UNIVERSITY OF ILORIN

THE ONE HUNDRED AND EIGHTY-FOURTH (184th) INAUGURAL LECTURE

OPTIMAL APPLICATION OF MATERIALS JOINING TOWARDS RAPID NATIONAL DEVELOPMENT

By

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My Lords Spiritual and Temporal,
Members of my Nuclear and Extended Family,
Distinguished invited Guests and Friends,
Gentlemen of the print and electronic media,
Members of the University of Ilorin Alumni Association,
Great University of Ilorin Students,
Ladies and Gentlemen.

1.0 Opening

I will lift up my eyes unto the hills, from where cometh my help, my help comes from the Lord [Ps.121:1]who lifted me up to this level on the academic ladder and enabled me to deliver this 184th inaugural lecture of this great University on a subject I had actively taught, practiced and researched on extensively. This is the fourth Inaugural lecture from the Department of Mechanical Engineering, the first was delivered by my mentor and Ph.D supervisor Prof. M.B. Adeyemi on a subject he titled “Industrial Growth through Research and Development” in 1995. Thereafter Prof. J.A. Olorunmaiye and Prof. O.A. Lasode presented their inaugural lectures.

The background story of how I opted for Mechanical Engineering and by extension specializing in Welding Science dated back to 1973 when I was in form three in the secondary school. I was initially inclined towards arts subjects before I had a close association with a senior student named Segun Ige who was the best student in their set. He influenced me strongly by guiding and assisting in beefing up my ability in mathematics and science subjects to the extent that I had the best science result in my 1975 set at Baptist Grammar School, Isanlu – Isin, Kwara - State. I was admitted after “A” levels for both Architecture at the University of Lagos and Mechanical Engineering at Ahmadu Bello University, Zaria. Architecture was a prime choice course in 1977 when I was to enter the University. Under pressure from parents I resumed at the University of Lagos but soon after withdrew and reported at Ahmadu Bello University, Zaria as a Mechanical Engineering student. I made a choice of Mechanical Engineering as a course after my “A” levels based on passion and the influence of Segun Ige who also read Mechanical Engineering at Imperial College, London. Both of us are Ph.D holders in Mechanical Engineering today and still maintain contact.

Before joining the University system, I worked at Ajaokuta Steel Company on Gas Pipelines and facilities and thereafter as a lecturer at Kaduna Polytechnic. My interest in Welding Technology dated back to the years I worked in these establishments. However by divine arrangement, upon my being employed at the University of Ilorin in 1989, Prof. M.B. Adeyemi accepted to supervise my Ph.D and offered a welding related research topic oblivious of my earlier interest in the same field. The underlying interest in Welding Science and Technology led to my becoming a Professor of Weldment Mechanics today.

Welding constituted one of the oldest engineering practices dating back to ancient ages. Welding can be defined as a method of repairs or creating metal structures by joining the metal through various fusion processes involving application of heat [www.gowelding.org]. There exists several manufacturing processes in mechanical engineering; the question is of what significance is welding within the context of our national development now?. I will like to take us through a broad range of products in which welding technology is applied.

The Maurzyce bridge over Sludwia river in central Poland shown in Fig.1 is the first entirely welded road bridge in the world.

Figure 1: First Entirely Welded Bridge (Maurzyce Bridge)

It was designed in 1927 by Prof. Stefan Bryla. It was in use between 1928 and 1977; a period of 49 years [en.m.wikipedia.org].

In addition the longest bridge in the world based in Kiev, Ukraine, as shown in Fig. 2 is a product of welding process.

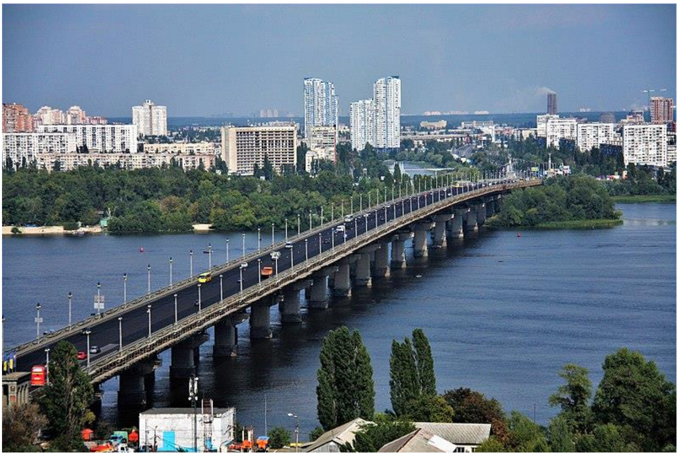

Figure 2: The longest entirely welded bridge (Paton bridge)

The bridge shown in Fig. 2 is named Paton bridge and it is 1543 metres long. It was opened to traffic in November 1953. Daily traffic on the bridge is 36,000 vehicles, indicating the reliability of welded joints in static and dynamic loading systems. Road and railway bridges in any nation are infrastructures that enhance rapid economic and social development. The welding process through which they are majorly made can therefore be said to be a major contributory factor to socio – economic development. The building of ships which dated back to 1930 up till today is largely carried out through welding process. Kyle Taylor was responsible for the invention of stud welding. It soon became a very popular process in ship building.

The West - East gas pipeline is 8,707km (Source: www.offshoretechnology.com). The fabrication, support trusses and other service facilities of the pipeline are majorly products of welding process. The repairs arising from willful or accidental damage is principally done through the welding process. Automobile industries world – wide applies welding techniques. At lesser scales of its application, particularly in developing countries like Nigeria, it finds application in building construction, over-head and underground fuel tanks, underground gas pipelines, agricultural processing machinery, automobile repairs and so on. The application areas is almost inexhaustible, thus justifying the choice of this topic.

2.0 History of Welding Technology

Historical evidences of the iron age showed that Egyptians welded their iron tools together while during the middle ages blacksmithing was developed with consequent joining together of metals by hammering. It was in the 19th century that welding advanced when Edmund Davy discovered acetylene in 1836 while production of electric arc was credited to Sir Humphry Davy in 1800. Oscar Kjellberg of Sweden invented the covered electrode between years 1907 to 1914. The advent of world war 1 around this time brought about tremendous development of the welding process with other welding processes emerging [3]. In Nigeria the application of the welding process in our national development is traceable to 1896 when the first railway-line between Lagos and Abeokuta was constructed. Further extensive application of the welding process was in 1901 in the construction of the Carter bridge. In Nigeria they are processes that entails both extensive riveting and welding.

