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Effects of manufacturing processes on the metallurgical and mechanical properties of mild steel fabricated components and equipment

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Abstract

The mechanical performance and structural integrity of mild steel components are strongly influenced by the thermal and mechanical conditions experienced during manufacturing. A comprehensive understanding of how elevated temperatures and production processes affect the metallurgical and mechanical properties of mild steel is therefore essential for the accurate design and safe operation of engineering components and equipment. In engineering practice, designers frequently rely on material property data obtained from design handbooks or standards, which are typically determined under ambient laboratory conditions. However, these properties may change significantly after exposure to the thermal cycles associated with manufacturing processes such as machining, flame cutting, welding, and forming. Consequently, the use of unmodified room-temperature material properties in design calculations may introduce inaccuracies that compromise structural reliability and increase the risk of premature component failure.

To investigate these effects, mild steel specimens obtained from the original material used in the fabrication of engineering equipment were subjected to comprehensive metallurgical and mechanical characterization. Corresponding specimens extracted from the fabricated equipment were evaluated using the same standardized testing procedures and laboratory facilities. Comparative analyses were performed using chemical composition analysis, optical microscopy, scanning electron microscopy (SEM), Vickers hardness testing, tensile testing, and wear testing to assess the influence of the manufacturing processes on the material properties.

The experimental results revealed measurable changes in both the chemical composition and micro-structure of the fabricated material. A slight increase in carbon content was observed after fabrication, accompanied by a corresponding increase in hardness. The SEM and optical microscopy examinations confirmed significant microstructural modifications resulting from the thermal cycles experienced during production. Mechanical testing further showed that the manufacturing processes caused a considerable reduction in the ultimate tensile strength of the fabricated material. In contrast, the wear behaviour improved, with the fabricated material exhibiting a lower specific wear rate than the parent material, indicating enhanced wear resistance as a consequence of the increased hardness.

Overall, the findings demonstrate that manufacturing processes can substantially alter the metallurgical characteristics and mechanical performance of mild steel fabricated components. These changes should be carefully considered during engineering design and material selection to ensure that the material properties used in structural analysis accurately represent the condition of the fabricated component. Incorporating manufacturing-induced property variations into design calculations will improve prediction accuracy, enhance structural reliability, and reduce the likelihood of premature failure during service.

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Keywords: Mild steel; Manufacturing processes; Metallurgical properties; Mechanical properties; Welding; Heat treatment; Micro-structure; Scanning Electron Microscopy.

1. Introduction

A thorough understanding of the metallurgical and mechanical changes that occur during manufacturing and fabrication processes is essential for the design, production, and long-term reliability of engineering components and equipment. Throughout fabrication, metallic materials are subjected to various thermal and mechanical operations, including machining, flame cutting, welding, forming, and heat treatment. These processes can significantly alter the micro-structure and mechanical properties of the material, thereby influencing its structural integrity, failure mechanisms, and service life. Consequently, designers and fabricators must consider the effects of manufacturing-induced material changes during design and material selection to minimize the risk of premature component failure and ensure safe operation [1].

The metallurgical condition of a metal including its chemical composition, inclusion content, grain structure, segregation, residual stresses, and degree of cold work plays a critical role in determining its corrosion behaviour and mechanical performance [2,9,10]. These metallurgical characteristics directly influence important engineering properties such as strength, ductility, toughness, hardness, fatigue resistance, and fracture behaviour, all of which are key factors in the selection of materials for engineering applications.

Material selection is one of the most important stages in engineering design because it determines the ability of a component to withstand the operational loads and environmental conditions encountered during service. In many applications, achieving adequate fracture resistance requires selecting materials with high ductility and tolerance to manufacturing defects, thereby reducing the likelihood of brittle fracture [3,11]. However, increasing ductility is often accompanied by reductions in hardness, wear resistance, and yield strength. To overcome this limitation, surface engineering techniques such as carburizing, nitriding, induction hardening, and other case-hardening processes are frequently employed to improve surface hardness and wear resistance while maintaining a ductile core [4,6].

The selection of metallic materials therefore requires careful consideration of numerous mechanical and physical properties, including tensile strength, yield strength, modulus of elasticity, ductility, fatigue strength, fracture toughness, hardness, shear strength, machinability, coefficient of friction, impact strength, corrosion resistance, density, coefficient of thermal expansion, thermal conductivity, and electrical resistivity [1,3,5]. The relative importance of these properties depends on the intended service conditions and functional requirements of the component.

