Comparison Dogbone and Rectangular Specimen for Tensile Test Mechanical Properties Using Steel Plate Cold Rolled Commercial (SPCC)

Saiful Din Sabdin[1*], Mohd Aidil Shah Abdul Rahim [2], Mohd Khairul Nizam Ab Ghani[3]
[1,3] Department of Metal Fabrication Structure (Oil & Gas), ADTEC JTM Kampus Tangkak, [2] Department of Metal Fabrication Structure (Oil & Gas), Proton Advance Automotive Technology Institute (ADTEC Melaka).
*Corresponding author's email: saifulkdh@yahoo.com

Abstract: Tensile testing is a fundamental method for evaluating the mechanical properties of materials under uniaxial tension. The standard tensile test specimen, also often referred to as the dogbone specimen due to its shape with a narrowed gauge section and enlarged ends is designed to produce uniform stress distribution and ensure deformation and fracture occur within the gauge section. This configuration is preferred in standards such as ASTM E8/E8M for determining tensile strength, yield strength, and modulus of elasticity, which are considered true representations of a material's intrinsic properties. An alternative geometry, the rectangular specimen, features a uniform cross-section and is occasionally used for practical purposes, particularly in educational or resource-limited settings. While easier to prepare, the rectangular shape does not control stress distribution as effectively as the dogbone, and this can lead to premature failure near the grips or overestimation of strength. This study compares the tensile behavior of dogbone and rectangular specimens made from Cold Rolled Commercial (SPCC) steel plates of varying thicknesses. Testing is conducted using a Universal Tensile Testing Machine (UTM), and the results are analyzed to evaluate how closely the rectangular specimen approximates the mechanical properties obtained from the standard geometry. The objective is not to challenge the standard, but to explore whether rectangular specimens can offer sufficiently reliable data for non-critical applications. This study highlights the trade-offs between geometric precision and preparation efficiency, acknowledging the limitations introduced by simplified specimen designs.

Keywords: *Tensile Test, Dogbone , Rectangular*

1.0 INTRODUCTION

Industries such as automotive, aerospace, and construction rely heavily on tensile testing data to ensure that materials meet design and safety requirements. Understanding the mechanical behavior of metallic materials under tensile loading is vital in the field of materials science and structural engineering (Nurisna and Anggoro 2024). Tensile testing, a widely recognized and standardized method, enables the determination of key mechanical parameters including ultimate tensile strength (UTS), yield strength, Young's modulus, and ductility all of which are fundamental to assessing material suitability for various industrial applications (Sabdin et al., 2019). This study focuses on the comparative analysis of two common specimen geometries used in tensile testing: the Dogbone specimen and the rectangular strip specimen. While the Dogbone specimen is engineered with a reduced cross-section to ensure failure occurs within the gauge length, the rectangular specimen maintains uniformity throughout its length, offering potential benefits in ease of preparation and alignment. Using Cold Rolled Commercial Steel (SPCC) as the base material, specimens were prepared and tested in accordance with ASTM E8M-09 standards. The SPCC material served as a consistent base across all specimens and was used as a reference to compare the tensile response of both dogbone and rectangular specimen geometries. By maintaining the same material and varying only the specimen shape and thickness, the study aims to isolate the influence of geometry on the mechanical properties obtained. This approach provides a clear comparative guide for evaluating the suitability of rectangular specimens as alternatives to the standard dogbone shape, particularly in non-critical testing applications.

The tensile tests were performed using a universal testing machine, and data such as load, elongation, and cross-sectional area were recorded for stress-strain analysis. The objective is to evaluate which specimen geometry yields more consistent and representative mechanical properties of SPCC steel. Ultimately, this research provides insight into the influence of specimen geometry on tensile test results and highlights considerations for selecting appropriate test configurations in both academic studies and industrial quality control practices. However, the preparation of dogbone specimens typically requires precision machining, contour cutting, and dimensional accuracy, which can be time-consuming and resource intensive. In contexts such as educational institutions, initial screening, or facilities with limited machining capability, this becomes a practical challenge. As a result, rectangular specimens which are simpler to fabricate using straight cuts and require less preparation time are sometimes considered as a practical alternative. Although they do not provide the same stress distribution control as dogbone specimens, they may still be viable for non-critical testing. This study examines whether rectangular specimens can provide tensile test results that are reasonably close to those obtained using standard dogbone specimens, while acknowledging the inherent limitations introduced by their geometry.