3.0 Welding Process Application in Different Sectors

Virtually all key sectors of our national economy apply welding process in form of manufacturing, fabrication or repair services. A list of some of these sectors are:

*Automobile Industry
*Buildings, Tents and Bridges
*Oil and Gas Industry (Pipelines, storage tanks, refineries)
*Domestic Appliances
*Agricultural machinery and Silos
* Transport sector
* Aviation industry
* Marine industry

3.1 Welding Application in the Automobile Industry

The scale of manufacture of automobiles is a major index of a nation's technological development. Extensive application of welding process in the automobile industry occurs at the various stages of factory construction, production equipment installation and vehicle production stages. A vehicle comprises of over 4000 component parts produced by diverse manufacturing processes[4]. Welding constitutes one of the major operations in the production of a vehicle, where a variety of structural components and engine parts are welded. About 4500 spot welding operations are carried out on one vehicle; essentially through application of robotic (Tungsten Inert Gas) and Metal Inert Gas arc welding. The floor pan of a vehicle is the largest body component to which a multitude of panels and braces are either robotically welded or bolted. Other parts welded include front and rear door pillars, chassis, brackets and mounts. Fig. 3 shows welding performed by robots in an automobile manufacturing industry.

Fig.3 Industrial Robots Welding Car Body (Source: Rexroth - Bosh group)

Robot welding is the use of mechanized programmable tools (Robots), which completely automate a welding process by performing the weld and also properly positioning the part. Other specialized welding processes that find application in the manufacture of automobiles include friction welding, which is used to make half shafts, axle cases, steering column, hydraulic cylinder, piston rods and engine valves. Another currently developed welding process called magnetic pulse welding is targeted at producing light weight parts in hybrid gas/electric vehicles and bonding of dissimilar metals without use of filler metals [5].

There was a fairly active level of car assembly and local production of some car parts in Nigeria in the 1970s with an all time high level of 108,000 cars per annum. At an estimated rate of 500 spot welds on assembling operations out of a total of about 4000 spot welds associated with one vehicle production; it is estimated that about 54 million spot welds are done on vehicles during this time. This is aside of manual welding processes that also take place in some plants. Typical auto plants were Peugeot Automobile Nig. Ltd and Volkswagen Nig. Ltd. With the weakening of the Nigeria economy over the years, the output of these companies declined drastically. The consciousness of the need to resuscitate the automobile companies prompted the government to set up the National Automotive Design and Development Council, vested with the authority to award new licenses to vehicle manufacturers. This prompted private investors to invest in vehicle production with extensive application of resistance spot welding, arc and gas welding. Some of these products are seen as Proforce PF2 for conveying cash. Specific data is however not available on the volume of welding activities carried out by these companies because of an inconsistent operational pattern.

3.2 Welding Application in the Agricultural Sector

Commercial farming largely entails mechanization of most manual activities. Within the agricultural sector, there exists soil preparation, planting, harvesting and crop processing equipment. There are also irrigation, silos, animal husbandry and others [2]. Every of the mechanical devices applicable to agriculture involves extensive welding activities. The most often applied welding type under mass production situations is Tungsten Inert Gas welding (TIG), resistance welding (seam or spot) where flat sheets are applied and gas welding/cutting. Some selected agricultural equipment having some level of welding operations carried out on them are: Ploughs, Cultivators, Harrows, Harvesters, Choppers, Sprayers, Green houses/ Protective structures, Axles, Planters and Seed drills. It is informative to note that about 140 million dollars was used in importing agricultural machinery by the Federal Government of Nigeria between 2016 and 2018 [United States Export Portal, Punch Newspaper, 28th December, 2018]. This literally translates into massive welding job opportunities if the country develops appropriate local technology.

3.3 Welding in the Oil and Gas Sector

The oil and gas sector is the dominant sector where extensive regulated welding practices take place in Nigeria, largely in terms of the worth of every weld produced. Both upstream and downstream of the oil industry are deeply engaged in welding. The upstream of the oil sector comprises of Offshore oil / gas production facilities, Drilling rigs and Intervention vessels. Other facilities that goes with the equipment such as; structures, frames, scaffolds and so on are mostly welded structures. Downstream sector comprises of petroleum refining, transportation and storage which are also predominantly welded structures. Overall, oil gas pipeline length in Nigeria could not be obtained precisely but a breakdown of the network is as shown in Table 1, with weldments at every pipeline joint.

Table 1: Nigeria Oil / Gas Pipeline Network (Source: Theodora.com/pipeline/Nigeria)

Product Type	**Project Name**	**Start Point**	**End Point**	**Diameter (inches)**	**Length (km)**
Oil	---	Escravos	Kaduna	16″, 24″	674
Oil	- -	Kwale	Brass (offshore)	10″, 14″ 24″, 36″	206
Oil	-	Ramuekpe	Bonny	24, 28, 48	134
Gas	Trans – Nig Pipeline Offshore Gas	Warri	Ramuekpe	16″	NI
Gas	Gathering System	Bange Field	Bonny Terminal	32″	268
Gas	Escravos – Lagos Pipeline System	Escravos	Lagos	36″	340
Gas	Aladja System Pipeline	Oben	Ajaokuta	24″	294
Gas	Greater Ughelli System	Ughelli	Warri	-	-
Gasolene		Kaduna	Gusau	6″, 10″	356
Propane		Kaduna	Maiduguri	4″, 6″, 12″	1050
Ethylene		Kaduna	Warri	16″	
		Lagos	Ilorin	6″, 12″, 16″	259
		Port/ Harcourt	Yola	6″	333
		Warri	Lagos	12″, 16″	312

Oil pipelines are made from steel with inner diameter typically ranging between 100 and 1,220 mm while length range of Spirally Submerged Arc Welding (SSAW) welded steel pipes is 6 - 18 m. Taking an average pipeline length of 12 m, for the Warri – Kaduna crude oil pipeline of 674 km, we would have approximately 56,166 welded joints apart from other pipeline fittings that would be welded. This figure reflects the massive amount of welding works involved in major Oil and Gas installations. Similar level of welding activities obtains also in gas pipelines. Fig. 4 shows typical oil/gas pipeline and welded spots.

