FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA

MANUFACTURING PROCESSES AND MACHINING OPERATIONS: THE INSEPARABLE MARRIAGE

BY:

ENGR. PROF. SUNDAY ALBERT LAWAL
B.Eng, M.Eng (Minna), PhD (Malaya), NIMechE, MNSE,
LMMTS, R.ENG (COREN)
Professor of Mechanical Engineering

INAUGURAL LECTURE SERIES 118

THURSDAY 25TH SEPT. 2025

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

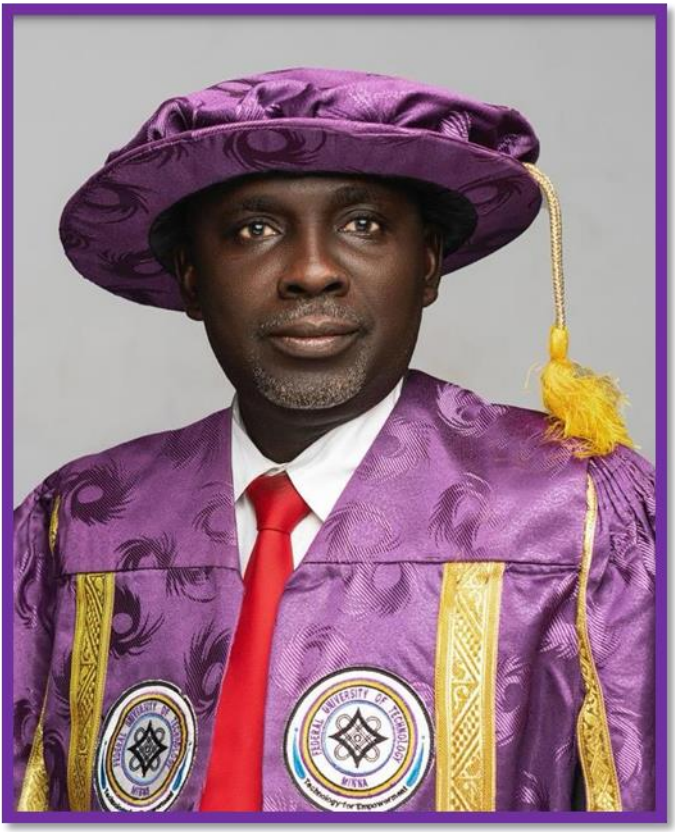
MANUFACTURING PROCESSES AND MACHINING OPERATIONS: THE INSEPARABLE MARRIAGE

BY

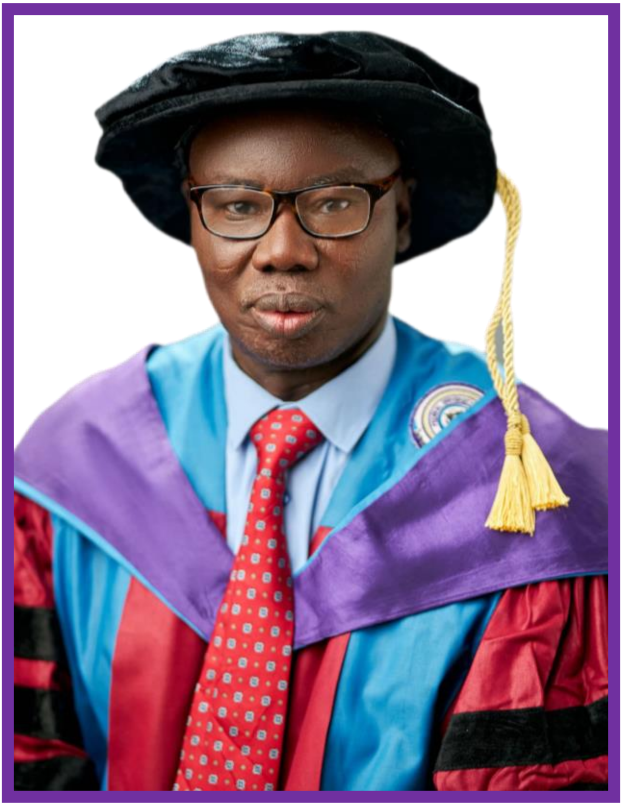
ENGR. PROF. SUNDAY ALBERT LAWAL
B.Eng, M.Eng (Minna), PhD (Malaya), NIMechE, MNSE, LMMTS, R.ENG (COREN)
Professor of Mechanical Engineering

INAUGURAL LECTURE SERIES 118

THURSDAY 25th SEPTEMBER, 2025



Prof. Faruk Adamu Kuta
B.Sc. (UDUS), M.Tech. (FUTMIN), PhD (ATBU)
Vice-Chancellor



Engr. Prof. Sunday Albert Lawal
B.Eng, M.Eng (Minna), PhD (Malaya), NIMechE,
MNSE, LMMTS, R.ENG (COREN)
Professor of Mechanical Engineering

PREAMBLE

I am deeply grateful to God and honoured to deliver the 118th Inaugural Lecture of this great institution, the Federal University of Technology, Minna.

Vice-Chancellor, Sir; Deputy Vice-Chancellors; Registrar; Bursar; Librarian; Dean of Postgraduate School, my Dean, School of Infrastructure, Process Engineering and Technology; Deans of various Schools; Directors of Units and Centres; Head of Departments, Professors and members of University Senate; other members of academic and non-academic staff; distinguished guests; the greatest FUTMINNA students; ladies and gentlemen.

I would like to begin by affirming that I am a true testament to God's grace and mercy. My parents were completely stack illiterate, and the fact that I am standing here today, to deliver this lecture, is solely due to divine intervention. As stated in 1 Corinthians 4:7, ***"For who makes you different from anyone else? What do you have that you did not receive? And if you did receive it, why do you boast as though you did not?"*** Therefore, I have no reason to take pride in any personal achievement here today before this distinguished audience. For the scripture says "***For He says to Moses, I will have mercy on whomever I will have mercy and I will have compassion on whomever I will have compassion, so then it is not of him who wills, nor of him who runs but of God who shows mercy (Romans 9:15 and 16***). Truly, I am a product of God's mercy and grace.

Vice-Chancellor and esteemed guests, back in 1980, after completing the first school leaving certificate examination and while awaiting entrance examination to secondary school, two of my friends and I decided to wear what we called *jagbo* (a type of fancy footwear) to school, which was considered a violation of school rules at the time. It was prohibited to wear shoes to school, but feeling like graduates of primary school, we chose to defy this rule by wearing *jagbo* (refer to Plate 1).

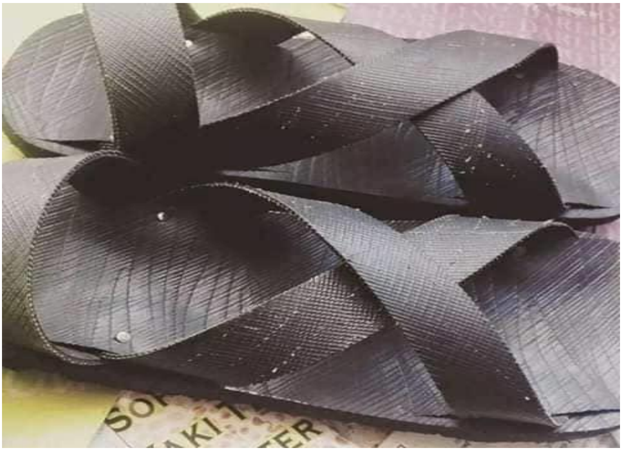


Plate 1: Jagbo footwear

My class teacher singled me out for punishment and, in addition to the penalty, commented in Yoruba language: ***"Eni abata kafi owo re ra atupa, oni ohun di eni aji tana wo,"*** which translates roughly to, ***"Someone who ought to be sold and have a lamp purchased with the proceeds claims to be worthy of being in the spotlight."***

Ladies and gentlemen, it is that boy of 1980 once deemed fit to be sold to buy a lamp—who now stands before you to present the 118th Inaugural Lecture of the Federal University of Technology, Minna, titled ***Manufacturing Processes and Machining Operations: The Inseparable Marriage.***

The Bible says in Genesis 45:3, ***"Then Joseph said to his brothers, 'I am Joseph! Is my father still alive?' But his brothers were unable to answer him, because they were terrified at his presence."*** May God who redefined my destiny do the same for you and reintroduce you to those who once dismissed you.

1.0 INTRODUCTION

Engineering is a broad discipline that applies scientific principles, mathematical techniques, and practical knowledge to design, develop, and maintain systems, structures, machines, and processes that solve real-world problems. It is divided into various branches, each specializing in a specific area of technological development and innovation. Among these, Mechanical Engineering holds a prominent position as one of the foundational pillars of engineering. Engineering, particularly Mechanical Engineering, plays a crucial role in the fields of manufacturing and machining, which are central to modern industry. Manufacturing engineering focuses on the process of converting raw materials into finished products, while machining is a subset that involves the precise shaping, cutting, and forming of materials into components using various tools and techniques (Katina *et al*, 2023).

