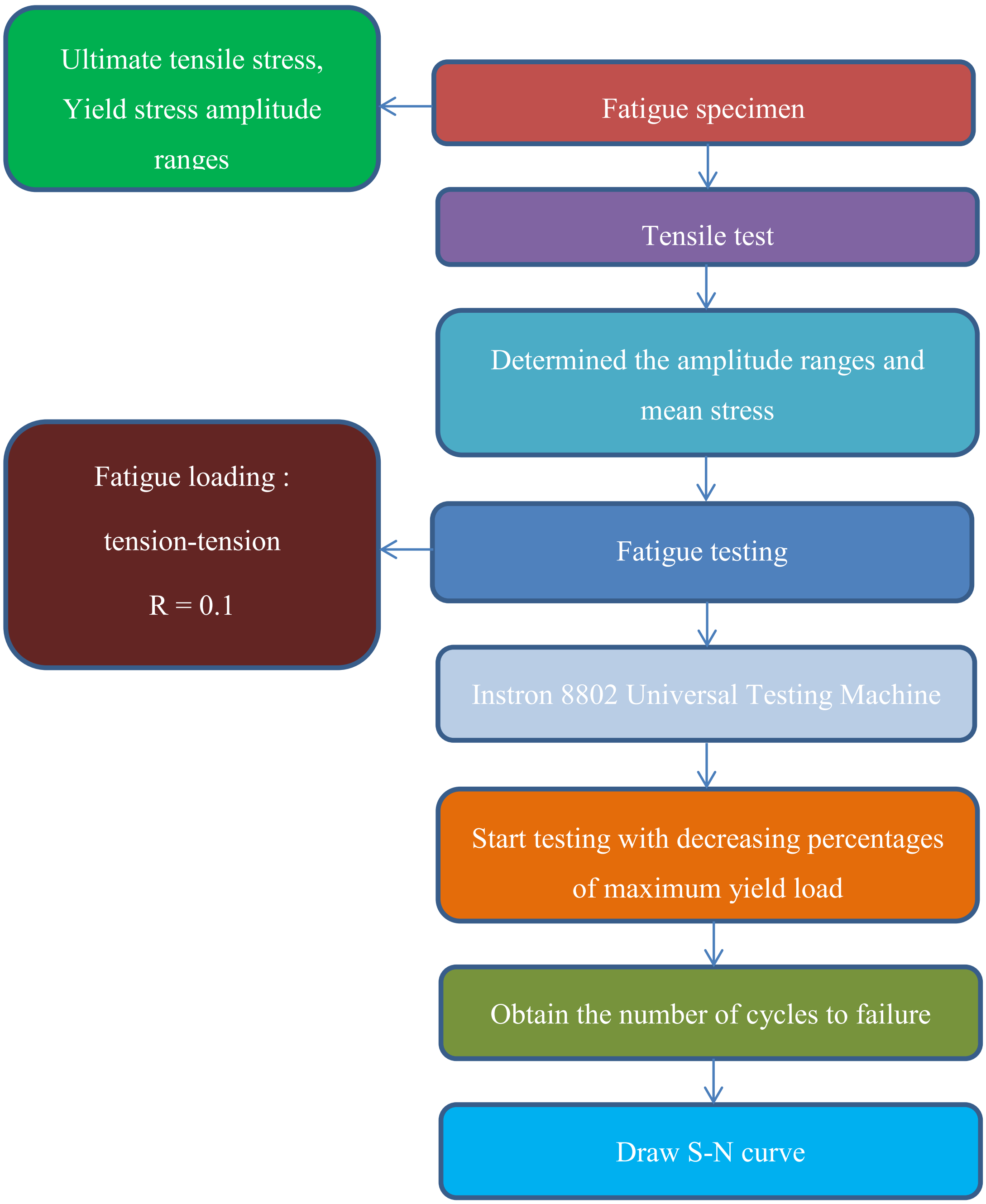


Figure 4 : Fatigue testing flow

3.3 Material specification

Fatigue material : Aluminium alloy

Grade designation : AA6061-T6

Chemical composition : 95.8% Al, 0.35% Cr, 0.4% Cu, 0.7% Fe, 1.4% Mg, 0.15% Mn, 0.4% Si, 0.15% Ti, 0.25% Zn.

Tensile strength : 45000 psi (310 MPa)

Yield strength : 40000 psi (276 MPa)

Elongation : 12-17%

3.4 Specimen designs and requirement

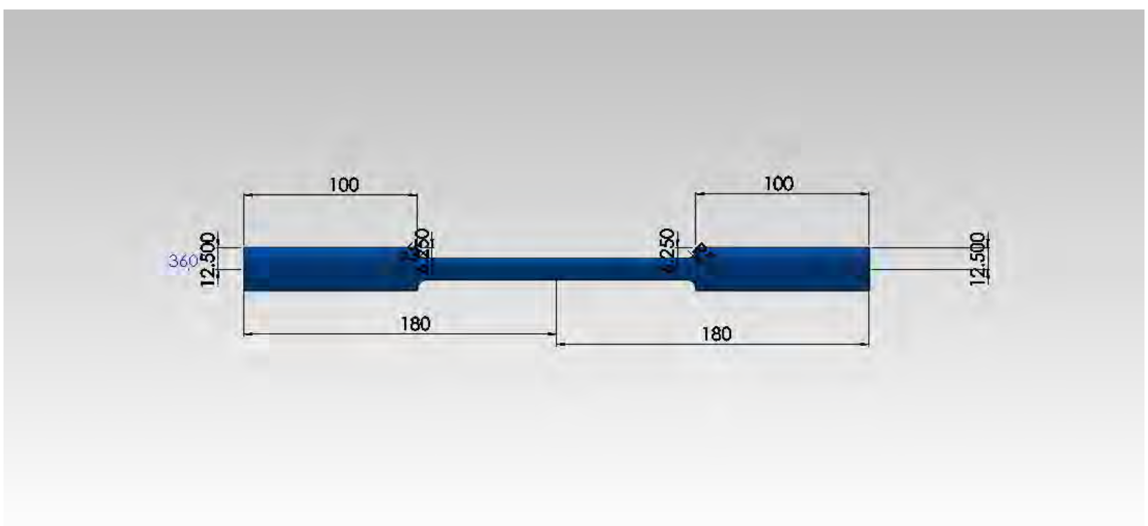


Figure 5 : Dog bone specimen design according to ASTM E8 standards