Fig. 4: Oil and Gas Pipeline Network with Welded Joints

3.4 The Informal Sector of Welding Practice

These are the categories of welding practice referred to as road side welders, some are also called metal and structural fabricators with some not necessarily by the road side. As a matter fact, some are involved in multi – million Naira projects such as roof trusses, storage tanks for fuel, truck body works and so on. Accurate data relating to the contributions of this sector to the economy is not precisely available. We can however capture the size of this informal welding sector from the worth of the imported predominant raw material used by the sector. Nigeria imports of Iron and Steel in 2017 was $469.66 million dollars.[Source: United Nations COMTRADE database on International Trade]. The unique peculiarities of this sector are that they are the highest provider of employment opportunities; wide range of services such as iron bending, automobile parts welding engage a considerable high population of young people for job opportunities. For example registered workshops of self – employed electric arc welders with active presence of journeymen and apprentices in Ilorin East, Ilorin West and Ilorin South local government areas totaled 932 as at 2014[6]. Based on the data from these three local governments, relative to the total number of 774 local governments in Nigeria, it is estimated that the number of registered welding workshops in Nigeria may be about 240,456. This is of an enormous size that plays a significant role in the economy of Nigeria. For this audience to appreciate how versatile this informal sector of welding is, Table 2 shows a list of typical products made at micro and small scale levels by this sector.

Table 2: Typical Products Fabricated at Informal Welding Sector

No	Product name	Remarks
1	Gates	Motorized gates are imported
2	Trusses	
3	Windows and Doors	Large imports of Doors exists
4	Oven	
5	Iron bed	
6	Tank Support	
7	Ladder	
8	Truck Chassis	
9	Fuel Tank	
10	Agricultural Tools	
11	Metal Furniture	
12	School swing	
13	Baby Utilities	
14	Hospital Furniture	
15	Others	

Each product has the potential of transforming into an industry with proper financial and managerial support from government.

This sector mainly applies manual shielded arc welding process. Common weld failure in this sector are [7]:

- Incomplete penetration
- Lack of fusion
- Undercuts
- Porosity
- Cracks

3.5 Welding Training

There exists academic degree programmes in welding engineering which is considered as a specialization under materials and metallurgical engineering. The non-academic form of welding training referred to as professional welders training are structured and controlled by the Nigeria Institute of Welding (NIW) (Established by the Federal Government of Nigeria) with headquarters based in Petroleum Training Institute, Effurun, Delta State. All professional welding training Institutes are to be accredited by NIW being the recognized national body overseeing the welding practice. The larger umbrella body that controls the activities of welding institutes world-wide through their national bodies is the International Institute of Welding(IIW). The International Institute of Welding was founded in 1948 with headquarters in France. The vision of the few countries that formed IIW initially was to be the international vehicle by which innovation and best joining practices could be promoted, while providing an international platform for the exchange and dissemination of evolving welding technologies and applications. The IIW is today having a membership in over 56 countries from six continents with its focus on joining, soldering, brazing, adhesive bonding, and micro-joining; other allied activities include quality assurance, non-destructive testing, standardization, inspection, health and safety, education, training, certification, design and fabrication.

Welding training in the formal sector has an international outlook with the certificates and diplomas presentable world-wide. Typical areas of training towards obtaining a certificate takes about one year while diploma takes about two years. Some of the training schools which are based largely in Port – Harcourt and Lagos offer training on Weld Inspection, Pipeline Welding, Under-Water Welding, etc. They treat such topics as Metal arc welding, Fabrication welding, Blue-print welding, Flux-cored welding, Pipe welding, Gas Tungsten arc welding(GTAW), Joint preparation, Fumes, Safety and Electric shock, Technical drawing , oxy – acetylene welding, other welding positions, etc. [Source: www.study.com/welding course]. There are several courses leading to internationally recognized certificates in welding; the ultimate often referred to as gold standard is 6G certification. To qualify for this, a welder must be able to weld a stationary pipe inclined at 45^o all round non – stop, must be capable of welding in all positions (Vertical, horizontal and overhead) and capable of welding with either left or right hand. Expectedly, remuneration for such level of certification is $58,998 equivalent to N21,239,280 @N360/dollar exchange rate as annual salary as at 2017 (www.earlbeck.com, assessed on 4/8/2019)

3.6 Welding of Some Selected Materials

About 90% of materials welded in the formal and informal sectors of the welding industry in Nigeria are categorized under mild steel with carbon content (C) ranging between 0.15 - 0.30%. Mild steel welding does not require any special precaution or process in order to obtain a sound welded joint. There are however the welding of other non-common materials such as cast iron, aluminium and stainless steel that demand special processes in order to effect a strong weld. Very often welding of these uncommon metals takes place in repairs and service workshops. Typical example obtains in automobile workshop where extensive repair welding takes place on the engine and body.

3.6.1 *Welding of Mild Steel*

Mild steel are ferrous materials with 0.15 – 0.30% carbon content. They have very good weldability index. Although carbon is the most significant alloying element affecting weldability, the effect of other alloying elements such as Silicon (Si), Manganese (Mn), Sulphur (S), etc. can be estimated by converting them to their carbon equivalent(C.E.). It is susceptible to underbead cracking from hydrogen increases when the carbon equivalent exceeds 0.4%. As a means of preventing crack, electrodes with low – H_2 are to be used [8].

3.6.2 *Welding of Stainless Steels*

Stainless steels (SS) are corrosion resistant steels. All stainless steels has iron(Fe) as the main element and chromium(Cr) in amounts ranging from 11 - 30%. Cr is the main corrosion resistant element. For this presentation, Austenitic stainless steel shall be highlighted in some details. Austenitic stainless steel (ASS) is the most corrosion resistant among the four groups of stainless steels. It contains nothing less than 16% Cr with a significant presence of Ni and Mn. ASS are readily joined by arc, resistance, friction, electron and laser beam welding processes. Most commonly used methods of joining ASS are shield metal arc welding (SMAW), Gas metal arc welding (GMAW), Gas Tungsten arc welding (GTAW) and Flux cored arc welding (FCAW). Information about the chemical composition of the SS is required before an intelligent choice of electrode type can be made. There exists standard tables of recommended filler metal alloys for welding various grades of SS. Welding procedure entails use of lower welding current and high welding speed relative to welding parameters used for mild steel.

This setting reduces heat input, carbide precipitation and minimize warpage and distortion.