Mechanical engineers specializing in manufacturing and machining design, optimize, and oversee the production processes to ensure efficiency, precision, and cost-effectiveness. They work with advanced technologies like Computer Numerical Control (CNC) machines, robotics, and automated systems that perform tasks such as milling, turning, drilling, and grinding with high accuracy. In this context, the integration of manufacturing processes and machining operations is essential. The two are interdependent, with manufacturing providing the framework for mass production and machining offering the detailed finishing and refinement needed to achieve product specifications. This synergy is vital in industries such as automotive, aerospace, electronics, and consumer goods, where the quality, performance, and reliability of parts are paramount. In summary, Mechanical Engineering's focus on manufacturing and machining forms the backbone of industrial production, making it key to the advancement of technology, the development of high-quality products, and the growth of global economies. Figure 1 shows some of the engineering fields (Ivanov *et al*, 2025)

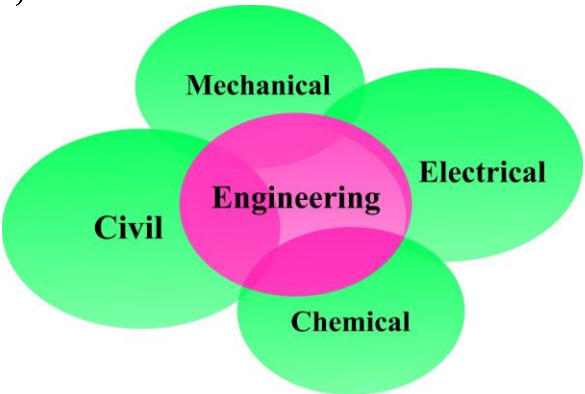


Figure 1: Some engineering fields

1.1 Manufacturing processes

Manufacturing processes refer to the series of steps and techniques involved in converting raw materials into finished products. These processes encompass a wide range of operations, including forming, casting, moulding, machining, joining, and finishing. Each process is selected based on the material type, product design, and desired characteristics of the final product. For instance, machining processes like milling, drilling, and turning are used for precise shaping and cutting, while forming processes like forging and extrusion shape materials through deformation. Manufacturing processes also incorporate modern technologies such as automation, computer-aided design (CAD), and additive manufacturing (3D printing) to enhance efficiency, accuracy, and productivity. The choice and optimization of manufacturing processes are critical for achieving cost-effectiveness, quality, and scalability in production, making them integral to industries ranging from automotive and aerospace to electronics and consumer goods. Figure 2 shows the chart for manufacturing processes (Mishra *et al*, 2014).

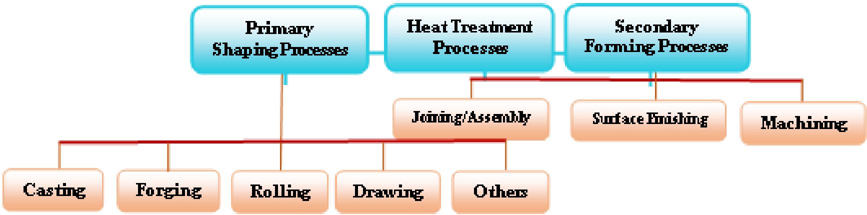


Figure 2: Manufacturing processes

1.2 Machining operation

Machining operations are a subset of manufacturing processes that involve the controlled removal of material from a workpiece to shape or finish it according to precise specifications. These operations are typically performed using machine tools such as lathes, milling machines, drills, and grinders. Machining can be classified into processes like turning, milling, drilling, and grinding, each serving different functions depending on the desired outcome. For example, turning involves rotating the workpiece while a cutting tool shapes it, while milling uses rotating cutting tools to remove material as the workpiece moves. Machining operations are known for their high precision and are crucial in producing parts with tight tolerances, smooth finishes, and intricate details. These operations are widely used across industries such as aerospace, automotive, and manufacturing, where the quality and accuracy of components are essential. Modern machining also integrates advanced technologies like Computer Numerical Control (CNC), which enhances efficiency and repeatability, making it a vital process in today's production systems. Figure 3 shows the chart for a machining process (Gasanov *et al*, 2019; Onysko *et al*, 2024).

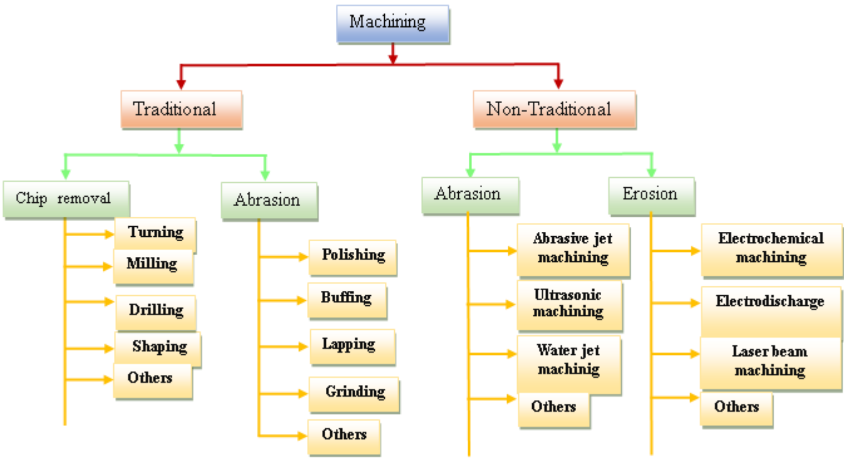


Figure 3: Machining processes

2.0 MANUFACTURING PROCESSES AND MACHINING OPERATIONS: THE INSEPARABLE MARRIAGE

The relationship between manufacturing processes and machining operations can be likened to the relationship between Adam and Eve, as described in the biblical narrative. In the same way that Adam and Eve were created to complement each other, forming a unified partnership, manufacturing processes and machining operations are inherently interdependent, each complimenting the other to achieve a common goal in production. In the Garden of Eden, Adam was given responsibility over the land, but it was recognized that he needed a partner—Eve—to fulfil his purpose effectively. Similarly, manufacturing processes, which encompass the broad steps of transforming raw materials into products, require the precision and refinement of machining operations to bring those products to their final form. While manufacturing processes lay the groundwork, shaping materials through casting, forming, or moulding, machining operations provide the detailed finishing touches, such as cutting, drilling, and grinding, that ensure the final product meets exact specifications.

Just as Adam and Eve's relationship symbolizes the ideal of partnership and interdependence, where each plays a distinct yet vital role, the bond between manufacturing and machining is essential. One cannot function fully without the other. Manufacturing processes provide the structure, while machining brings the precision, together achieving a harmony necessary for producing high-quality products. In essence, the relationship between manufacturing processes and machining operations mirrors the complementary nature of Adam and Eve – a partnership where each enhances and compliments the other, resulting in something far greater than either could achieve alone (Gen 2:8-18).

3.0 MY CONTRIBUTION

My research primarily centres on machining operations, with a particular emphasis on the turning process. A crucial first step in conducting meaningful research is to review existing work to avoid duplicating what has already been done. Examining the works of others have provided valuable guidance and direction throughout all of my research efforts.

3.1 Reflecting on the past

I have extensively studied the work of leading experts in machining operations, with a particular focus on the turning of ferrous and non-ferrous materials while building my research area. My research also delves into the preparation and application of cutting fluids, as well as the impact of cutting tools and machining parameters on key performance indicators such as surface roughness, cutting forces, temperature, tool wear, and chip formation (Lawal and Babakano, 2011, Lawal *et al*, 2012, Lawal *et al*, 2013a, Lawal *et al*, *2013b*).

3.2 Turning process

Several factors impact machining characteristics, including tool wear, surface roughness, cutting force, cutting temperature, material removal rate, chip formation, and energy consumption. These factors encompass cutting speed, feed rate, depth of cut, workpiece materials, cutting tool materials, tool geometry, type of cutting fluid, and its application method. I have dedicated significant time to investigate these factors and currently focus on studying the effects of cutting fluids on various materials, with an emphasis on developing environmentally friendly options. Metal cutting, a key manufacturing operation, involves removing excess material from a workpiece in the form of chips using a cutting tool or solid tool. Figure 4 show the mechanics of cutting. Figure 4 shows the turning process.

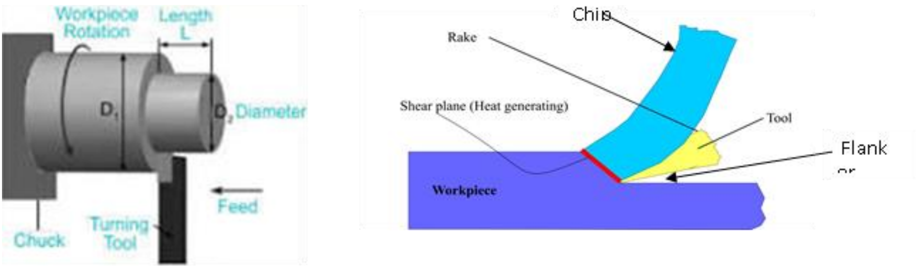


Figure 4: Turning process / cutting process

Figure 4 illustrates a typical metal cutting process, where a wedge-shaped cutting tool is set to a specific depth of cut and moves relative to the workpiece. Under these conditions, pressure is applied to the workpiece, creating compression near the tool's tip. This causes the workpiece to deform in shear, resulting in the removal of a layer of material in the form of a chip. The continuous movement of the cutting tool relative to the workpiece leads to ongoing shearing of the metal ahead of the tool. Shear occurs along a plane known as the shear plane, where significant heat is generated. To mitigate this heat, the use of cutting fluid is essential. Cutting fluid serves three primary functions: cooling, lubrication, and chip removal during the machining process. It has been found that certain materials, whether as workpieces or cutting tools, should not use water-based (emulsion oil) cutting fluids during machining. For instance, machining with ceramic tools generally requires avoiding fluid application, as it can lead to thermal shocks and potential tool breakage. However, some ceramic tools, especially those made from Si_3N_4 or with "whiskers" for enhanced toughness and thermal shock resistance, can tolerate cutting fluids and may benefit from their use (Gasanov *et al*, 2019)

3.3 Cutting fluids for machining processes

3.3.1 Functions of the cutting fluid

Cutting fluids serve three primary functions in machining operations:

(i) Cooling: Cutting fluids help dissipate the heat generated during the cutting process, reducing the temperature of both the cutting tool and the workpiece. This helps to prevent overheating, which can lead to thermal damage, tool wear, and reduced machining accuracy.

(ii) Lubrication: They reduce friction between the cutting tool and the workpiece, which minimizes tool wear and improves the smoothness of the cutting process. Effective lubrication also helps in achieving better surface finish and prolonging the life of the cutting tool.

(iii) Chip removal: Cutting fluids assist in flushing away chips and debris from the cutting area, thereby preventing their accumulation. This ensures a clear-cutting path and reduces the likelihood of chip recutting, which can negatively affect the quality of the machined surface.