2.0 LITERATURE REVIEWS

Several studies have investigated the impact of specimen geometry on tensile testing outcomes. For instance, Baba et al. (2023) demonstrated that dogbone specimens provide more consistent fracture locations within the gauge section compared to rectangular specimens, which often experience premature failure near the grips. Other researchers Faidallah et al (2023) found that rectangular specimens may yield slightly higher tensile strength values due to non-uniform stress distribution. These findings highlight the importance of specimen design in ensuring accurate and representative mechanical property data.

These studies underscore the widespread use of tensile testing particularly with dogbone specimens to evaluate and validate the mechanical integrity of welded or fabricated components under various conditions. Dak et al. (2025) investigated the tensile performance of P92/304L dissimilar weld joints at temperatures from 450 to 850 °C. The study showed that both ultimate tensile strength and yield strength decreased significantly as temperature increased, indicating reduced mechanical performance at higher temperatures. Essa et al. (2025) found that using an eccentric shoulder tool at 0° tilt in FSW of AA6082-T6 gave the highest tensile strength (216.5 MPa) and finest grain size, showing better weld quality than the aligned tool. Drastiawati et al. (2025) found that lower heat input in GMAW (0.60 kJ/mm) at 10 L/min gas flow produced higher tensile strength (469.07 MPa) on SS400 steel compared to higher heat input (0.83 kJ/mm) at 15 L/min, supporting energy-efficient welding for sustainability. Nunes et al. (2025) optimized GMAW for welding additively manufactured aluminium alloys, finding that using ER5356 filler, pure argon gas, and laser cleaning reduced porosity and improved weld quality especially for PBF-LB parts prone to oxidation. de Lima et al. (2025) studied WAAM of 316L-Si stainless steel using GMAW-CCC and found that vertically built specimens had higher tensile strength (734 MPa) but lower elongation than horizontal ones (606 MPa), showing anisotropic mechanical behavior due to build direction and microstructure variation.

Sancar and Sarikavak (2025) found that arc voltage most affects weld quality in 10 mm dissimilar steel sheets, and tempering improves joint ductility. Liu et al. (2025) found that the arrangement and thickness of sheets in three-layer clinched joints affect tensile shear strength, with thicker top sheets and certain configurations giving the best results. Mancini et al. (2025) confirmed that including weld induced curvature in models improves accuracy of stress predictions in thin welded strip plates, reducing error from 25% to 8%. Shazly et al. (2025) validated solid state welding of 4-inch pipes using simulations and Dogbone tensile tests. The welded joints withstood high pressures (490 bar) and loads above yield strength, showing strong, sustainable performance for pipelines. Bouha et al. (2025) used friction stir welding to repair defective polyethylene pipes and evaluated the mechanical strength using tensile tests on Dogbone specimens, showing effective restoration of pipe strength for maintenance. Many researchers have used these types of tests to validate their findings.

The tensile testing was carried out by applying longitudinal or axial load at a specific extension rate to a standard tensile specimen with known dimensions (gauge length and cross-sectional area perpendicular to the load direction) till failure (Ramadhani and Ridwan 2025). The applied tensile load and extension are recorded during the test for the calculation of stress and strain (Saputri et al., 2025). A range of universal standards provided by professional societies such as American Society of Testing and Materials (ASTM), British standard, JIS standard and DIN standard are selected based on preferential uses. Each standard may contain a variety of test standards suitable for different materials, dimensions and fabrication history.