3.6.3 *Welding of Cast Iron*

Cast iron(C.I) is a family of ferrous alloy materials that contains more than 2% C and 1 – 3% Si together with small quantities of sulphur and phosphorous. Their property, such as good fluidity, makes them a primary choice for a casting process. Their limitation however is lower toughness and ductility relative to steel [8]. A large percentage of automobile engine blocks, brake drums, clutch plates and cam shafts are made of cast iron (C.I.). Several of the older vehicles still ply the roads and subjected to repairs and maintenance which sometimes involve welding. For purposes of discussing the welding procedure; focus will be given to gray cast iron. Gray cast iron has the following composition in %wt: C (2.0 – 4.0), Si(1.0 min.), S(0.2), P(0.6), Mn(1.0 max.), Fe (Balance). Gray C.I. is the most common type of cast iron often used in machinery building and automotive industries. Uncontrolled Gray C.I. welding is highly susceptible to cracking. The welding procedure mainly focuses on controlling the post weld cooling rate in order to prevent a crack. The welding processes employed for welding cast irons include SMAW, GMAW, FCAW, oxy-fuel gas welding, braze welding and thermit welding. Main focus in this presentation is SMAW. The best method to decrease the cooling rate is to preheat the casting to prevent the cast iron from absorbing heat from the weld area. Recommended preheat temperature range for arc welding is 40 – 335^{o}C. C.I. can be arc welded with Nickel, Ni-alloy, mild steel, and Cu-alloy covered electrodes. Joint designs applicable to carbon steel are equally suitable for C.I.; for butt welds with V edge preparation, a 60^o to 80^o groove angle is suitable. When repairing cracked castings, a hole of about 3.5 mm in diameter should be drilled at the ends of each crack to prevent its further propagation. Recommended preheat temperature for repair welding is 370^{o}C for about 30 minutes using oxy-fuel gas torch[8].

The Ni-alloy covered electrodes are recommended for welding cast iron. Post weld heat treatment (PWHT) of C.I. weldments should be carried out in order to effect stress relief of welds that are restrained or applied in severe service conditions. PWHT entails heating the entire casting to about 600^{o}C and cool slowly at a rate not exceeding 28^{o}C per hour.

3.6.4 *Welding of Aluminium Alloys*

Aluminium (AL) alloys are extensively applied in industrial and general applications. Automobile engine blocks are of recent made of die cast aluminium alloys. Knowledge of welding the material is essential for repair purposes and as a production process. Fusion welding of aluminium can be done using GMAW, GTAW, resistance spot and seam welding. Solid state welding processes that can equally be used are friction, diffusion, explosion, high frequency and cold welding. Proper selection of filler metal is a vital step in successful welding of Al while using the GMAW or GTAW processes. In GMAW of aluminium constant – voltage power source and constant speed electrode drive are normally used with small diameter electrodes. Argon shielding gas is most commonly used for manual welding with spray type of metal transfer. Major problems encountered in welding aluminium are cracking and porosity[8].

4.0 My contributions to knowledge

My contributions to knowledge can be broadly classified into four:

(a) Research findings in welding science and experimental residual stresses
(b) Metal treatment and composite materials development
(c) Computer modelling of temperature distributions in production
(d) Machine and equipment development

4.1 Welding and residual stresses research findings

Machine building often entails both welding and machining. Residual stresses arising from cutting forces during milling operation alone was examined by Adedayo [9]. Evaluation of residual stresses was carried out through successive layer metal removal method. Strains associated with these stresses were monitored by series of strain gauges attached to opposite side of milled flat plate. The bi-axial stresses were obtained through Hooke's expression that relates strains and stresses. Tensile stresses as high as 105 MN/m^2 were observed. It was also observed that the direction of milling had a significant effect on the magnitude and type of stress induced in the metal plate [9].

Welding of alloy steels with high demand for sound mechanical properties requires a high degree of control of thermo-mechanical condition with regards to their effect on mechanical and metallurgical properties. An appropriate choice of welding speed is vital to production rate, quality of weld and mechanical properties of weld. The effectiveness of any weld depends on the heat input to the joint. The net heat input, H_{net}(J/mm) into a weldment is given by the following expression:

$$H_{net} = \frac{60 * \mu V I}{\omega} \quad (1)$$

Where: μ - heat transfer efficiency
V - arc voltage (volts)
I - arc current
.ω – travel velocity of heat source (mm/ min)

According to Adedayo and Odepidan [10], peak metal temperatures attained during arc welding is inversely proportional to the welding speed. Mechanical properties such as hardness, tensile strength and toughness were found to be relatively higher at lower welding speeds [10]. A typical trend as applicable to tensile strength is depicted in Fig. 5.

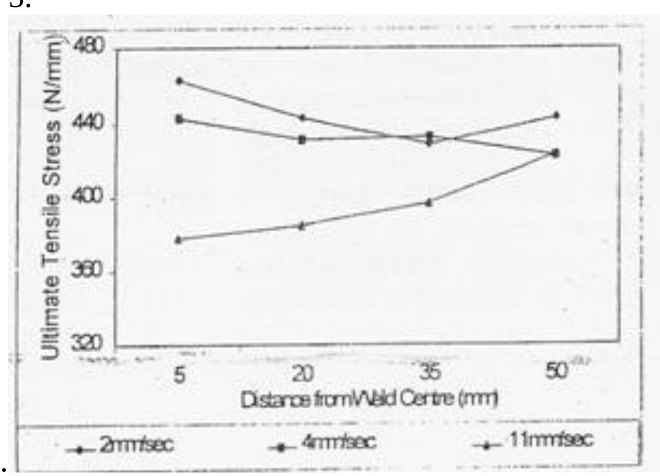

Fig.5: Effect of welding speed on tensile strength

At these lower levels of welding speed the effects of heat input arising from regulated welding speed on mechanical properties are more pronounced around the heat affected zone (HAZ).

In another work, Adedayo [11] examined the effect of welding speed on residual stresses. Longitudinal and Transverse residual stresses in the weldment were determined through strain change measurements resulting from successive stress relaxation. Higher levels of tensile longitudinal residual stresses of about 80 MN/m^2exist around the heat affected zone at the higher welding speeds tested [11]. Peak temperatures and consequently heat input in the weldment is inversely proportional to welding speed.

Cooling rate is one of the most significant factors affecting metal properties during and after a welding process. With or without any externally imposed cooling devise, very high cooling rate takes place around the heat affected zone (HAZ) in an arc welding process. In a research on the effect of pre-heat temperature on mechanical properties of ferrous metals; Adedayo and Momoh [12] established that hardness properties around the heat affected zone increased with metal preheat at 200^oC while toughness and tensile strength decreased. Mechanical properties of hardness, tensile strength and toughness in arc welded mild steel plates are higher in the HAZ relative to base metal region [12]. This research becomes significant in the welding of in–process high temperature systems and pipelines.