Water-based Cutting Fluids and Oil-based Cutting Fluids each have distinct characteristics and applications:

1. **Cooling Efficiency:**
   - (i) Water-based Cutting Fluids: Typically offer superior cooling properties due to their high thermal conductivity and ability to absorb heat effectively. They are often used in applications where high heat dissipation is critical.
   - (ii) Oil-based Cutting Fluids: Provide less cooling compared to water-based fluids but are better at lubricating. They are less effective at heat removal, which can be a drawback in high-temperature applications.

2. **Lubrication:**
   - (i) Water-based Cutting Fluids: Generally, offer less lubrication compared to oil-based fluids, which can lead to higher friction and tool wear in some cases. They are often used in combination with additives to improve lubrication.
   - (ii) Oil-based Cutting Fluids: Excel in providing lubrication, reducing friction between the cutting tool and the workpiece. This helps in achieving a smoother finish and reducing tool wear.

3. **Application and Maintenance:**
   - (i) Water-based Cutting Fluids: Typically, they are easier to clean and have less environmental impact, but they can be prone to bacterial growth and corrosion if not properly maintained. They require regular monitoring and treatment to prevent these issues.
   - (ii) Oil-based Cutting Fluids: Tend to be more stable and have a longer shelf life, but they are more challenging to clean and can have a higher environmental impact due to their petroleum

content. They often require more extensive disposal and handling procedures (Debnath and Reddy, 2019),

3.3.2 Classification of cutting fluids

Cutting fluids are classified based on their composition and properties. Here are the primary categories:

1. Water-Based Cutting Fluids:

(i) Soluble Oils (Emulsions): These fluids are a mixture of oil and water, where the oil acts as a lubricant and the water provides cooling. They are often used for their good cooling and moderate lubrication properties.

(ii) Semi-Synthetics: These fluids combine water with a small amount of oil and various additives. They offer improved cooling and lubrication compared to soluble oils and are less prone to bacterial growth.

(iii) Synthetics: These are entirely water-based fluids with no oil content. They provide excellent cooling and are highly effective in reducing friction. Synthetics are often used in high-speed machining and are formulated to minimize bacterial growth and corrosion.

2. Oil-Based Cutting Fluids:

(i) Straight Oils: These are pure oils with no water content, often including mineral oils, animal fats, or vegetable oils. They provide excellent lubrication but are less effective at cooling compared to water-based fluids.

(ii) Adhesive Oils: These are oil-based fluids that contain additives to improve adhesion to the workpiece and cutting tool thereby enhancing lubrication and reducing friction.

3. Specialty Cutting Fluids:

(i) Chlorinated Fluids: These fluids contain chlorine compounds to improve lubrication and reduce tool wear. However, they can be harmful to the environment and are being phased out in favour of more eco-friendly alternatives.

(ii) Phosphate Esters: These are used in specific applications where high-pressure lubrication is required. They are known for their ability to provide excellent lubrication under extreme conditions.

4. Dry Machining:

(i) No Cutting Fluid: In some cases, cutting fluids are not used at all. This is referred to as dry machining and is chosen to avoid the use of fluids for environmental or economic reasons. Advanced tool coatings and machine technology can make dry machining feasible.

Each type of cutting fluid is selected based on the specific requirements of the machining operation, including cooling, lubrication, environmental impact, and maintenance considerations (Debnath and Reddy, 2019).

3.3.3 Formulation of sustainable cutting fluid

The formulation of cutting fluids involves creating a mixture designed to enhance machining performance by providing cooling, lubrication, and chip removal. The process generally includes the following steps:

1. **Selection of Base Fluids**: Choose suitable base fluids, which can be water-based or oil-based. Common choices for water-based fluids include soluble oils, semi-synthetics, and synthetics, while oil-based fluids include straight oils and adhesive oils. In the case of sustainable formulations,

vegetable oils such as palm kernel oil, cottonseed oil, and neem oil are used as base fluids.

2. **Incorporation of Additives**: Additives are mixed with the base fluids to improve specific properties. These can include:

    (i) **Antioxidants**: To prevent oxidation and prolong fluid life.

    (ii) **Corrosion Inhibitors**: To protect machinery and workpieces from corrosion.

    (iii) **Emulsifiers**: To stabilize the mixture of oil and water in emulsion-based fluids.

    (iv) **Surfactants**: To improve the wetting properties and dispersion of the fluid.

    (v) **Extreme Pressure Agents**: To enhance lubrication under high pressure and temperature conditions.

3. **Formulation Process**: The base fluid and additives are combined in precise ratios. This process may involve heating, mixing, and homogenizing to ensure a uniform and stable product. The formulation process is carefully controlled to achieve the desired properties, such as viscosity, thermal stability, and lubricating effectiveness.

4. **Testing and Optimization**: The formulated cutting fluid is tested for performance in various machining conditions. Key performance metrics include cooling efficiency, lubrication effectiveness, chip removal capability, and environmental impact. Based on these tests, the formulation may be adjusted to optimize performance.

5. **Quality Control**: Ensuring consistent quality and performance involves regular monitoring and testing of the

cutting fluid throughout its lifecycle, from production to application.

By following these steps, the formulation of cutting fluids aims to enhance machining processes while meeting specific requirements for cooling, lubrication, and sustainability (Debnath and Reddy, 2019).

The deployment of statistical tools is key to the evaluation of the effectiveness of cutting fluids. In this wise, I found Taguchi method very useful in most of my investigations. On one of such occasions, after formulating a cutting fluid from a vegetable oil, Taguchi method came handy as shown in Table 1.

Table 1: Variables and levels employed in the factorial design

Factor	Symbol	Level (% volume)	
		Minimum (-)	Maximum (+)
Emulsifying agent	A	8.0	12
Anticorrosive agent	B	2.0	4.0
Antioxidant	C	0.5	1.0
Biocide	D	0.5	1.0

The experimental run for both palm kernel and cottonseed oils are shown in Tables 2 (A and B) based in Table 1, while pH value was chosen as the only response.

Table 2A: pH value of 2^4 full factorial with random run order indicated for PKO

Run	A	B	C	D	pH value
1	8	2	1	1	10.43
2	12	4	0.5	0.5	10.88
3	12	4	0.5	1	10.75
4	8	2	0.5	1	10.69
5	8	2	1	0.5	10.74
6	8	4	1	0.5	10.83

7	12	2	0.5	0.5	10.57
8	12	2	1	1	10.52
9	12	4	1	0.5	10.74
10	8	4	0.5	1	10.69
11	8	4	0.5	0.5	10.84
12	12	2	1	0.5	10.62
13	12	4	1	1	10.74
14	8	4	1	1	10.73
15	12	2	0.5	1	10.72
16	8	2	0.5	0.5	10.79

Table 2B: pH value of 2^4 full factorial with random run order indicated Cottonseed Oil

Run	A (%)	B (%)	C (%)	D (%)	pH value
1	12	2	1	1	10.81
2	8	4	1	0.5	11.09
3	8	4	1	1	11.02
4	12	2	0.5	0.5	10.81
5	8	4	0.5	1	11.06
6	12	2	1	0.5	10.78
7	8	4	0.5	0.5	11.17
8	8	2	1	0.5	10.86
9	12	4	0.5	1	11.05
10	8	2	0.5	0.5	10.91
11	12	4	0.5	0.5	11.04
12	8	2	1	1	10.86
13	12	2	0.5	1	10.8
14	12	4	1	0.5	11.02
15	12	4	1	1	11.04
16	8	2	0.5	1	10.83

Analysis of variance using expert design software shows that the statistical check for these models are adequate for both PKO and cottonseed oil as shown in Tables 3 (a and b).

Table 3A: Analysis of variance (ANOVA) for the pH value model (PKO)

Source	Sum of Squares	DF	Mean Square	F- Value	Prob > F	Remark
Model	0.213	13	0.016	32.769	0.03	significant
A	0.003	1	0.003	4.999	0.155	insignificant
B	0.078	1	0.078	156.8	0.006	significant
C	0.021	1	0.021	42.05	0.023	significant
D	0.034	1	0.034	68.45	0.014	significant
AB	0.004	1	0.004	7.2	0.115	insignificant
AC	0.00003	1	0.00003	0.05	0.844	insignificant
AD	0.021	1	0.021	42.05	0.023	significant
BC	0.007	1	0.007	14.45	0.063	insignificant
BD	0.00003	1	0.00003	0.05	0.844	insignificant
CD	0.005	1	0.005	9.8	0.088	insignificant
ABC	0.007	1	0.007	14.45	0.063	insignificant
ABD	0.007	1	0.007	14.45	0.063	insignificant
BCD	0.026	1	0.026	51.2	0.019	significant
Residual	0.001	2	0.0005			
Total	0.214	15				

Table 3b: Analysis of variance for the model (CSO)

Source	Sum of squares	DF	Mean Square	F Value	Prob>F	Remark
Model	0.227	4	0.057	53.037	< 0.0001	significant
A	0.013	1	0.013	11.829	0.006	significant

B	0.209	1	0.209	195.634	< 0.0001	significant
C	0.002	1	0.002	2.109	0.174	insignificant
D	0.003	1	0.003	2.576	0.137	insignificant
Residual	0.012	11	0.001			
Total	0.239	15				

The R^2 and adjusted R^2 for both formulations are within the acceptable range as shown in Table 4 (a and b).