This has led to a research gap in understanding the extent to which simplified geometries can replicate the mechanical performance of standardized specimens. Recent studies have begun to explore this issue by comparing tensile results from rectangular specimens to dogbone counterparts, particularly in contexts where rapid testing, resource constraints, or educational purposes justify the use of non-standard shapes. However, the lack of comprehensive data on their limitations, variability, and applicability in engineering practice suggests that further investigation is warranted. Addressing this gap can provide valuable insights for situations where standard specimens are impractical, and help establish guidelines for the responsible use of alternative geometries in tensile testing.

Based on previous studies and literature reviews, there are two types of preparations in tensile strength measuring. Experiments were carried out and subjected to an external tensile loading where the sample will undergo elastic and plastic deformation. Initially, the metal will elastically deform giving a linear relationship of load and extension. These two parameters are then used for the calculation of the engineering stress and engineering strain to give a relationship as illustrated using Equation (1) and Equation (2) as follows: where, σ is the tensile strength in MPa, F is the maximum load and A is the cross-section area.

$$\sigma = \frac{F}{A} \tag{1}$$

$$\varepsilon = \frac{\Delta L}{L_0} = \frac{L - L_0}{L_0} \tag{2}$$

Where, E is strain in MPa, L is final length in mm and L_0 is initial gauge length. During elastic deformation, the engineering stress-strain relationship follows the Hook's law and the slope of the curve indicates the Young's modulus. Young's modulus is of importance where deflection of materials is critical for the required engineering applications. Where, E is Young's modulus. Tensile ductility of the specimen can be represented as % elongation or % reduction in area as expressed in the equations (3),(4) & (5) given below.

$$E = \frac{\sigma}{\varepsilon} \tag{3}$$

$$\%\ \text{Elongation} = \frac{\Delta L}{L_0} \times 100 \tag{4}$$

$$\%\ \text{RA} = \frac{A_0 - A_f}{A_0} \times 100 = \frac{\Delta A}{A_0} \times 100 \tag{5}$$

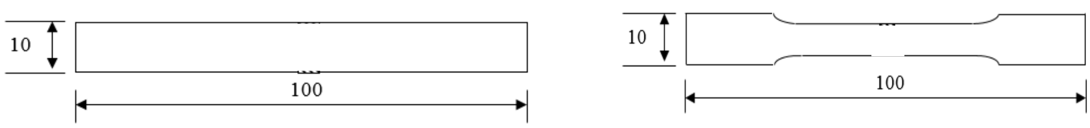
Where A_f is the cross-sectional area of specimen at fracture. The fracture strain of the specimen can be obtained by drawing a straight line starting at the fracture point of the stress-strain curve parallel to the slope in the linear relation. The interception of the parallel line at the x axis indicates the fracture strain of the specimen being tested.

3.0 METHODOLOGY

The experiments were carried out using the specific ASTM standard used E8/E8M-09 in dimension (mm) for dogbone specimens and the information gathered from the literature Kumar et al., (2025) & Terry et al., 2025). Rectangular specimen its dimensions as per ASTM E8/E8M-09 according to uniform cross section prepared to similar standard in figure 1. Based on experimental findings in this study, random selection of the plate thickness was made. Material properties cold rolled is illustrated in Table 1 according to automotive body structure application. The experiment is organized by nine specimens from both types with three types of thickness 0.5, 0.8, 1.0 mm without welded and purely base metal.