The physical, electrical, magnetic, and structural properties of metals are highly dependent on temperature. Exposure to elevated temperatures during manufacturing or service may induce significant micro-structural transformations that alter the engineering performance of the material [5]. Consequently, heat treatment has become an important manufacturing process for modifying material properties to satisfy specific engineering requirements. For structural applications, high strength and toughness are generally desirable, whereas electrical applications often require low electrical resistivity and high electrical conductivity. The thermal history experienced by a material therefore determines its suitability for a particular engineering application [5,6].

When metals are heated, thermal energy increases atomic vibration, causing expansion of the crystal lattice. This phenomenon, known as thermal expansion, results in increases in the length, surface area, and volume of the material. Since different metals possess different coefficients of thermal expansion, engineers must account for these dimensional changes during component design to prevent excessive thermal stresses, distortion, or structural failure. Typical examples include pipelines, pressure vessels, bridges, and railway tracks, where thermal expansion and contraction must be accommodated throughout the service life of the structure [5,7,12].

Heating also causes changes in the crystal structure of many metals through allotropic phase transformations. These transformations occur when atoms rearrange into different crystallographic structures under specific temperature conditions, producing corresponding changes in mechanical properties. Iron exhibits one of the most significant allotropic transformations among engineering metals. At elevated temperatures, iron changes from ferrite to austenite, allowing increased carbon solubility within the crystal lattice. Subsequent cooling transforms the austenite into various microstructural constituents such as ferrite, pearlite, bainite, or martensite, depending on the cooling rate. These transformations strongly influence hardness, strength, ductility, toughness, and wear resistance, and they form the metallurgical basis of many industrial heat-treatment processes used for steels [7,8,13].

In the present study, the effects of manufacturing processes on the metallurgical and mechanical properties of mild steel fabricated components were investigated experimentally. Mild steel specimens obtained from the original stock material and from the finished fabricated equipment were subjected to comprehensive chemical, metallurgical, and mechanical characterization using standard laboratory procedures and testing equipment. For ease of identification, specimens taken from the original mild steel stock were designated **Sample A**, while specimens extracted from the fabricated equipment were designated **Sample B.** Comparative analyses of the two specimen groups were conducted using chemical composition analysis, optical microscopy, scanning electron microscopy (SEM), Vickers hardness testing, tensile testing, and wear testing to evaluate the influence of manufacturing processes on the micro-structure and engineering properties of the fabricated material.

2. Material and method

2.1. Materials

2.1.1. Specimens

The specimens used in this study were prepared in accordance with the applicable international testing standards and the specific requirements of the various testing equipment employed at the respective laboratories where the experiments were conducted. The dimensions, geometry, and preparation procedures of the specimens varied depending on the type of mechanical or metallurgical test performed and the operational specifications of the corresponding test equipment. Appropriate specimen preparation techniques were adopted to ensure consistency, accuracy, and reliability of the experimental results.

2.1.2. Equipment

The experimental investigation was conducted using standard laboratory equipment for metallurgical characterization and mechanical property evaluation. An optical microscope was employed for low-magnification examination of the specimens to observe the general microstructural features, while a scanning electron microscope (SEM) was used for high-resolution imaging and detailed microstructural analysis.

The chemical composition of the specimens was determined using an argon emission spectrometer, which enabled the identification and quantification of the elemental constituents of the mild steel samples. Surface hardness measurements were performed using a Vickers hardness testing machine in accordance with the applicable testing standards.

Tensile tests were conducted using an **Instron 3369R Universal Testing Machine** equipped with an electromechanical load sensor capable of accurately controlling the tensile strain within the active gauge length of the specimens under a maximum load capacity of **10 kN**. The machine was used to determine the tensile strength and deformation characteristics of the test specimens.

The wear behaviour of the specimens was evaluated using a wear testing machine operating under controlled test conditions to determine the wear characteristics and compare the wear resistance of the parent material with that of the fabricated component.

2.2. Method

2.2.1. Optical microscopy

Optical microscopy was performed on both Sample A and Sample B at a magnification of **600×** to examine and compare their microstructural characteristics. This technique was employed to evaluate the effects of the manufacturing processes on the metallurgical structure of the mild steel specimens. Optical microscopy is a widely used metallographic characterization method that provides valuable information on grain morphology, grain size, phase distribution, inclusion content, and other microstructural features that influence the mechanical behaviour of engineering materials.