Table 4a: Statistical value for PKO cutting fluid

Statistic	value
R^2	0.9953
Adjusted R^2	0.9650
Predicted R^2	0.7009
Adequate Precision	21.275

Table 4b: Statistical value for CSO cutting fluid

Statistic	value
R^2	0.9507
Adjusted R^2	0.9328
Predicted R^2	0.8957
Adequate Precision	18.3211

Equations (1) and (2) were generated for the pH value for the PKO and CSO, these equations can be deployed to formulate cutting fluids using different proportions of additives (Lawal, 2013).

$$pH = 10.71 - 0.012 * A + 0,07 * B - 0,036 * C - 0.046 * D + 0.015 * A * B - 1.25 \times 10^{-3} * A * C + 0.036 * A * D + 0.021 * B * C - 1.25 \times 10^{-3} * B * D - 0.018 * C * D - 0.021 * A * B * C - 0.021 * A * B * D + 0.040 * B * C * D \quad (1)$$

$$pH = 10.95 - 0.028 * A + 0,11 * B - 0,012 * C - 0.013 * D$$

Table 5: Results of stability (as percentage of water separation) and pH values

	PKO (%)			CSO (%)		
	5	10	15	5	10	15
pH value	12.5	10.6	10.2	11.92	10.7	9.8
Stability	98.2	97.0	94.0	98.0	96.8	95.0

3.4 Application of formulated cutting fluids in the machining process

Vegetable oil-based cutting fluids are gaining popularity in machining due to the harmful environmental and health effects associated with conventional mineral oils. However, the suitability of lesser-known vegetable oils as cutting fluids has been minimally explored. Cutting fluids are critical in machining processes, impacting tool life, workpiece quality, and overall productivity. They play a key role in minimizing tool wear, reducing surface roughness, and ensuring a better-machined finish by preventing overheating of both the workpiece and cutting tool. This prompted me to undertake a comprehensive investigation into this topic.

3.4.1 Formulation of cutting fluid from palm kernel and cotton seed oils in turning AISI 4340 alloy steel

The selection of additives for formulating oil-in-water emulsions using palm kernel and cottonseed oils is based on the fact that cutting fluids derived from these oils are environmentally friendly and safe for workers. A full factorial design of experiments was used in the formulation process. The effects of these formulated cutting fluids on surface roughness and cutting force during the turning of AISI 4340 steel with coated carbide tools were analysed using the Taguchi method and compared with conventional mineral oil-in-water emulsion cutting fluids. A four-factor, three-level experimental design (L_{27}) was adopted for the Taguchi method. Minitab-14, a statistical analysis software widely used in engineering, was employed for analyzing the signal-to-noise (S/N) ratio and ANOVA. The input parameters considered were cutting speed, feed rate, depth of cut, and types of cutting fluids. The high water-to-oil ratio (90% water to 10% oil) in the formulation of vegetable oil-in-water emulsion cutting fluids enhances heat conductivity and provides environmentally friendly properties.

The optimal cutting parameters for surface roughness, determined using the S/N ratio, are: cutting speed (200 m/min), feed rate (0.18 mm/rev), depth of cut (1.75 mm), and cutting fluid (2.97 mm^2/s). For cutting force, the optimal parameters are: cutting speed (200 m/min), feed rate (0.18 mm/rev), depth of cut (1.00 mm), and cutting fluid (2.97 mm^2/s). ANOVA results indicate that cutting speed (64.64%) and feed rate (32.19%) are the most significant factors affecting surface roughness, while depth of cut (33.1%) and cutting fluid (51.1%) are significant factors affecting cutting force. Multiple regression analysis confirmed the reliability of the experimental measurements. The regression models developed for both surface roughness and cutting force were found to be accurate, with confirmation tests validating the regression equations. The findings from this experiment clearly demonstrate that both palm kernel oil (PKO) and cottonseed oil (CSO) based cutting fluids are effective alternatives for machining AISI 4340 steels with coated carbide tools (Lawal et al., 2014a).

In the same study, the influence of cutting fluids on flank wear during the turning of AISI 4340 with coated carbide inserts was analyzed. The performance of three types of cutting fluids was compared using the Taguchi experimental method. The results indicated that palm kernel oil-based cutting fluids outperformed the other two fluids in minimizing flank wear. Regression analysis with Minitab 14 software was used to develop mathematical models for predicting flank wear based on cutting parameters such as cutting speed, feed rate, depth of cut, and cutting fluids. Experiments were conducted using the optimized values to validate the regression equations, resulting in a 5.82% error. The optimal cutting parameters for minimizing flank wear, as determined using the S/N ratio, were: cutting speed of 160 m/min (level 1), feed rate of 0.18 mm/rev (level 1), depth of cut of 1.75 mm (level 2), and palm kernel oil-based cutting fluid with a viscosity of 2.97 mm^2/s (level 3). ANOVA results showed that cutting speed (85.36%) and feed rate (4.81%) were the most significant factors influencing flank wear (Lawal et al., 2014b).

3.4.2 Formulation of cutting fluid from castor oil in turning AISI 304 alloy steel

The need to reduce energy consumption in production processes is increasingly important due to the negative environmental impacts of fossil fuel-based electrical energy. This research addresses this challenge in the orthogonal turning of AISI 304 alloy steel. Experiments were conducted under both dry and wet conditions using mineral oil-based and vegetable oil-based cutting fluids. During the turning process, the effects of input parameters—cutting speed, feed rate, and depth of cut—on energy consumption and surface roughness were examined. Empirical models were proposed to optimize energy efficiency and surface finish.

Minitab 17 statistical software, utilizing response surface methodology (RSM), was employed for experimental design, and multi-response optimization was carried out using grey relational analysis (GRA). The results indicate the optimal cutting parameters for the dry environment as a cutting speed of 396.46 rev/min, feed rate of 1.17 mm/rev, and depth of cut of 0.5 mm. For wet turning with mineral oil-based cutting fluid, the optimal parameters are 600 rev/min cutting speed, 0.33 mm/rev feed rate, and 0.01 mm depth of cut. In wet turning with vegetable oil-based cutting fluid, the optimal parameters are 600 rev/min cutting speed, 0.5 mm/rev feed rate, and 0.25 mm depth of cut. ANOVA results show that in dry turning, depth of cut has the most significant impact (83.11%). In wet turning with mineral oil-based cutting fluid, cutting speed has the greatest effect (38.87%), while in wet turning with vegetable oil-based cutting fluid, feed rate is the most influential factor (52.44%) (Olaiya *et al.*, 2020).

3.4.3 Formulation of cutting fluid from jatropha oil in turning AISI 304 alloy steel

This study focused on the environmental biodegradability of jatropha oil and its effect on tool wear and workpiece surface roughness, driving the need to evaluate and compare the performance of jatropha oil-based cutting fluid (JBCF) with mineral oil-based cutting fluid (MBCF) during the turning of AISI 304 alloy steel. Tests were conducted on the physiochemical properties, fatty acid composition (FAC), cutting fluid formulation with a 1:9 oil-to-water ratio, turning operations, and response surface methodology (RSM) experimental design. The FAC results indicated that jatropha seed oil (JSO) contains approximately 21.6% saturated fat, with 14.2% attributed to palmitic acid. The physiochemical property analysis showed a pH value of 8.36, viscosity of 0.52 mm^2/s, resistance to corrosion, good stability, and a milky color. The signal-to-noise (S/N) ratio for the main effect plots for JBCF were 1250 cutting speed (CS), 1.15 feed rate (FR), and 0.65 depth of cut (DOC); for MBCF, the values were 500 CS, 1.15 FR, and 0.65 DOC, with R-squared (R^2) = 85.14% and adjusted R^2 = 71.76% for JBCF surface roughness (Ra) and R^2 = 71.24% and adjusted R^2 = 56.35% for JBCF tool wear (Tw). For MBCF, R^2 = 84.44% and adjusted R^2 = 70.43% for Ra, and R^2 = 70.48% and adjusted R^2 = 55.92% for Tw. In conclusion, JBCF exhibited better performance with lower surface roughness, reduced tool wear, higher environmental biodegradability, and overall better suitability for turning AISI 304 alloy steel compared to MBCF, aligning with findings from previous studies (Awode *et al*., 2020).

3.4.4 Formulation of cutting fluid from melon and benniseed oils in turning AISI 304L alloy steel

This study investigated the formulation and performance evaluation of cutting fluids made from melon seed and beniseed oils, which are considered environmentally friendly. The experiments were conducted using AISI 304L alloy steel as the workpiece and tungsten carbide as the cutting tool, with a commercial mineral oil-based cutting fluid used as a control. The viscosities of the melon seed oil and beniseed oil-based cutting fluids were 1.53 mm^2/s and 0.86 mm^2/s, respectively, with pH values of 8.2 and 8.7. The optimal multi-response turning parameters were achieved at a cutting speed of 159 rev/min (level 3), feed rate of 0.9 mm/rev (level 3), depth of cut of 1 mm (level 2), and a cutting fluid viscosity of 1.53 mm^2/s (level 3). ANOVA results indicated that feed rate has the most significant impact on surface roughness (92.93%) and cutting temperature (27.51%) (Agu *et al.*, 2019).

3.4.5 Formulation of cutting fluid from jatropha oil in turning AISI 1525 alloy steel

This study was designed to investigate the performance of a lesser-known vegetable oil, jatropha oil, as a cutting fluid in machining. The jatropha oil was characterized to determine its phytochemical, physiochemical, and lubricity-related properties. The effects of jatropha oil emulsion on surface roughness, cutting temperature, and chip formation during the turning of AISI 1525 steel alloy with a coated carbide tool were examined and compared with those of mineral oil. The experimental plan followed a Taguchi L9 (3^3) orthogonal array. Additionally, multi-response optimization was carried out using Grey relational analysis (GRA). The results showed that jatropha oil-based cutting fluid outperformed mineral oil-based cutting fluid under most machining conditions. GRA revealed that the optimal multi-response performance for both jatropha oil-based and commercial mineral oil-based cutting fluids can be achieved using the same cutting velocity (355 m/min) and feed rate (0.10 mm/rev), but with varying depths of cut—1.00 mm for jatropha oil and 1.25 mm for mineral oil (Kareem *et al.,* 2020).

4.0 OTHER AREAS OF MY CONTRIBUTIONS TO KNOWLEDGE

4.1 Joining Processes

Mr Vice-Chancellor and distinguished guests, the domain of my expertise and contributions is broader than machining processes already covered in this lecture. I have also ventured into other aspects of manufacturing engineering.