Most welding processes of thin plates are single pass. Effective weld of thick plates however requires multi-pass. Every weld pass affects heat – treatable material properties of the HAZ. The thermal cycle changes the microstructure within the vicinity of the HAZ and subsequently the mechanical properties. Adedayo and Babatunde [13] examined this heat influence on C25 carbon steel. The peak temperatures of the welded plate increased by 15.1% under double pass weld and 41% for a four – pass weld under minimal inter-pass weld heat break. Toughness and tensile strength of carbon steel increases with multi-pass weld while metal hardness decreased [13]. It is the area of application that will justify which of the properties is of relative importance.

Welding in saline water environments such as the atlantic ocean (Salinity = 35g/L) is inevitable and likely to induce properties different from conventional aqueous environment due to the severe quenching properties of Sodium Chloride. Circumstances that may arise are off-shore welding of oil drilling rigs, pipelines that ruptured, sealine of leaking ship rivets, etc. Adedayo and Oyatokun [14] examined the effect of welding and simultaneous boundary saline water cooling on mechanical properties of AISI 1013 carbon steel plate. Plate hardness around the vicinity of weld fusion zone increased under all welding conditions with higher values observed as coolant salinity is increased relative to a plain water – cooled weld; giving maximum micro hardness values of 280.1 and 189.3 HV respectively at distance 5 mm from the weld line under the two welding conditions [14]. This variation across the weld zones is depicted in Fig. 6

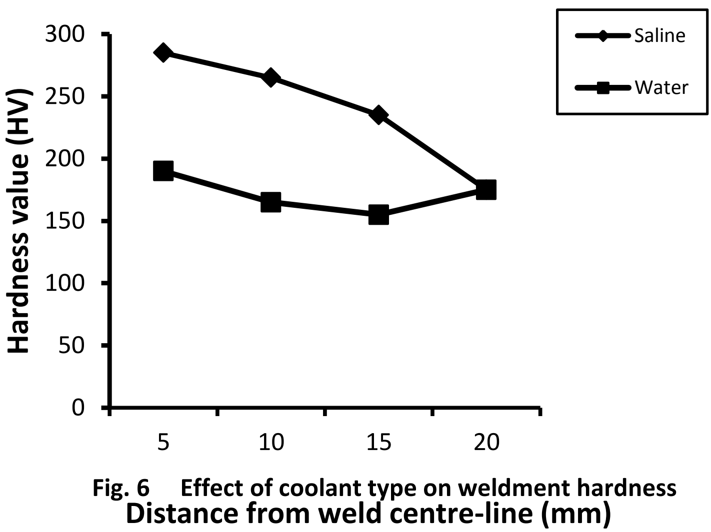

Fig. 6 Effect of coolant type on weldment hardness

The material strength was however reduced under saline water cooled welding conditions

There exists several valuable metals that are highly susceptible to cracks when welded by conventional methods. Spring steels is typical of such metals. Localized heating of the weld plate at the boundary parallel to weld line in the welding of AISI 8438 spring steel was studied. The concept of localized parallel heating aimed at curtailing side effects of welding is an uncommon methodology which we tried and got valuable results. Some energy is saved relative to the conventional total material preheat process. Material toughness was examined and the study observed values of 1.02, 0.88, 0.7 MN/m crack extension force under 600, 400 and 200^{o}C parallel heating conditions indicating that the toughness value increases with increasing localized parallel boundary heating temperatures[15].

As a way of ameliorating the side effects of welding in aqueous environment (commonly referred to as underwater welding process) and possible enhancement of some mechanical properties; Yahaya and Adedayo [16] carried out post weld thermal soaking at different temperatures of AISI 1018 welded plate and examined mechanical properties. Their results show that the aqueous environment as-weld sample exhibited higher hardness and tensile strength of 45.3 HV and 448.12 N/mm^2 respectively while the hardness and tensile strength of the post weld tempered specimen were 44.9 HV and 378.98 N/mm^2respectively. This translates into 0.82% and 15.4% reduction in hardness and strength respectively due to post weld heat treatment. Tendency for crack initiation is reduced with hardness reduction and an improvement in toughness was observed at a particular optimum temperature [16].

Several Aluminium products in an automobile engine and several other engineering products are products of plastic deformation or pressure die – casted. Sieyondji and Adedayo [17] examined the effect of pressure and die temperature on residual stresses across a squeeze die – cast aluminium cylinder. Punch pressure range of between 0 and 110MN/m^2 were examined and die temperature range of 30 – 200^oC. The outcome of this work showed that longitudinal residual stresses increased with applied pressure attaining a maximum compressive value of 50.61 MN/m^2. Also pressure die casting at an elevated die temperature reduced longitudinal, transverse and radial residual stresses by as much as 70% [17].

Residual stresses in quenched and tempered C25 steel materials was examined by Adedayo *et al*.[18]. Quenching was done in both water and oil. Stress relief annealing at 200, 400 and 600^oC was subsequently carried out. Strain gauges were mounted and modified sach boring technique was used in obtaining the residual stresses. Water quenchant induced higher values of residual stresses than oil. A residual stress relief of 27.5, 34.4 and 45.3% for water and 10.9, 25.4 and 30.3% for oil quenchants at 200, 400 and 600^oC thermal stress relief temperatures respectively were reported [18].

4.2 Computer Modelling of Welding and Quenching Processes Research Findings

Beyond laboratory experimental works in welding, I also did extensive computational modelling by direct coding and application of software. Modelling and simulation forms a virtual experimental platform or a virtual laboratory which is very versatile such that many unknowns or results of welding processes can be predicted and tested in advance of final parts joining. It has the potential of overcoming the limitations of physical experiments thus allowing for a more efficient welding process. Prior knowledge of thermal histories in quenching by computer modelling is cost saving and helps in prediction of diverse metallurgical transformation associated with heat treatment. The specific areas of my focus are welding and quenching processes some of which are highlighted here. A two - dimensional finite-difference model capable of predicting temperature history at various points on a solid cylinder in quenching process was carried out by Adedayo and Babatunde [19]. Solution to the Fourier's heat conduction equation coupled with the boundary condition was numerically solved using Finite-difference and energy balance around a nodal system. The resulting numerical equation was solved by Gauss – Siedel iterative method. Hardness variation was derived from simulated cooling curves and Jominy curves. Computed results were compared with a typical practical model as shown in Fig. 7. The results show that the model can reasonably predict temperature histories of quenched solid steel cylinders [19].