Prior to microscopic examination, the specimens were prepared following standard metallographic procedures. Each specimen was sequentially ground using silicon carbide abrasive papers with grit sizes of **240, 320, 400, and 600** to remove surface irregularities and obtain a smooth finish. The ground specimens were subsequently polished using diamond polishing suspensions with particle sizes of **1.0 µm** and **0.5 µm** to produce a mirror-like surface suitable for metallographic analysis.

The polished specimens were chemically etched with **2% Nital** (2% nitric acid in ethanol) to reveal the micro-structure and grain boundaries. The etched specimens were then examined using a metallurgical optical microscope, and representative micrographs were captured for comparative analysis of the parent material (Sample A) and the fabricated component (Sample B).

2.2.2. Scanning Electron Microscopy (SEM)

Scanning Electron Microscopy (SEM) was employed to investigate the microstructural characteristics of both Sample A and Sample B at high magnifications ranging from **7,000× to 9,000×**. The primary objective of the SEM analysis was to examine the detailed surface morphology and microstructural features of the specimens and to assess the effects of the manufacturing processes on the fabricated mild steel components. The high-resolution imaging capability of SEM enabled the observation of fine structural details that could not be adequately resolved using optical microscopy.

Prior to examination, the specimens were prepared in accordance with standard metallographic procedures to obtain clean, smooth surfaces suitable for SEM analysis. The prepared samples were mounted and examined using the scanning electron microscope under appropriate operating conditions, and representative micrographs were acquired for comparative evaluation of the parent material (Sample A) and the fabricated component (Sample B). The SEM images were subsequently analyzed to identify microstructural modifications induced by the production processes and to correlate these changes with the observed mechanical properties.

2.2.3. Chemical composition analysis

Chemical composition analysis was conducted using an argon emission spectrometer to determine the elemental composition of both the parent mild steel (Sample A) and the fabricated component (Sample B). The objective of the analysis was to identify any compositional changes that may have occurred as a result of the manufacturing and fabrication processes.

The measured chemical compositions of the two samples were compared with the standard chemical composition of AISI 1020 mild steel to verify the material grade and evaluate the influence of the production processes on the fabricated component. Particular attention was given to variations in the concentrations of key alloying elements, including carbon, manganese, silicon, and aluminium, as these elements have a significant influence on the metallurgical characteristics and mechanical performance of mild steel.

The comparative analysis provided an assessment of whether the thermal and mechanical processes involved in fabrication produced measurable changes in the chemical composition of the finished component relative to the original parent material used in its construction.

2.2.4. Vickers hardness test

Vickers hardness testing was performed on both the parent material (Sample A) and the fabricated component (Sample B) to evaluate the influence of the manufacturing and thermal processing on the hardness characteristics of the mild steel. The test was conducted to determine whether the thermal cycles and fabrication processes, such as welding, flame cutting, and associated heat treatment effects, resulted in significant changes in the surface hardness of the material.

Prior to testing, the specimens were prepared according to standard metallographic procedures. Each specimen was cut to the required dimensions and its surface was ground and polished using a rotary grinding and polishing machine to obtain a smooth, flat finish suitable for accurate indentation measurements. The prepared specimens were then mounted on the Vickers hardness testing machine, where hardness measurements were obtained under controlled loading conditions in accordance with the relevant international testing standards. The measured hardness values were subsequently compared to assess the effects of the production processes on the mechanical properties of the fabricated material.

2.2.5. Tensile Test

Tensile testing was carried out on both the parent mild steel (Sample A) and the fabricated component (Sample B) using an **Instron® 3369 Universal Testing Machine** to evaluate the effects of the manufacturing processes on the tensile properties of the material. The primary objective of the test was to determine the extent to which the thermal cycles and fabrication processes, including welding and flame cutting, influenced the tensile strength and deformation behaviour of the mild steel.

The tensile specimens were prepared in accordance with the applicable testing standards, with nominal dimensions of **55 mm gauge length, 5 mm width, and 3 mm thickness**. Prior to testing, the specimens were machined to the required dimensions to ensure consistency and accuracy of the experimental results.

The tests were performed using the Instron® 3369 testing machine equipped with an electromechanical load sensor capable of accurately controlling the tensile strain within the gauge section of the specimen under a maximum load capacity of **10 kN**. During testing, tensile load was applied continuously until specimen failure, and the corresponding stress-strain response was recorded. The resulting tensile properties of the parent material and the fabricated component were subsequently compared to evaluate the influence of the manufacturing processes on the mechanical performance of the mild steel.