4.1.1 Friction Stir Welding

4.1.1.1 Effect of AISI H13 steel-tapered tool on dissimilar friction stir welding

This study examined the effect of AISI H13 steel-tapered tool on dissimilar friction stir welding of 7075-T651 and 1200-H19 aluminium alloys. Three mechanical tests which include hardness, tensile strength, and impact energy were conducted to study the effect of tilt angle, rotational and welding speeds on the weld integrity. 50 and 175 HV were respectively obtained as hardness values for AA1200- H19 and AA 7075- T651, the hardness values were measured for three selected welding speeds of 30, 60 and 90 mm/min representing low, medium and high at a constant rotational speed of 1500 rpm, a tool tilt angle of 2°. The hardness increases with the welding speed from 81.99 to 98.5 HV as the speed increased from 30 to 60 mm/min and dropped to 77 HV at 90 mm/min. The impact energy increased from 12.9 to 21.4 J with an increase in the welding speed from 30 to 60 mm/min and dropped to 5.4 J at 90 mm/min.The ultimate tensile strength (UTS) increased from 126.04 to 151.54 MPa with an increase in the welding speed from 30–60 mm/min and decreased from 151.54 to 128.37 MPa, the hardness at 1500rpm and 60 mm/min increased from 70.22 to 98.58 HV with an increase in the tilt angle from 1- 2°, a further increase from 2–3 o reduced the hardness from 98.58 to66 HV, UTS increased from 123.32 to 151.54 MPa as tilt angle increased from 1–2 ° and decreased to 122.2 MPa, the medium tilt angle of 2°,rotational and traverse speeds of 1500 rpm and 60 mm/min respectively gave the highest impact energy of 21.4 J (Attah *et al*., 2021). Figure 5 show the typical friction stir welding process.

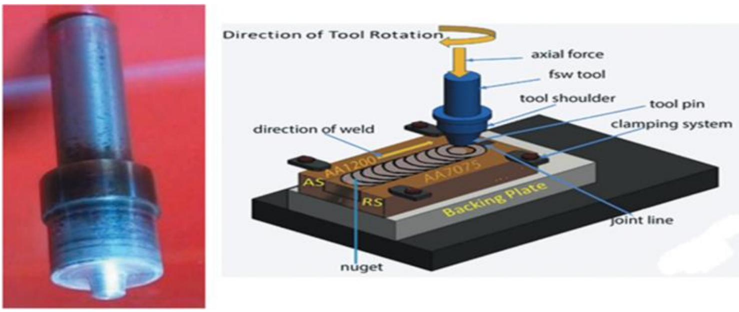


Figure 5: Typical friction stir welding process

4.1.1.2 Material placement and tool's speed of rotation effects on the tensile strength and hardness of weldment of dissimilar aluminium alloy

This research equally looked at how material placement and tool's speed of rotation affects the tensile strength and hardness of weldment manufactured in a butt configuration. The 6 mm thick plates were joined while alternating the material positioning between advancing side and retreating sides. By changing the tool rotational speed and material placement, ten joints were fabricated and were subjected to mechanical tests, the hardness and tensile properties were evaluated. The result shows that maximum UTS values of 152.48 and 142.75 MPa were obtained for categories X and Y weldment with the placement of AA 1200 on advancing and retreating sides separately at 1500 rpm speed of rotation with superior surface outlook. While, lowest values of UTS of 115.5 and 111.51 MPa were obtained for categories X and Y when AA1200 was placed on the advancing and retreating sides separately. Maximum and minimum hardness for category X were 97 and 70.6 HV, while for category Y were 85.5 and 66.4 HV. It was concluded that category X weldment gave better mechanical properties. Hence softer materials should be positioned on advancing side (Attah *et al*., 2022).

4.1.1.3 Effect of rotating and the welding speed and tool tilt angle on mechanical properties of friction stir welding

The response surface technique approach was used, in this study, to determine the best processing parameters for the three responses. For the friction stir welded dissimilar AA7075-T651 and AA1200- H19 aluminium alloys, the rotating and the welding speed, as well as the tool tilt angle, were used as input variables. Mechanical tests were performed on the weldment and the average hardness ranges from 64.26 to 99.72 HV, while the Ultimate Tensile Strength (UTS) ranges from 111.51 to 152.48 MPa. The impact energy was found to vary between 2.9 and 21.4 J. The results from the Signal to Noise (S/N) ratio revealed optimal welding parameters for hardness, UTS and impact energy as 1500 rpm speed of tool rotation, 30 mm/min transverse speed, and 2° tool tilt angle, while for UTS, it is a rotational speed of 1500 rpm, 90 mm/min transverse speed, tool tilt angle of 2° and finally for impact energy as 1500 rpm rotational speed, 30 mm/min transverse speed and 2° tool tilt angle. The results from the grey relational analysis gave optimal process parameters of 1500 rpm rotational speed, 60 mm/min transverse speed and 2° tool tilt angle. The results from the ANOVA revealed that tool rotational speed has the highest significant contribution of 41.79% to the hardness of the weldment followed by the rotational speed (34.46%) and then the transverse speed (19.44%). For UTS, tool rotational speed has the highest significant contribution (35.03%) followed by tool tilt angle (33.72%) and then transverse speed (30. 23%). Also, tool rotational speed has the highest significant effect on the impact energy of the weldment (37.45%) followed by transverse speed (32.00%) and then a tool tilt angle of (27.02%). Empirical models were developed using the Minitab 17 software with the central composite design (CCD) from which the UTS of 150.99 MPa, hardness of 99.102 HV and impact energy of 20.039 were obtained and were found to be close to the experimental values obtained. This study is significant as it gives insight into the optimum processing parameters of joining AA7075-T651 and AA1200- H19 aluminium alloys using the FSW and can be recommended for producing high quality welds with good joint integrity (Attah *et al*., 2023).

4.1.1.4 Effect of tool geometry on the corrosion behaviour and microstructure of friction stir welded AA7075-7651 and AA1200-H19

In this study, the friction stir welding (FSW) process was employed to investigate the effect of tool geometry on the corrosion behaviour and microstructure of friction stir welded AA7075-7651 and AA1200-H19 using Central Composite Design. The workpieces were machined and welded, and the interfaces were milled. A 2-level full factorial experimental design was deployed using Response Surface Methodology (RSM). A rotational speed of 1500 rpm, welding speed of 30, 60, and 90 mm/min, and a 2° tilt angle of the tool with a plunge force of 7 kN were utilized. The results show that regardless of the tool geometry, multi response optimum weldment can be achieved at 60 mm/min welding speed and a tilt angle. The microstructure of the optimal weldments presents an ‘onion ring’ pattern, indicating proper mixing of the alloys during FSW. Analysis of the corrosion behaviour revealed a decrease in the polarization resistance when the transverse speed increased from 30 to 90 mm/min, as polarization resistance has a direct relationship with corrosion rate. It can be concluded that FSW ensures excellent weldment, as evident in the microstructural evolution of the resulting weldments, and that tool geometry plays a significant role in the corrosion inhibition efficiency of the alloys (Attah *et al*., 2024).

4.2 Material development

4.2.1 Sustainable development of brake pad

Over the years, asbestos was used as reinforcement material in brake pads production. However, due to its carcinogenic nature, it has lost its favour and there is need to find an alternative material. In this study, brake pads were produced from locally sourced non-hazardous raw materials using grey relational analysis. The materials used for production include seashell, epoxy resin (binder), graphite (friction modifier) and aluminium oxide (abrasive). Twenty- seven different samples were produced using seashell as reinforcement material by varying the process parameters. Rule of mixture was used for formulation and a weight percent of 52% reinforcement, 35% binder, 8% abrasive and 5% friction modifier were used for production. Grey relational analysis was conducted in order to scale the multi-response performance to a single response. The results indicate that optimum performance can be achieved with 14 MPa moulding pressure, 160 C moulding temperature, 12 min curing time and 1 h heat treatment time. Analysis of variance shows that curing time has the least significant effect on the mechanical properties, while curing time of 24.26% and 55.23% has the most significant effect on coefficient of friction and wear rate respectively on the brake pad developed (Abutu *et al*, 2018). Plate 2 show brake pad produced from environmentally friendly materials

Plate 2: Brake pad

4.2.1.1 Effects of particle size distribution on the performance of brake pad developed from coconut shells and seashells-based composite

In this study, locally sourced natural materials (coconut shells and seashells) were used separately to produce composites. The powders were sieved with sieve size of 10 μm and characterized using a particle size analyser (DLS) in order to ascertain their particle size distribution. Also, the effects of particle size distribution on the performance

of sourced coconut shells and seashells-based composite was investigated. About 52% of the characterized powder was afterward used along with other ingredients (35% binder, 8% alumina and 5% graphite) to produce composites using moulding pressure (14 MPa), moulding temperature (160 ºC), curing time (12 min) and heat treatment time (1 hr). The performance of the composites was thereafter evaluated using standard testing procedures. The results of particle size analysis indicated that the seashell powder (0.27) possesses lower distribution width (PDI) compared to the coconut shell powder (0.342) while the coconut shell (542.3 nm) showed lower Z-average diameter compared to the seashell powder (1096 nm) with some little traces of nanoparticles (<10 μm). Also, the experimental results obtained from composite characterization indicated that the coconut shell-based samples exhibited better performance in terms of its mechanical and tribological properties compared to the seashell-based samples (Abutu *et al*, 2019a)