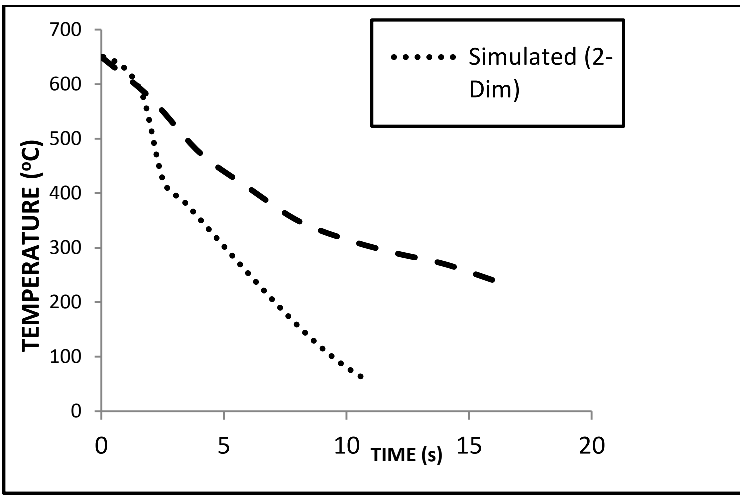

Fig.7: Experimental and Simulated Thermal Histories at Radius 5mm under Water Quench

Simulation of temperature history in the heat affected zone and base metal of a welded plate under preheat and multi-pass welding conditions were analyzed by Adedayo [20]. Fourier's and energy balance equations of heat conduction were used and solved by finite-difference(FD) methods. At a typical distance of 42.5 mm from weld centre-line differences in peak temperature between computer model and experimental was 68^{o}C when plate was preheated to 200^{o}C before welding [20].

Apart from modeling the conventional type of welding which is arc welding of plates, I carried out some work also on uncommon welding methods such as flash butt welding. Flash butt welding is a resistance type metal joining process designed to produce butt welds between two materials of similar cross section. A one – dimensional finite element (FE) modelling of the temperature profile in axi-symmetric flash butt welded steel rods was carried out by Olabamiji and Adedayo [21] , the result was verified by experimentation. A linear interpolation function was used in the weighted residual expression which was transformed into a temperature matrix form. Non-uniform nodal spacing was used in order to capture more details of temperature values around the HAZ in view of the prolonged computational time. At a distance 5 mm from weld centre the thermal profile computed by finite element (FE) model were compared with experimental results. Peak temperature values of 134.8^{o}C and 132^{o}C were obtained for FE modelling and experimental results respectively indicating a good agreement within 2.1% [21].

In furtherance of research efforts in modelling and simulation of weld temperature Bamigboye and Adedayo [22] applied ANSYS 16.0 finite element software in predicting thermal history of flash butt welded bars at diverse welding conditions and bar sizes. Temperature profiles along the longitudinal and radial directions of the bar were obtained. A typical bar diameter of 25 mm and length 250 mm at a flash duration of 4 seconds indicated peak temperature values of 1400, 1238.90, 910.18 and 650.68^{o}C at axial distances 0, 1, 3 and 5 mm respectively from weld centre line [22]. This is graphically depicted in Fig. 8.

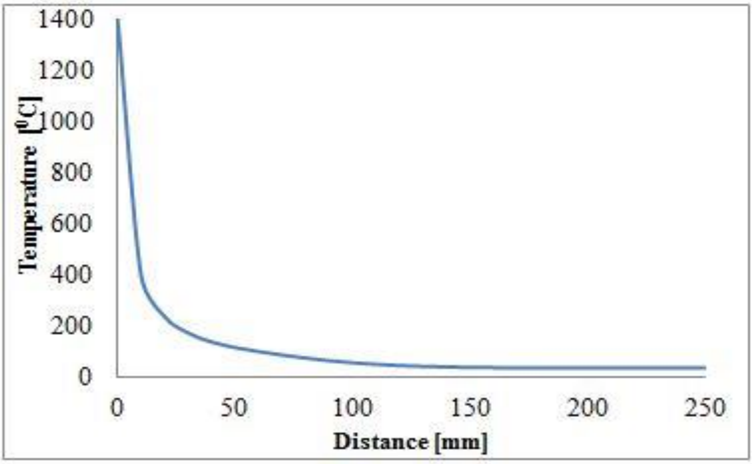

Fig. 8: Peak Temperature Variation with Distance from Weld Centre along the Bar Length

The simulated temperatures were compared with values obtained by other similar works and a close correlation was observed.

4.3 Materials Treatment and Composite Materials Development Research Findings

Adeyemi and Adedayo [23] looked at the possibility of application of locally available vegetable oils as quenchants for hardening medium carbon steel. Specifically groundnut oil and palm kernel oil were investigated. Groundnut oil exhibited superior mechanical properties relative to palm oil as a quenchant. Palm kernel oil quenchants however imparted superior hardness properties compared with groundnut oil. They are both environmental friendly and suitable substitutes to currently applied mineral and synthetic polymer quenchants. Average hardness values of 723, 485 and 317.0 VHN were observed after quenching in respect of water, palm kernel and ground – nut oil respectively while the as – received specimen has 226.0VHN. Palm kernel is a better medium for martempering [23].

There exists various methods of effecting quench agitation towards rapid cooling effect. Adedayo *et al.* [24] developed an approach that draws the work-piece through the quenchant at a predetermined speed. Material strength increased by as much as 19.30% when immersion speed increased by 63.41% [24]. This trend is depicted in Fig. 9.

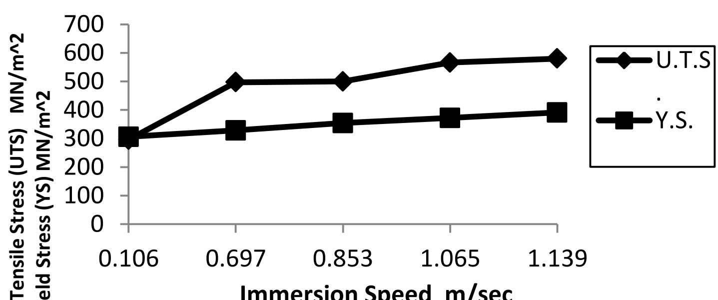

Fig. 9 Variation of Material Strength Properties with Immersion Speed

Several modern engineering products require materials with unusual combination of properties which conventional metal alloys, ceramics and polymeric materials cannot meet, thus justifying the research on composite materials. In what can be considered as transformation of wastes into valuable materials, Iron ore tailings derived from beneficiation of iron ore sourced from

Iron ore company, Itakpe – Okene was used by Onitiri and Adedayo [25] as reinforcement in the making of Iron – ore tailings / Epoxy composites (ITR – EC). Tensile tests were carried out on epoxy reinforced with iron ore tailings at varying volumetric percentages and particle sizes to determine the effect of the filler on the yield strength, tensile strength and Young's Modulus of Elasticity of the epoxy composite produced. The 30% volumetric content of the 300μm particle size of iron ore tailings is the optimum for obtaining maximum Young's Modulus. Relative to the strength of pure epoxy, a reduction in tensile strength of ITR-EC was observed [25].