Table 1: Material specification

Material (SPCC)	Commercial quality
Tensile strength	262 -344.74 MPa
Yield strength	172.36 -241.32 Mpa
Elongation	35-42
reduction of area	58 %



a) Rectangular b) Dogbone

***Figure 1** Tensile specimen rectangular and Dogbone sample according to ASTM E8M-09 in dimension (mm) (Cao et al., 2013)*

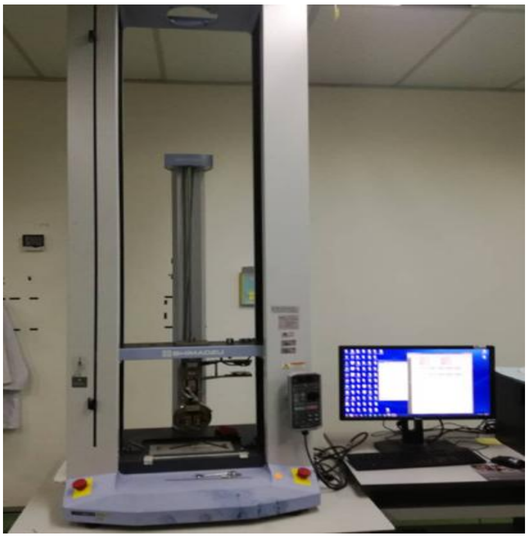


Figure 2 *Tensile strength Shimadzu 20N (source: UTeM Melaka)*

4.0 DATA ANALYSIS AND FINDINGS

Table 2 present the tensile strength results for two types of specimens: dogbone and rectangular (strip), both made from cold-rolled thin steel plates. The tests aim to evaluate the influence of specimen geometry on the tensile performance before proceeding to welded specimen analysis. The tensile strength values range between 303.34 MPa and 342.708 MPa for dogbone specimens, and 323.438 MPa to 341.875 MPa for rectangular specimens. This falls within the typical tensile strength range (262–344.74 MPa) provided for cold-rolled steel sheets, indicating consistency in material performance.

Table 2: Results of tensile strength

No. of sample	Comparison			
	Dogbone	Tensile Strength (MPa)	Rectangular	Tensile Strength (MPa)
1	0.5A	313.542	0.5AR	326.25
2	0.5B	342.708	0.5BR	336.875
3	0.5C	340.792	0.5CR	341.875
4	0.8A	305.339	0.8AR	324.609
5	0.8B	303.34	0.8BR	323.438
6	0.8C	309.245	0.8CR	335.547
7	1.0A	318.75	1AR	335.124
8	1.0B	314.583	1BR	333.125
9	1.0C	316.042	1CR	340.625

The tensile test results show that rectangular specimens consistently exhibit higher tensile strength compared to dogbone specimens across all thicknesses (0.5 mm, 0.8 mm, and 1.0 mm). This suggests that specimen geometry significantly affects the mechanical performance, with rectangular types providing a more uniform stress distribution during testing. A clear trend is observed where rectangular specimens consistently demonstrate higher tensile strength than the corresponding dogbone specimens across all thicknesses (0.5 mm, 0.8 mm, and 1.0 mm). This suggests that the rectangular geometry may better preserve material integrity under tensile loading, potentially due to reduced stress concentration compared to the narrowed section in dogbone samples.