Wear Test: Wear testing was conducted to evaluate the wear resistance of both the parent mild steel (Sample A) and the fabricated component (Sample B), with the aim of determining the influence of the manufacturing processes on the tribological behaviour of the material. Wear is the progressive loss of material from a solid surface resulting from mechanical interaction between contacting surfaces under relative motion, with the removed material forming wear debris.

Five test specimens were extracted from the original mild steel used in the fabrication of the equipment and designated as **A1, A2, A3, A4, and A5**. Each specimen was tested individually using a wear testing machine under a normal load of **10 N** over a sliding distance of **3 mm**. The wear test data obtained for each specimen were used to determine the corresponding specific wear rate, after which the average specific wear rate for Sample A was calculated.

Similarly, five specimens obtained from the fabricated equipment were designated as **B1, B2, B3, B4, and B5** and tested under the same operating conditions to ensure consistency and comparability of the experimental results. The measured wear data were used to calculate the specific wear rate of each specimen, and the average specific wear rate for Sample B was subsequently determined.

The wear performance of the parent material and the fabricated component was then compared to assess the effects of the manufacturing and thermal processing on the wear characteristics of the mild steel. The comparative analysis provided valuable insight into the relationship between fabrication-induced microstructural changes and the wear resistance of the material.

3. Results and discussion

The optical micrographs of the parent mild steel (Sample A) and the fabricated component (Sample B) are presented in **Figures 1** and **2**, respectively. The micrographs provide a comparative assessment of the microstructural features before and after the manufacturing processes, thereby illustrating the influence of fabrication on the phase distribution, grain morphology, and overall microstructure of the material. The observed microstructural changes are discussed in relation to the thermal history experienced during production and their implications for the mechanical performance of the fabricated component.

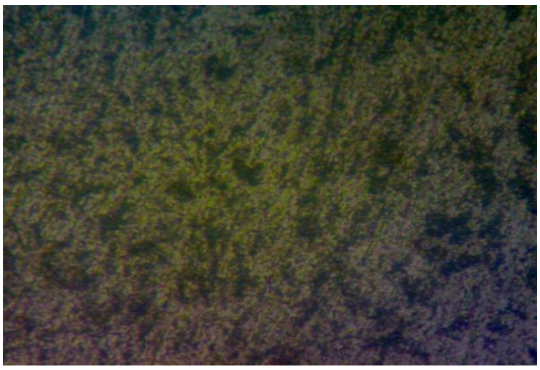

Figure 1 Optical Microscopy Image of Sample A

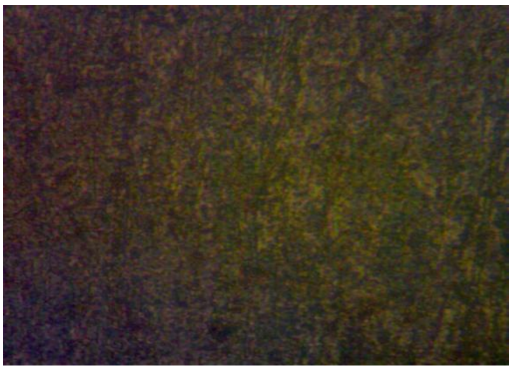

Figure 2 Optical Microscopy Image of Sample B

The optical micrograph of **Sample A** (parent material), examined at a magnification of **600×**, revealed a microstructure predominantly composed of coarse ferrite and acicular pearlite. The pearlite colonies were dispersed throughout the ferritic matrix, with ferrite constituting the dominant phase. The high volume fraction of ferrite relative to pearlite is characteristic of low-carbon mild steel and is indicative of enhanced ductility and good formability. The observed microstructure is consistent with the expected metallurgical structure of AISI 1020 mild steel in its as-received condition.

In contrast, the optical micrograph of **Sample B** (fabricated component), also obtained at a magnification of **600×**, exhibited significant microstructural modifications resulting from the thermal cycles associated with the manufacturing processes. The microstructure consisted of ferrite, martensitic regions, and interconnected creep cavities with well-defined grain boundaries. The presence of martensite suggests localized phase transformation caused by rapid heating and cooling during fabrication processes such as welding or flame cutting, while the observed creep cavities indicate the occurrence of microstructural degradation associated with thermal exposure. These changes demonstrate that the production processes altered the original microstructure of the parent material, leading to modifications in its mechanical behaviour and overall performance.