Further research work on Iron – ore tailings / Polypropylene composites (ITR – PPC) was carried out by Adedayo and Onitiri [26] by looking at compressive behaviour of Polypropylene filled with Iron Ore Tailings. Polypropylene(PP) produced using the Compo – indirect squeeze casting(C-ISC) process exhibited better compressive strength relative to Iron ore tailings reinforced polypropylene composites at particle volume contents above 10% (150μm particle size used)[26]. This work provides an avenue to address the pollutant effect of iron ore tailings by putting it into judicious use through addition as fillers in plastics.

4.4 Machine and Allied Products Development

Further steps were taken in my welding research endeavours towards designing and developing machines, laboratory equipment, domestic appliances, etc. that addresses local needs, suitable substitutes to imported types and addressing perceived shortfalls of those facilities at Laboratory levels. I have designed and developed over 30 products in the range of products classified above that can be described as either a new concept, improved modifications on existing types or exploring locally available materials in making an existing product.(see Table3).

Table 3: Some Selected Product Development Projects Supervised by Adedayo (unpublished)

S/ No	Product(s) Description	Year Developed	Product Class	Perfection State	Present Usage
1	Adjustable height electricity workers ladder	2003	Electricity workers Utility Product	Perfected	Faculty of Engrg And Technology
2	Office fire and burglar proof system	2003	Office appliance	Perfected	HOD(Mech – Engrg) Office
3	Orthopedic wheel chair	1999	Hospital appliance	In – Process	Exhibitions
4	Heavy duty inter-locking Block making machine	2017	Equipment	In-Process	Exhibitions
5	Design, construction and testing of office blind.	2003	Office appliance	Perfected	Staff Office
6	Design and construction of a screw press	2002	Workshop	In-Process	
7	Design and fabrication of a 2mm capacity flat sheet bending device.	2001	Workshop	In – Process	
8	Pressing board, Camp bed, Cloth dryers, Electronics stand, Metal furnitures Etc		Domestic products	Perfected	

Among the published machine products is the Design, Construction and Testing of a DC – powered sliding gate carried out by Adedayo and other researchers [27]. The design principle entails effecting a sliding motion of the gate through a rack and pinion mechanism. It is designed to be battery powered, locally sourced materials and cost effective. The video is depicted in Fig.10. Provisions were made for remote control operations and powering of the DC 50W, 24V motor.

remote controlled gate in operation.mpg

Fig. 10 Powered Sliding Gate Using locally Available Materials (*Video*)

Operational performance tests showed a opening velocity range of 0.21 m/s to 0.15 m/s with a 40 – 80 kg weight gate [27].

Another machine product that had spanned over 17 years of research efforts before present level of perfection is an orthogonal power transmission, engine powered lawn mower.

Abolarinwa and Adedayo [30] built upon previous research efforts on mowers made by Olawuyi, Alayande and Adedayo in 2002 [28], Azeez and Adedayo in 2006 [29] on Design and Development of Lawn Mowing Machines. A 5.5 Horse Power internal combustion engine was used to power the developed mower with power transmission through a belt to a set of bevel gears that drove the cutter. Tests carried out on a lawn of average weed height of 800 mm showed a cutting rate of 3.16

m^2/min with peak vibration level of 152.4 mm/sec. while maximum noise level was 94.1dB[30]. A typical video clip of operation on the mower is shown in Fig.11.

lawn mower in operation.mpg

Fig.11 Developed 5.5HP Lawn Mower in Operation (*Video*)

A typical double bladed lawn mower of about double the capacity of previously developed mower was designed and developed by Jolayemi and Adedayo [31]. A simple capacity test carried out showed cutting rate of 10.16m^2/min. A major emphasis in the design of the mowers is the use of locally available materials as component parts including the cutter.

Inadequate laboratory facilities is one of the major deficiencies of several engineering departments in our tertiary institutions in Nigeria. The major factor responsible for this is inadequate fund to import laboratory equipment. Most laboratory equipment entails high precision manufacturing processes. In order to address this problem I also carried out researches into local development of engineering laboratory equipment some of which are hereby presented. Awe *et al.* [32] in 2017 designed and developed a 5-ton capacity Brinell Hardness Testing Machine which was put to practical usage in the materials laboratory of Mechanical Engineering Department, University of Ilorin. Fig. 12 shows the pictorial outlook of the machine. The focus of the research was the use of 100% locally sourced components without compromising the high accuracy of results required. The machine has dimension specification: Base (602mm × 602mm); Height (1219.2mm) and total Weight is 135kg. A 5-Ton hydraulic jack, with attachments for workpiece support was placed rigidly on the lower I-channel. Spherical steel ball from ball bearings was used as indenter ball, positioned in a casing and rigidly fixed to the upper channel of machine in an inverted position. Hydraulic jack pressure was monitored through oil pressure meter connected through an orificeat the base. An upward movement of the ram lifts workpiece against stationary indenter. Indentation diameter on workpiece is measured with a micrometer travelling microscope. Repeated tests carried out on Aluminium, Copper and Plastic gave diameters 2.9, 3.2, 7.5mm coressponding to 74.10, 60.56 and 9.5BHN. Similar tests carried out on Brinell Hardness Tester Model (EEDB) and serial number (EEDB/13) give 79.6, 69.1 and 9.5 BHN, the percentage variation of locally developed machine from the standard machine used is 6.91, 12.36 and 0% respectively. Test results show good reliability for use in basic material testing.