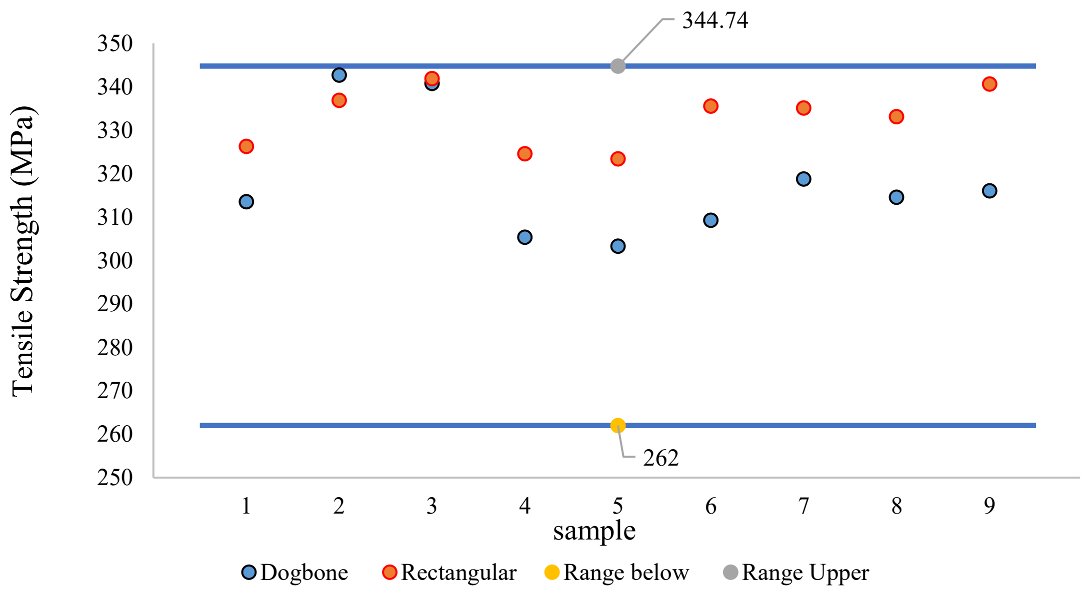


***Figure 3** Range of measured Tensile strengths*

The data shows a clear overall trend where rectangular specimens consistently have higher tensile strength averages than dogbone specimens across all tested thicknesses. This highlights how the specimen geometry significantly influences how stress is distributed during tensile testing, ultimately affecting failure behaviour and measured strength. At the thinner 0.5 mm thickness, the difference between dogbone and rectangular specimens is quite small, only about 0.79%, indicating that when the material is thin, the shape of the specimen does not greatly impact the tensile strength results. This might be because thinner samples experience less severe stress concentrations or localized deformation during testing.

However, for the thicker samples of 0.8 mm and 1.0 mm, the rectangular specimens show a much higher tensile strength 7.15% and 6.26% greater, respectively, compared to dogbone specimens. This suggests that as thickness increases, the dogbone shape tends to promote necking or localized stress concentration, which reduces the apparent tensile strength. In contrast, the rectangular specimens provide a more uniform stress distribution across the sample, leading to a more accurate and higher tensile strength measurement in table 3.

Table 3: Average Results tensile strength

Thickness (mm)	Dogbone Average (Mpa)	Rectangular Average (Mpa)
0.5	332.35	334.99
0.8	305.98	327.86
1.0	316.46	336.29

5.0 DISCUSSION AND CONCLUSIONS

This study presents a comparative analysis of tensile strength, yield strength, and elongation for two specimen geometries dogbone and rectangular tested on SPCC steel at three thicknesses: 0.5 mm, 0.8 mm, and 1.0 mm. The findings reveal how geometry influences tensile testing outcomes.

a) Tensile Strength Comparison

Rectangular specimens exhibited higher average tensile strength values across all thicknesses. While the difference was minimal at 0.5 mm (+0.79%), it increased to 7.15% and 6.26% at 0.8 mm and 1.0 mm, respectively. However, this increase is likely due to stress concentration near the grips and the absence of controlled deformation, rather than representing true material strength.

b) Yield Strength and Elongation

Both geometries produced yield strength and elongation values within acceptable limits for SPCC steel. Although results from rectangular specimens appeared more consistent in some cases, they must be interpreted cautiously due to non-standard stress distribution.

c) Specification Compliance

All tensile strength values remained within the specified range for SPCC steel, confirming material compliance regardless of specimen geometry.

It is important to emphasize that the dogbone specimen is standardized not by convenience but by design specifically to yield tensile strength and modulus of elasticity values that reflect true material behaviour. The narrowed gauge section localizes deformation and ensures that failure occurs away from grips, minimizing external influences on the test result. This study does not challenge the validity of the standard but instead evaluates whether rectangular specimens can provide practical approximations in settings where standard preparation is impractical. While rectangular specimens offer efficiency in preparation and show reasonably consistent results, they should not be used as substitutes for dogbone specimens in critical applications or where precision and standard compliance are required. Their use is best limited to educational, preliminary, or screening purposes, and always with full awareness of their geometric limitations.

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