The SEM micrographs of the specimens acquired at a magnification of **9,000×** are presented in **Figures 3** and **4**. **Figure 3** shows the microstructure of the parent mild steel (Sample A), while **Figure 4** illustrates the microstructure of the fabricated component (Sample B). These high-magnification SEM images provide a detailed comparison of the surface morphology and microstructural features of the two specimens, enabling the assessment of the microstructural changes induced by the manufacturing and fabrication processes.

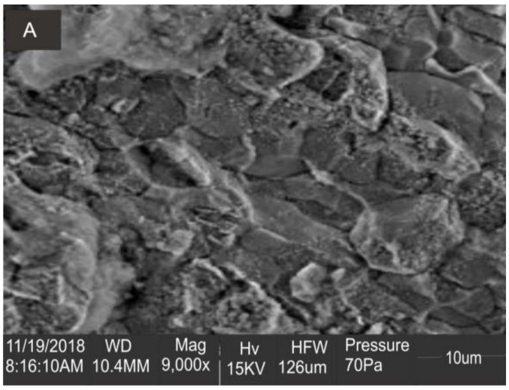

Figure 3 SEM Image from Sample A

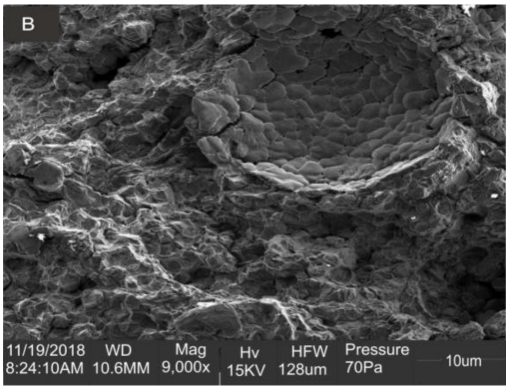

Figure 4 SEM Image from Sample B

The SEM micrograph of **Sample B** (Figure 4) reveals the formation of a finer-grained microstructure compared with the parent material. This grain refinement is attributed to the thermal cycles experienced during the manufacturing processes, including localized heating and subsequent cooling associated with fabrication operations. The observed reduction in grain size indicates that the production-induced heat treatment altered the original microstructure of the mild steel, which is expected to influence its mechanical properties, particularly hardness, strength, and wear resistance.

Chemical Analysis: The results of the chemical composition analysis, presented in table **1 and 2**, identified the material used for the fabrication of the equipment as **AISI 1020 mild steel**. Prior to this investigation, the exact material grade was unknown because the raw material had been procured from the open market without certified material documentation. The chemical analysis therefore served not only to verify the material grade but also to evaluate the influence of the manufacturing processes on the elemental composition of the fabricated component.

A comparison of the chemical compositions of the parent material (Sample A) and the fabricated component (Sample B) revealed slight variations in the concentrations of several alloying elements. Specifically, the carbon content increased from **0.0185 wt.%** in the parent material to **0.0294 wt.%** in the fabricated component, while the manganese content increased from **0.2372 wt.%** to **0.3227 wt.%**. Conversely, slight reductions were observed in the silicon and aluminium contents after fabrication.

These compositional variations are attributed to the thermal and metallurgical effects associated with the manufacturing processes, including welding, flame cutting, and other fabrication operations. Although the observed changes are relatively small, they are sufficient to influence the microstructural evolution of the material and may contribute to the changes observed in its hardness, tensile properties, and wear behaviour. The findings demonstrate that manufacturing processes can induce measurable modifications in the chemical composition and, consequently, the overall performance of fabricated mild steel components.

Table 1 Chemical composition of Sample A

	Fe	**C**	**Si**	**Mn**	**P**	**S**	**Cr**	**Ni**
	99.54	0.0185	0.0106	0.2372	<0.000	<0.000	<0.007	<0.005
Avg	99.52	0.0172	0.0151	0.2425	<0.000	<0.000	0.0098	0.0070
SD	0.0124	0.0023	0.0034	0.0050	0.0000	0.0000	0.0020	0.0027
	Mo	Cu	Al	Ti	V	Co	Nb	W
	<0.000	0.0165	0.0638	<0.000	<0.000	<0.000	<0.000	<0.000
Avg	<0.000	0.0183	0.0653	<0.000	<0.000	<0.000	<0.000	<0.000
SD	0.0000	0.0014	0.0027	0.0004	0.0000	0.0000	0.0000	0.0000
	Sn	C.E						
	<0.003	0.0628						
Avg	<0.002	0.0638						
SD	0.0013	0.0026						