4.2.1.2 Development of brake pad

In this work, locally sourced non-hazardous materials were used to produce brake pad using grey relational analysis (GRA) and experimental design via central composite design. Raw materials selected for production include coconut shell, epoxy resin (binder), graphite (friction modifier) and aluminum oxide (abrasive). Twenty-seven samples were produced separately using coconut shell as reinforcement material by varying process parameters. Formulation of the brake pads samples was done using rule of mixture and a weight percent of 52% reinforcement material, 35% binder, 8% abrasive and 5% friction modifier were used for the production. Grey relational analysis (GRA) shows that optimal process performance can be obtained using moulding pressure, moulding temperature, curing time and heat treatment time of 14 MPa, 140 °C, 8 min and 5 h, respectively. Optimized sample was produced using the optimal set of process parameters obtained from GRA and compared with commercially available sample produced by Ibeto Group. The experimental results showed that the performance of the optimized coconut shell-reinforced brake pad compared satisfactorily with commercially available samples and capable of producing less brake noise and vibration during application. Analysis of variance shows that curing time with a contribution of 30.38% and 31.40% has the most significant effect on the hardness and ultimate tensile strength of the coconut shell-reinforced friction material, respectively, while heat treatment time with a contribution of 46.3% and 24.23% has the most significant effect on the wear rate and friction coefficient of coconut shell-reinforced brake pad, respectively. The effects of all the factors on the properties of the friction materials are significant since their *p* values are greater than 0.010 (1%) (Abutu *et al*, 2019b)

Over the years, asbestos has been used as reinforcement material in the production of brake pads production but it has lost favour due to its carcinogenic nature, as a result, there is need to investigate other possible substitute which can offer similar tribological properties as the carcinogenic material (asbestos). Several works have been carried out using different reinforcement materials with the aim of finding a possible replacement for asbestos. In this work, Rule of Mixture (ROM) was utilised for sample formulation and the tribological properties of natural based material (coconut shell and seashell) were investigated using experimental design (response surface methodology) and multi-response optimisation technique (Grey relational analysis). The multi-response performance of the formulated brake pads samples was compared with a commercial brake pad sample. The research findings revealed that sample can be produced using 52% reinforcement, 35% binder, 8% abrasive and 5% friction modifier while the Grey relational analysis (GRA) showed that optimum multi-response performance of the developed coconut shell based sample can be achieved using MP, MT and CT and HTT of 12MPa, 100 ^{o}C, 6mins and 2hrs respectively while that of the developed seashell based brake pad can be achieved using MP, MT and CT and HTT of 10MPa, 160 ^{o}C, 12mins and 2hrs respectively. Also, the Analysis of variance (ANOVA) results show a percentage error of less than 5% indicating minima noise effect. In addition, the optimized coconut shell-based brake pads fall within the category of class H (μ >0.55) type of brake pads while seashell-based sample falls within the class G (μ: 0.45-0.55) type of brake pads. It therefore concluded that the use of coconut shell can serve as a better substitute for asbestos-based brake pads (Abutu *et al*., 2020)

4.3 Lubricant

Jatropha oil which is a non-edible vegetable oil that is sustainable, biodegradable and environmentally friendly is thought to be a good substitute for mineral oil for lubricant production. The physicochemical, rheological, temperature, thermo-oxidative stability and corrosion properties of Nigerian Jatropha oil and commercially available mineral oil base lubricant (SAE 20W50) were determined for suitability as base stock for lubricant production. The Jatropha oil has specific gravity of 0.91, free fatty acid of 15.6 mg KOH/g, pH of 5.82, saponification value of 220.46 mg KOH/g and Iodine value of 88.9g I_2/100 g fat. Assessment of the rheological and temperature properties of the Jatropha oil gave kinematic viscosity at 400C and 1000C as 83.2 cSt and 63.5 cSt respectively, viscosity index of 145.5, pour point of -11.20C, cloud point of -8.30C and flash point of 2640C. The peroxide value of the Jatropha oil was 5.98 meq/Kg and it was of corrosion grade 0. The jatropha oil has better viscosity index compared to the SAE 20W50, whereas the SAE 20W50 is better than the jatropha oil in other measured properties. The properties of the Jatropha oil need to be improved except its cold flow, flash point and corrosion inhibition properties (Woma *et al*, 2023; Woma *et al*, 2019; Woma and Lawal, 2019).

5.0 ON GOING RESEARCH

1. Development of Nanofluid for Machining Carbon Fibre Reinforced Plastic (CFRP) (Lawal *et al*, 2024; Lawal *et al*, 2023)
2. Development of nano – enhanced insulating or transformer oil
3. Laser -enhanced solar manufacturing system

6.0 A NATION'S MANUFACTURING STRENGTH AND HER GLOBAL RANKING

The relationship between a nation's manufacturing capacity and its military, economic, and political strength is deep and multifaceted. Manufacturing is often considered a foundation for national power, as it directly supports the growth and sustainability of these three key domains:

1. Military Strength

(i) **Arms Production:** Manufacturing allows a nation to produce military equipment, vehicles, and weapons domestically, reducing reliance on foreign suppliers and increasing strategic autonomy.

(ii) **Supply Chain Security:** Strong domestic manufacturing ensures that a nation has secure access to essential goods like ammunition, spare parts, and other critical supplies during conflicts.

(iii) **Innovation and Technology:** Advanced manufacturing facilitates the development of cutting-edge defence technologies, giving a military a technological edge in warfare.

2. Economic Strength

(i) **Job Creation and GDP Growth:** A robust manufacturing sector is a key source of employment and economic growth. It generates jobs, stimulates economic activities, and contributes significantly to a nation's GDP.

(ii) **Trade and Exports:** Manufacturing drives exports, helping to create trade surpluses, build foreign reserves, and reduce trade deficits, thereby stabilizing the national economy.

(iii) **Industrial Base and Innovation:** Manufacturing often stimulates broader technological advancements, thereby fostering innovation and contributing to economic resilience and diversification.

3. Political Strength

(i) **Global Influence:** Nations with strong manufacturing sectors often wield greater global influence due to their economic leverage and technological leadership. This can translate into diplomatic power and leadership roles in international organizations.

(ii) **Autonomy and National Security:** A self-sufficient manufacturing sector makes a nation less vulnerable to international supply chain disruptions or economic sanctions, enabling it to pursue independent foreign and domestic policies.

(iii) **Domestic Stability:** Manufacturing can contribute to internal stability by providing employment opportunities, promoting social mobility, and supporting a strong middle class, which are essential for political cohesion.

Historical Examples

(i) **World War II:** The U.S. and Soviet Union demonstrated the power of industrial capacity in determining military outcomes. The U.S. "Arsenal of Democracy" supplied vast quantities of war materials, thereby playing a decisive role in the Allied victory.

(ii) **China's Rise:** China's economic ascent is closely tied to its massive manufacturing sector, which has bolstered its economic clout, military modernization, and geopolitical influence.

Manufacturing capacity is often a bedrock upon which national strength is built. It not only supports the military and economic pillars but also enhances a nation's political influence. A country with strong manufacturing capabilities is more likely to maintain a stable and powerful global position.

7.0 CONCLUSION

In conclusion, the integration of manufacturing processes and machining operations represents a fundamental synergy essential for advancing industrial capabilities and achieving precision in modern manufacturing. As we have explored, manufacturing processes lay the groundwork by defining how materials are transformed into products, while machining operations refine these processes, thereby enhancing accuracy and quality. The harmonious interplay between these elements not only drives innovation and efficiency but also shapes the future of manufacturing industries.

The inseparable marriage between these domains underscores the importance of a holistic approach to manufacturing. It highlights the need for continuous collaboration between process engineers and machinists, and the imperative of embracing advancements in technology to remain competitive. By understanding and leveraging this synergy, industries can achieve optimal performance, reduce costs, and meet the ever-evolving demands of the global market.

8.0 RECOMMENDATIONS

1. **Foster Interdisciplinary Collaboration:** Encourage ongoing communication and collaboration between professionals in manufacturing processes and machining operations. Cross-disciplinary teams can address complex challenges more effectively and drive innovation.

2. **Invest in Advanced Technologies:** Adopt cutting-edge technologies and tools that bridge the gap between manufacturing processes and machining operations. Technologies such as CNC machines, additive manufacturing, and advanced simulation software can enhance precision and efficiency.

3. **Promote Continuous Learning and Training:** Invest in training programs that keep professionals updated with the latest techniques and best practices. Continuous learning will ensure that both manufacturing and machining operations evolve in tandem with technological advancements.

4. **Enhance Quality Control Measures:** Implement robust quality control systems that integrate both manufacturing and

machining processes. This will help in identifying and addressing potential issues early, ensuring high standards of product quality.

5. **Support Research and Development:** Invest in research and development initiatives focused on improving manufacturing processes and machining techniques. Collaboration between academia and industry can lead to breakthroughs that enhance overall performance.

6. **Encourage Sustainability Practices:** Integrate sustainable practices into manufacturing and machining operations. This includes optimizing resource use, reducing waste, and implementing eco-friendly technologies to minimize environmental impact.

9.0 ACKNOWLEDGEMENTS

First and foremost, I am grateful to God the Almighty through Jesus Christ our Lord for His mercy and grace and for counting me worthy to see this day.

My profound gratitude goes to the Vice Chancellor, Prof Faruk Adamu Kuta, the Deputy Vice Chancellor (Academic), Engr Prof Abdullahi Mohammed, the Deputy Vice Chancellor (Administration), Prof Uno E. Uno, The Registrar, Mallam Danlami Mallam, the Bursar, Dr. Mrs. Hadiza Goje and the University Librarian, Prof S. Katamba. My appreciation also goes to the following former Principal Officers of the University: Prof. Tukur Sa'ad who employed me, Prof M.S. Audu who approved my release for PhD training, Prof. Abdullahi Bala who appointed me as Head of Department, Prof A.O. Osunde, Prof S.O.E Sadiku, Prof O.O Morenikeji, Prof E. Udensi, Mal. M.D. Usman, Mrs. V.N Kolo and Mr. A.N Kolo, I say thank you.