Table 2 Chemical composition of Sample B

	Fe	**C**	**Si**	**Mn**	**P**	**S**	**Cr**	**Ni**
	99.47	0.0294	<0.000	0.3227	<0.000	<0.000	<0.004	<0.000
Avg	99.39	0.0584	0.0116	0.3322	<0.000	<0.000	0.0076	<0.000
SD	0.0177	0.0331	0.0021	0.0141	0.0000	0.0000	0.0048	0.0000
	Mo	Cu	Al	Ti	V	Co	Nb	W
	<0.000	0.0141	0.0424	<0.000	<0.001	<0.000	<0.000	<0.016
Avg	<0.000	0.0146	0.0468	<0.000	0.0036	<0.000	<0.000	<0.030
SD	0.0000	0.0010	0.0048	0.0006	0.0027	0.0000	0.0000	0.0438
	Sn	C.E						
	<0.000	0.0853						
Avg	<0.001	0.1189						
SD	0.0024	0.0366						

3.1.1. Vickers Hardness

Vickers hardness testing was performed on specimens obtained from both the parent mild steel (Sample A) and the fabricated component (Sample B) to evaluate the effect of the manufacturing processes on the hardness characteristics of the material. The hardness test results are presented in **Table 3**.

The results indicate a significant increase in the hardness of the fabricated component (Sample B) compared with that of the parent material (Sample A). This increase in hardness is attributed to the thermal and mechanical effects associated with the manufacturing processes employed during fabrication. In particular, repeated heating followed by relatively rapid cooling during operations such as welding and flame cutting likely promoted microstructural transformations, including the formation of harder phases and grain refinement.

The observed increase in hardness is consistent with the microstructural changes identified through optical microscopy and scanning electron microscopy, which revealed evidence of phase transformation and refined grain structures in the fabricated material. These findings suggest that the thermal history experienced during fabrication modified the original metallurgical structure of the mild steel, resulting in enhanced hardness. While increased hardness generally improves wear resistance, it may also influence other mechanical properties, such as ductility and tensile strength, as discussed in the subsequent sections.

Table 3 Vickers Hardness Test Values of Sample A and B

SAMPLES	TEST 1	TEST 2	TEST 3	AVERAGE
A	262.7	242.3	261.8	255.6
B	321	284.8	272.8	292.8

Tensile Test: The tensile properties of both the parent mild steel (Sample A) and the fabricated component (Sample B) were evaluated to assess the influence of the manufacturing processes on the mechanical performance of the material. The results of the tensile tests are presented in **Figures 5** and **6**.

The experimental results revealed that the average tensile strength of the parent material used for fabrication was **318.77 MPa**, which is considerably lower than the **400 MPa** tensile strength assumed during the design and structural sizing of the equipment. This discrepancy suggests that the actual mechanical properties of the purchased mild steel did not fully satisfy the design assumptions, highlighting the importance of material characterization prior to fabrication.

A further reduction in tensile strength was observed in the fabricated component (Sample B), with an average value of **232.12 MPa** obtained from five test specimens. This represents a substantial decrease in strength relative to the parent material and indicates that the manufacturing processes adversely affected the load-bearing capacity of the mild steel.

The reduction in tensile strength is attributed primarily to the thermal cycles associated with fabrication processes such as welding, flame cutting, and localized heating, which altered the original microstructure of the material. These thermal effects may have promoted phase transformations, residual stress development, and localized microstructural degradation, thereby reducing the material's ability to withstand tensile loading. The observed decline in tensile strength is consistent with the microstructural changes identified through optical microscopy and scanning electron microscopy, demonstrating the significant influence of manufacturing processes on the mechanical behaviour of fabricated mild steel components.

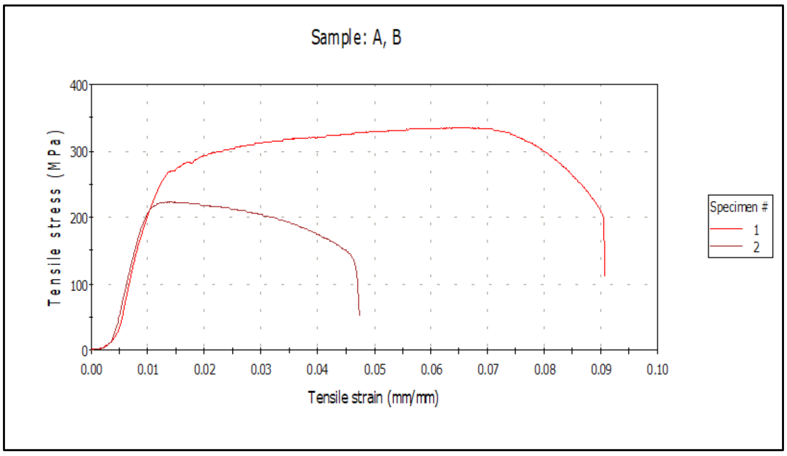

Figure 5 Ultimate Tensile Strength curve

The stress-strain curves presented in **Figure 5** demonstrate a noticeable difference in the deformation behaviour of the two specimens. The parent mild steel (Sample A) exhibited a higher strain at fracture of approximately **0.09 mm**, whereas the fabricated component (Sample B) fractured at a lower strain value of approximately **0.047 mm.** The greater strain exhibited by Sample A indicates superior ductility and a higher capacity for plastic deformation prior to failure.

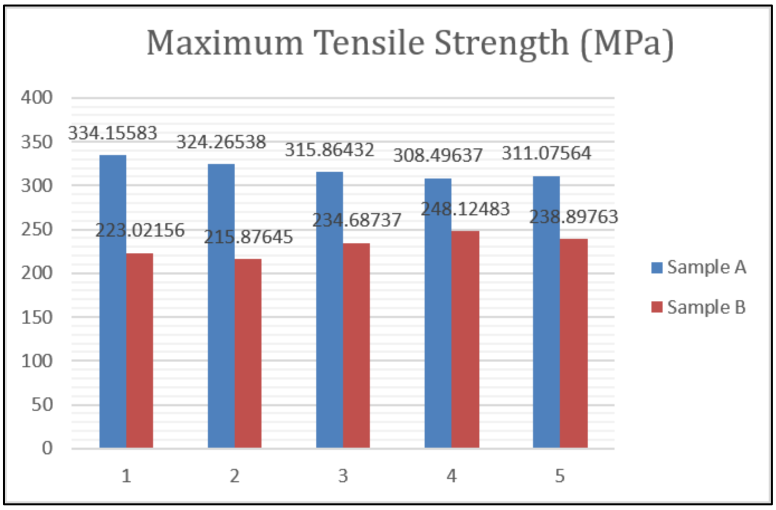

Figure 6 Graph of Ultimate Tensile Strength

In contrast, the reduced strain observed in Sample B indicates a significant loss of ductility following the manufacturing processes. This behaviour is consistent with the increase in hardness measured during the Vickers hardness tests conducted at the University of Lagos. The thermal cycles associated with fabrication operations, including welding and flame cutting, promoted microstructural transformations that increased the hardness of the material while reducing its ductility.

As the hardness of the fabricated material increased, its ability to undergo plastic deformation before fracture diminished, resulting in a more brittle mechanical response. Consequently, Sample B experienced premature fracture under tensile loading, exhibiting a lower strain-to-failure than the parent material. These findings demonstrate the trade-off between hardness and ductility and highlight the significant influence of manufacturing-induced heat treatment on the tensile deformation behaviour of mild steel fabricated components.

Wear Test: Wear testing was performed on both the parent mild steel (Sample A) and the fabricated component (Sample B) to evaluate the influence of the manufacturing processes on the wear resistance of the material. The primary objective was to determine whether the thermal cycles experienced during fabrication produced measurable changes in the wear behaviour of the mild steel.

The wear test results, presented in **Table 4** and **Figure 7**, indicate that the parent material (Sample A) exhibited a higher specific wear rate than the fabricated component (Sample B). The average specific wear rate of Sample A was **0.32**, whereas that of Sample B was **0.11**. The lower wear rate observed for the fabricated component demonstrates an improvement in wear resistance following the manufacturing processes.

This enhancement in wear resistance is attributed to the increase in hardness resulting from the thermal effects associated with fabrication. As confirmed by the Vickers hardness test, the fabricated material exhibited higher hardness values than the parent material. The increase in hardness, which is associated with the microstructural changes and the slight increase in carbon content identified during the chemical composition analysis, reduced the susceptibility of the material to abrasive wear. Consequently, the fabricated component experienced a lower rate of material removal under identical test conditions.

These findings are consistent with the established relationship between hardness and wear resistance, whereby harder materials generally exhibit lower wear rates under abrasive loading conditions. The results therefore demonstrate that, although the manufacturing processes reduced the tensile strength and ductility of the mild steel, they simultaneously improved its resistance to wear through microstructural modification and hardening.