I am indebted to all my teachers from Primary School through to the University level. I sincerely appreciate your contributions toward my academic career. My primary school teachers, Mr. A.A. Akure, Evang M.A. Balogun, Mr. Bolufawi and Mr. D.O. Aina. My secondary school teachers, Mr George (Chemistry) Mr. Joseph (Physics), Mr Jacob (Biology) and Mr. Olorunyomi (Mathematics). My Polytechnic teachers; Engr Abdullahi Sule and Engr Olorunyomi and Dr. John Manukaji. My university lecturers, Engr Prof. F.O Akinbode (B.Eng Supervisor), Engr. Prof. M.S. Abolarin (M.Eng Supervisor) and Prof Imtiaz Ahmed Choudhury (PhD Supervisor) without your guidance, care and support, it would have been difficult to complete my programme. Others include Engr. Prof. O.K. Abubakre, Engr. Prof. O.D. Jimoh, Prof. M.M. Ojapah. Late Prof Coleman, Late Vincent Ogwuagu and host of others.

I am highly indebted to all the staff members of School of Infrastructure, Process and Engineering Technology and School of Electrical and Engineering Technology for the understanding and love we share together. My Dean, Engr Prof. O.A. Olugboji and my immediate past Dean, Engr. Prof. Z.D. Osunde, you are indeed a blessing to the SIPET family.

To members of University Senate, I say a big thank you for your love and cooperation. To my beloved Department of Mechanical Engineering, I say thank you for being there for me always and to my Head of Department, Engr. Prof K.C. Bala down to the Office Assistant. I am grateful

To the management of TETFUND, thank you for your financial support towards my PhD programme.

I appreciate the Chairman and members of the University Seminar and Colloquium Committee for their efforts and encouragements. I am indebted to Engr. Dr. R.O. Medupin who painstakingly worked on the draft of this lecture, May God reward you abundantly in Jesus name (amen). Engr. Ibrahim Lukman Kehinde for your inputs to the preparation of the power points. I say thank you

I am also grateful to my spiritual leaders, Dr. & Mrs Michael Onimole, Bishop & Mrs Nnaji, Rev & Mrs. Michael Oladeji, Rev. Dr. & Mrs Matthias Echioda. Rev. & Mrs Micah Tswabki. I am equally grateful to the Council members and entire members of Chapel of Grace, Federal University of Technology Minna, Alumni Fellowship of Fellowship of Christian Students, Federal Polytechnic Bida and Patai Baptist Church Kuala Lumpur, Malaysia

To my professional colleagues, Nigeria Society of Engineers, Minna chapter and Nigeria Institution of Mechanical Engineers Minna chapter, I say thank you. I say thank you to all members of Anebira Forum of Federal University of Technology Minna.

I am grateful to the following to individuals and families: Dr. and Prof. Mrs. Akanya, Engr. Prof. Sadiku Salawu, Engr. Prof. Benjamin I. Ugheoke, Mr and Prof. Mrs. Lafia Araga, Dr and Dr. Mrs. M.D. Pemi, Dr. and Prof. Mrs. Philip Ibrahim, Engr. Prof. M.B. Ndaliman, Engr. Prof. A. Nasir, Engr. Prof O.A. Olugboji, Engr. Dr. T.D Ipilakyaa, Engr. Matthew Ajibade, Dr. and Mrs Elisha Kolo, Engr. Dr. Samuel Adinoyi, Engr. Dr. Ibrahim Ogu Sadiq, Engr. Prof and Mrs Jacob Tsado, Engr. Prof. A.S. Abdulrahman, Engr. Prof. A.S. Abdulkareem, Engr. Prof. Abdulsalami Kovo, Prof. T.J. Oladeji, Engr. Prof. Oyewole Adedipe, Engr. Dr. A. Bello, Engr. Dr. U.G Okoro, Engr. Segun Ogunleye, Engr. Simpa Mark Ibrahim, Engr. Dr. S.S. Lawal, Engr. Dr. Adamu Bala Garba, Prof. Badmos Ajayi Owolabi, Dr. Sola Joda, Mr. and Mrs. Monday Jeremiah, Mr and Mrs. Andrew Aina, Mr and Mrs. Daniel Alhassan, Mr and Mrs. Gideon Tsado, Pastor Patrick Aboi, Dr and Mrs Sola Akinwale, Mr. and Mrs. Augustine Kolawole, Mr and Mrs. John Ayeni, Rev and Mrs. Segun Olawepo and Rev and Mrs. Segun Oladimeji, Class of 1985 of ECWA Secondary School Igbaja, Class of 1985 of Abdul Aziz Attah Memorial College Okene and Class of 1995 of

Mechanical Engineering Department, Federal University of Technology, Minna.

I also salute, all my students, especially my postgraduate students (graduated and those yet to graduate), my graduated PhD students, Dr. A. K. Callistus, Dr. J. Abutu, Dr. B. I. Attah, Dr. T. Y. Woma, Dr. Kabiru Olaiya, Dr. Aba Aji, Dr. Osayi Anthony, Dr. E. I. Awode, Dr. James Mokwa, Dr. A.B. Garba, Dr. S.O Areo, Dr. Job Mopah, Dr. A.E Ajani, Dr. Seriki Onimisi, Dr. V.C. Nwachukwu and a host of Master students. I wonder how, I would have achieved this feat without your contributions and support.

My appreciation goes to my late parents, Mal. Lawal Omeiza and Mrs. Ajoke Lawal. Thank you, mother, for all your contributions to my academic journey. To my late brother, Festus Omeiza Lawal, thank you and how I wish you are here today.

To my siblings, Mr. and Mrs. Isah Lawal and Pastor and Mrs. Samuel Lawal, I am grateful for your contributions and sacrifice. May God Almighty who you serve reward you abundantly in Jesus name (amen).

To my in-laws, Mr Olaniyi Adesanya, Mr and Mrs. Oredeko and Mr and Mrs. Lamina, thank you for your prayers and advices.

To my wife, Mrs. Comfort Modupe Lawal words are definitely inadequate to express my appreciation for your sacrifice, counsel, prayer and support. I love you. My children, Favour Onyinoyi Lawal, Grace Ahuoyiza Lawal, Joy Ohunene Lawal and Simpa Albert Lawal, you are all wonderful children and thank you.

Whatever has a beginning must has an end, finally, to the audience, I have come to the end of this lecture, I cherish and appreciate your presence and rapt attention. God bless.

REFERENCES

Abutu J., **Lawal S. A.,** Ndaliman M.B., Lafia-Araga R.A., Adedipe O. & Choudhury I. A. (2019a). Production and Characterization of Brake pad developed from Coconut shell reinforcement material using Central Composite Design. *SN Applied Sciences.* 1:18.

Abutu J., **Lawal S.A.,** Lafia-Araga R.A., Ndaliman M.B. & Oluleye M. A. (2020). Microstructure and thermal analysis of brake pads developed from Asbestos -free materials, *Arid Zone Journal of Engineering, Technology and Environment,* 16(2), 375-386

Abutu J., **Lawal S.A.,** Ndaliman M.B., Lafia-Araga R.A., Adedipe O. & Choudhury I. A. (2018). Effects of process parameters on the properties of brake pad developed from seashell as reinforcement material using grey relational analysis, *Engineering* Science *and Technology, an International Journal,* 21, 787–797.

Abutu Joseph, **Lawal Sunday Albert,** Ndaliman Mohammed Baba, Lafia-Araga Ruth Anayimi and Oluleye Atinuke Modupe (2020), Tribological Properties of Friction Materials Developed from Non- Asbestos Materials using Response Surface Methodology, *International Journal of Engineering Materials and Manufacture,* 5(2) 40-49.

Abutu, J., **Lawal S. A**., Ndaliman, M. B., Lafia-Araga, R. A. and Abdulrahman A. S. (2019b). Effects of Particle Size Distribution on the Properties of Natural-Based Composite. *International Journal of Engineering Materials and Manufacture*, 4(4), 170-177.

Agu C.K, **Lawal S.A**, Abolarin M.S, Agboola, J.B, Abutu J and Awode E.I (2019), Multi Response Optimisation of Machining Parameters in Turning AISI 304l Using Different Oil-Based Cutting Fluids, *Nigerian Journal of Technology, 38 (2),*364 -375.

Attah B.I, **Lawal S.A**., Akinlabi E.T and Bala K.C (2021) Evaluation of mechanical properties of dissimilar aluminium alloys during friction stir welding using tapered tool, 8 (1909520) *Cogent Engineering*, 8:1, 1909520, DOI: 10.1080/23311916.2021.1909520

Attah B.I, **Lawal S.A**., Bala K.C, Ikumapayi O.M, Sahu S, Perwej M.I, and Akinlabi E.T (2022), Effects of Material Placement and Speed of Tool Rotation on Tensile Strength of dissimilar friction stir welded AA7075 and AA1200-H19 Aluminium Alloys, *Materials Today Proceedings*

Attah B.I, **Lawal S.A**., Bala K.C, Ikumapayi O.M, Adedipe O, Mahto R.P, and Akinlabi E.T (2023) *Optimization and numerical analysis of friction stir welding parameters of AA7075-T651 and AA 1200-H19 using tapered tool,* International Journal on Interactive Design and Manufacturing (IJIDeM) https://doi.org/10.1007/s12008-023 01329-1

Attah B.I., Medupin R.O, Ipilakyaa T.D, Okoro U.G, Adedipe O, Sule G., Ikumapayi O.M, Bala K.C, Akinlabi E.T and **Lawal S.A**. (2024), Microstructural and corrosion behaviours of dissimilar friction stir welded aluminium alloys, Manufacturing Review 11, 7 https://doi.org/10.1051/mfreview/2024003.