Table 4 Specific wear rate of Specimen

Sample	Initial Weight a	Final Weight b	Volume	Density d	Weight loss C = a-b	Sliding Distance (mm) S	Vol loss ΔV=C/d X1000	Specific Wear Rate W_S= ΔV/F x S
A1	5.4092	5.3992	3.20	1.69	0.010	3.0	5.9	0.20
A2	5.4185	5.3965	3.21	1.68	0.022	3.0	13.09	0.40
A3	5.3826	5.3612	3.15	1.70	0.021	3.0	12.35	0.41
A4	5.3978	5.3855	3.22	1.67	0.012	3.0	7.18	0.24
A5	5.4215	5.4198	3.20	1.69	0.017	3.0	10.06	0.34
Average								0.32
B1	6.3561	6.3470	3.10	2.05	0.0091	2.3	4.4	0.19
B2	6.3475	6.3412	3.00	2.10	0.0063	2.3	3.0	0.13
B3	6.3326	6.3287	3.04	2.08	0.0039	2.3	1.8	0.078
B4	6.3517	6.3482	3.16	2.01	0.0035	2.3	1.7	0.075
B5	6.4128	6.4095	3.11	2.06	0.0033	2.3	1.6	0.069
Average								0.11

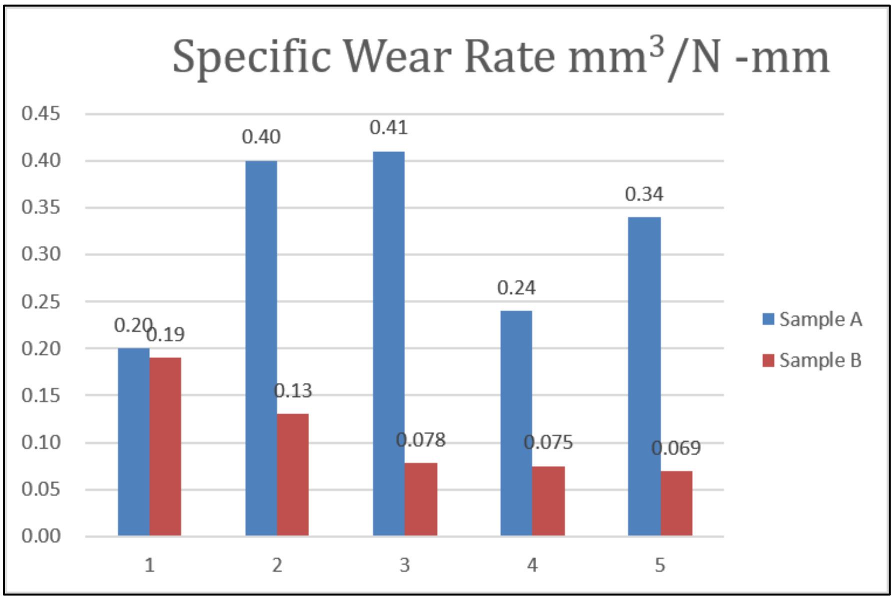

Figure 7 Graph of the specific wear rate of specimen A and B

4. Conclusion

This study has demonstrated the significant influence of manufacturing and fabrication processes on the metallurgical and mechanical properties of mild steel used in engineering components and equipment. The experimental results obtained from the optical microscopy, scanning electron microscopy (SEM), chemical composition analysis, Vickers hardness test, tensile test, and wear test confirm that the thermal and mechanical cycles associated with fabrication induce measurable changes in the microstructure and performance characteristics of the material.

The findings revealed that the manufacturing processes resulted in microstructural transformations, slight variations in chemical composition, increased hardness, improved wear resistance, and a corresponding reduction in tensile strength and ductility of the fabricated material. These changes have important implications for the structural integrity, reliability, and service performance of engineering components operating under mechanical and thermal loading conditions.

The study therefore highlights the necessity for engineers, designers, and fabricators to understand and account for the effects of manufacturing processes when selecting materials, performing design analyses, and developing fabrication procedures. Reliance on the nominal properties of the parent material without considering fabrication-induced modifications may lead to inaccurate design assumptions and increase the likelihood of premature component failure. Consequently, appropriate material characterization and post-fabrication evaluation should form an integral part of the design and quality assurance process to ensure the safety, durability, and operational efficiency of fabricated engineering products throughout their service life.

Compliance with ethical standards

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Disclosure of conflict of interest

There are no conflicts of interest to be disclosed.

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