Awode E. I., Abolarin M. S., **Lawal S. A.** and Adedipe O (2020), Performance Evaluation of Jatropha Seed Oil and Mineral

Oil-Based Cutting Fluids in Turning AISI 304 Alloy Steel, *International Journal of Engineering Materials and Manufacture* 5(3) 85-97, https://doi.org/10.26776/ijemm.05.03.2020.03

Debnath S. & Reddy M.M (2019), Innovations in Manufacturing for Sustainability, Materials Forming, Machining and Tribology, © Springer Nature Switzerland AG 2019 K. Gupta (ed.), https://doi.org/10.1007/978-3-030-03276-0_1

Gasanov M, Kotliar A, Basova Y, Ivanova M, Panamariova O (2019) Increasing of lathe equipment efficiency by application of gang-tool holder. In: Gapiński B, Szostak M, Ivanov V (eds) References 109 Advances in manufacturing II. Manufacturing 2019. Lecture notes in mechanical engineering, Springer, Cham, pp 133–144. https://doi.org/10.1007/978-3-030-16943-5_12

Genesis 2:8-18, The Holy Bible (NKJV, Thomas Nelson, Since 1798

Ivanov Vitalii, Artem Evtuhov, Ivan Dehtiarov, Justyna Trojanowska (2025), Fundamentals of Manufacturing Engineering Using Digital Visualization, Springer Tracts in Mechanical Engineering https://doi.org/10.1007/978-3-031-74360-3

Katina PF, Cash CT, Caldwell LR, Beck CM, Katina JJ (2023) Advanced manufacturing management: a systematic literature review. Sustainability 15(6):4702. https://doi.org/10.3390/su1506 4702

Kazeem R.A, Fadare D.A, Abutu J, **Lawal S.A** and Adesina O.S (2020) Performance evaluation of jatropha oil-based cutting fluid in turning AISI 1525 steel alloy, *CIRP Journal of Manufacturing Science and Technology* 31, 418–430

Lawal S.A and Babakano A. (2011). Performance Evaluation of Palm Oil as Biodiesel**.** *Leonardo Journal of Sciences*, 18 (10), 115- 122.

Lawal S.A, Medupin R.O, Yoro K.O, Okoro U.G, Adedipe O, Abutu J, Oladepo T.J, Abdulkareem A.S, Ndaliman M.B, Sekoai P.T, Jen T.C, (2023), *Nanofluids and their application in carbon fibre reinforced plastic: A review of properties, preparation and usage*. Arabian Journal of Chemistry doi:https://doi.org/10.1016/j.arabjc.2023.104908

Lawal S.A, Medupin R.O, Yoro K.O, Ukoba K.O, Okoro U.G, Adedipe O., Abutu J, Oladepo T.J, Abdulkareem A.S, Ndaliman M.B, Abdulrahman A.S, Eterigho-Ikelegbe O and Jen T.C (2024), Nano-titania and carbon nanotube-filled rubber seed oil as machining fluids, Material Chemistry and Physics 316, 129126

Lawal S.A., Choudhury I.A Sadiq I.O and Adedipe O (2014a). Vegetable - Oil Based Metalworking Fluids Research Developments for Machining Processes: Survey, Applications And Challenges. *Manufacturing Review* 1, 22. DOI: 10.1051/mfreview/2014021.

Lawal S.A., Choudhury I.A and Nukman Y. (2012). Application of vegetable oil-based metalworking fluids in machining ferrous metals –A review**.** *International Journal of Machine Tools and Manufacture*, 52, 1- 12.

Lawal S.A., Choudhury I.A and Nukman Y. (2013a). Developments in the Formulation and application of vegetable oil-based metalworking Fluids in Turning Process. *International*

Journal of Advanced Manufacturing Technology, 67, (5), 1765-1776.

Lawal S.A., Choudhury I.A and Nukman Y. (2013b). A Critical Assessment of Lubrication Techniques in Machining Processes: A Case for Minimum Quantity Lubrication Using Vegetable Oil- Based Lubricant. *Journal of Cleaner Production*, 41, 210 -221.

Lawal S.A., Choudhury I.A and Nukman Y. (2014). Evaluation of vegetable and mineral oil-in-water emulsion cutting fluids in turning AISI 4340 steel with coated carbide tools. *Journal of Cleaner Production*, 66, 610 – 618.

Lawal S.A., Choudhury I.A and Nukman Y. (2014b). Experimental Evaluation and Optimization of Flank Wear During Turning of AISI 4340 Steel with Coated Carbide Inserts Using Different Cutting Fluids**.** *Journal of Institution of Engineers, India (Series. C)* 96 (1), 21 -28.

Mishra R, Pundir A K, Ganapathy L (2014) Manufacturing flexibility research: a review of literature and agenda for future research. Glob J Flex Syst Manag 15:101–112. https://doi.org/10.1007/ s40171-013-0057-2

Olaiya K.A, **Lawal S.A**, Babawuya A and Adedipe O (2020) Parameters Optimisation of Energy Consumption in Turning of AISI 304 Alloy Steel, *Nigerian Journal of Technology, 39(2).* 452 – 463.

Onysko O, Kopei V, Barz C, Kusyi Y, Baskutis S, Bembenek M, Dašić P, Panchuk V (2024) Analytical model of tapered thread made by turning from different machinability workpieces. Machines 12:313. https://doi.org/10.3390/ machines12050313

Sunday Albert Lawal (2013), Effect of vegetable and mineral oil-in-water emulsion cutting fluids in turning aisi 4340 steel with coated carbide tools, PhD thesis submitted to the Department of Mechanical Engineering, University of Malaya, Malaysia

Woma T.Y, Ipilakyaa T.D, Abdullahi A.A., Okoro U.G, Bello A, Abutu J., **Lawal S.A,** Abdulrahman A.S, Olutoye M.A (2023), Evaluation of Friction Co-efficient and Wear Performance of Jatropha Oil Using Standard Steel Ball on Aluminum Disc Tribometer, J. Mater. Environ. Sci., 14, (10), 1266-1277

Woma T.Y, **Lawal S.A,** Abdulrahman A.S, and Olutoye M.A (2019), Nigeria Jatropha oil as suitable basestock for biolubricant production, *Jurnal Tribologi* 23, 97 112

Woma T.Y, **Lawal S.A,** Abdulrahman A.S, and Olutoye M.A and Ojapah M.M (2019) Vegetable Oil Based Lubricants: Challenges and Prospects, *Tribology Online,* 14 (2), 60 -70

PROFILE OF THE INAUGURAL LECTURER

Prof. Sunday Albert Lawal began his education career at ECWA LGEA Primary School, Ejiba in 1973 and transferred to LGEA Primary School Iddo-Gbedde in 1977 both in Kogi State. He got admission to the famous Abdul Azeez Attah Memorial College, Okene in 1980, later transferred to ECWA Secondary School Igbaja in 1983 and completed his secondary education in 1985. He proceeded to Federal Polytechnic Bida in 1988 and graduated in 1990. He got admission through direct entry into the Federal University of Technology Minna in 1991 and graduated in 1995/96 academic year. He obtained his Master's Degree from Federal University of Technology Minna in 2001. Prof S.A. Lawal left the shore of Nigeria on 30th December 2010 to Malaysia for his PhD program at prestigious University of Malaya, Malaysia, where he completed his PhD in two and half years.

He worked briefly for two years at Nigerian Paper Mill Jebba as technician in trainee between 1986 and 1988. He started his lecturing job with Taraba State Polytechnic Jalingo in 1997 and left in 1999. He joined the service of Federal University of Technology Yola now Modibo Adama University of Technology (MAUT) Yola in May 2005 as Assistant Lecturer and transferred his service from MAUT to Federal University of Technology Minna in August 2007 as Lecturer II, where he rose through the ranks to become a Professor of Mechanical Engineering in October 2020. Prof Lawal was with University of Mines and Technology Tarkwa (Essikado campus), Ghana from January 2023 to July 2024 for sabbatical appointment. He is a visiting Professor to Pan Africa University Nairobi, Kenya and University of Mines and Technology Tarkwa, Ghana.

Professor Sunday Albert Lawal has taught over fifteen courses at both undergraduate and postgraduate levels. He has supervised more than sixty undergraduate's projects, thirty master and twenty PhD (11 Main supervisors and 9 Co- supervisor) theses. He is still very much involved in teaching, research and community service. He has held the following positions in the university: Level Adviser, Departmental Examination Officer and Head of Department from January 2019 to January 2023. He has served in various committee at different levels in the university.

Prof Lawal has won several research grants and awards both local and international. He was awarded a research grant worth of N38 million in 2020 by NRF TETfund to develop nano-cutting fluid to machine carbon reinforced fibre plastic (CFRP) material. Prof Lawal and his team from Ghana, Kenya and Spain has been awarded Intra Mobility Grant by the European Commission to develop laser-enhance solar manufacturing system worth of 1.4 million Euro. He has published more than 80 scholarly research articles, some of these articles were published in Q1 and Q2 Journals. He has four book chapters to his credit. He has over 2000 citations in google scholar with h-index of 22. He has attended and presented papers at International and National conferences. Prof. Lawal got the Vice Chancellor's Commendation award for Outstanding Scholarly Publications in Scopus Index Journals in 2021, 2023 and 2024 by the Vice Chancellor of Federal University of Technology Minna. He was top 2% of the World researchers in 2022 and 2024 as published by Stanford University USA. He was at University of Brunel, University of Birmingham, Imperial College all in UK as Visiting Scholar in 2019 sponsored by Royal Academy of Engineering.

Prof. Sunday Albert Lawal is the Editor in- Chief of the Journal of Nigeria Institution of Mechanical Engineers and a reviewer for many International and National Journals. He has served as external examiner for postgraduate programs in Nigeria, Ghana, South Africa and Kenya universities. He has assessed candidates for professorial ranks for OAU Ife, ABU Zaria, University of Maiduguri, Federal University of Technology Owerri, Nigeria Defence Academy and served as resource person for COREN. His areas of research interest are machining characteristics, modeling and optimization, development and characterization of sustainable engineering materials and maintenance engineering.

Prof Lawal is a member of the Nigerian Institution of Mechanical Engineers, Nigeria Society of Engineers, Life Member of Malaysia Society of Tribology and a registered engineer with COREN. He is happily married to Mrs. Comfort Modupe Lawal and the marriage is blessed with children.