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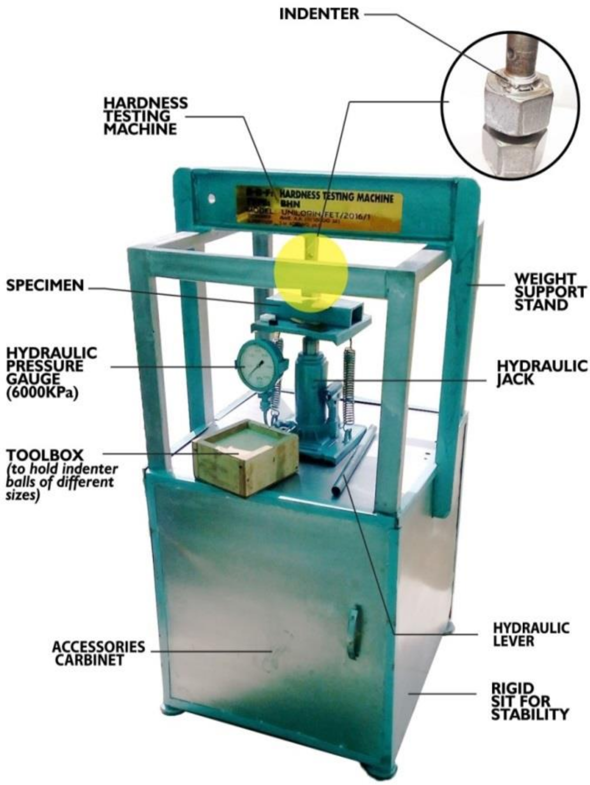

Fig.12: The Completed Hardness Testing machine

Another laboratory equipment in active usage at the Strength of Materials laboratory, Mechanical Engineering Department is a Beam Deflection Apparatus developed by Adedayo and Lawal [33] with the primary objective of obtaining the Young's Modulus (E) of a material. This is depicted in Fig. 13.

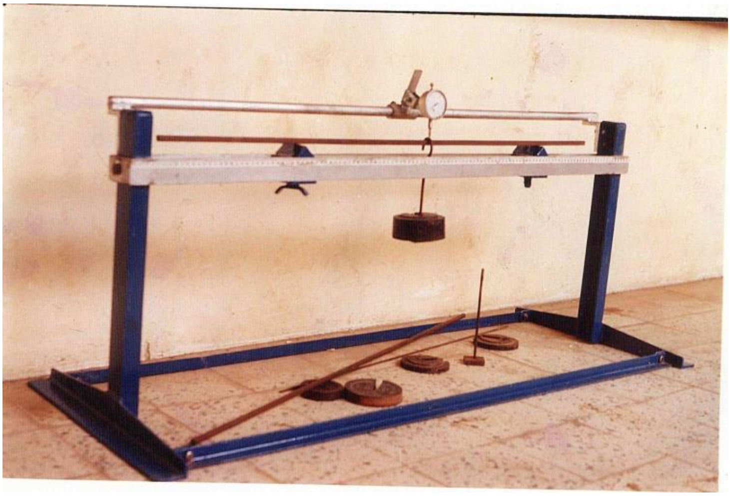

Fig. 13: Laboratory Beam Deflection Apparatus

This is obtained by relating physical dimensions taken on the test specimen (L, I) and slope of a load versus deflection graph obtained from the apparatus with Young's modulus of the test material (E = slope of graph x $\frac{L^3}{48I}$). Good estimate of Young's Modulus of steel were obtained in both circular and square cross sectional bars that were examined. A typical result for a circular bar is as shown in Table 4

Table 4: Experimentally obtained Young's Modulus with Accuracy of Evaluation

Material Length	Experimentally Obtained Young's Modulus	Reference Value of Young's modulus of Steel	Accuracy of Evaluation
L(m)	E_m(GN/m^2)	E_e (GN/m^2)	A(%)
0.60	208	200	96.00
0.70	213	200	93.50
0.80	205	200	97.50
0.90	212	200	94.00

Mr. Vice – Chancellor sir, I have developed, to a reasonable level of perfection many other simple engineering devices for both domestic and organisational use. However, since I am highlighting those in practical use at the University presently, I will like to include two others under basic appliances. It is an anti – burglary and fire-proof safe for keeping classified Departmental documents and an hybrid (Metal/Wooden) electricity workers adjustable height ladder. An anti-burglary / fire proof safe of volumetric size (256 x 10^3) cm^3 and 212 kg weight was designed and constructed for use in the HOD (Mechanical Engineering) office [34].

Fig. 14: Office Anti – Burglary Fire - Proof Safe

It is divided into two compartments. Pulling out of the compartments is effected through a screw mechanism. Locking of the safe is done through Mechanical devices as against the conventional use of keys.

Another utility appliance actively used in the central workshop of the Faculty of Engineering and Technology is a dual material of Metal/Wood adjustable height ladder [35] specifically meant for electricity workers. Conventional electricity poles ladder are made of wood with such disadvantages as low strength and limited level of collapsibility. An improved electrical pole ladder was designed for a maximum load of 100 kg and factor of safety of 3. It has a total length of 7.16 m and three overlapping lengths of 2.85 m in the collapsed state. The uppermost out of the three collapsed ladder segments is made of Benin mahogany wooden material due to electricity safety considerations while the other two are made from thick hollow square steel pipes.

Future Research Endeavours

Mr. Vice – Chancellor Sir, today's lecture touched on the most active areas of my research activities in the past three decades at the University of Ilorin. Apart from scholarly publications which are available to the global academic community, I look forward to focusing on the following research areas in subsequent years.

(i) *Production of Electrical Porcelain Materials from Local Clay Deposits*

Towards making my modest contribution to the development of various engineering products locally, attention will be given to one of the most used component in the electricity industry; that is porcelain insulator. Hitherto this electricity insulating material were imported but research will be intensified by exploring local clay deposits with other mixes under different mix ratios and the possibility of applying rapid prototyping technology in making the same product will also be explored.

(ii) Computer Modelling of Engineering Processes

Computer modelling of engineering processes as an alternative to experimental approach is now an established procedure. By way of improving on my previous research efforts on quenching, I will further look at computer modeling of temperature and residual stresses of materials that are subjected to agitated quenching. Of special interest in one of my earlier research output is agitation through controlled immersion speed. This process will be modelled.

(iii) *Further Development of Laboratory Equipment*

As a nation with great pressure on our foreign currencies, we need to continually focus on domestic development of laboratory equipment at all levels of education. I will further work on the Hardness testing machine particularly with respect to instrumentation and research into Tensile testing machine.

(iv) *Rockie – Boogie Carrier based Lawn Mower*

I hope to improve on the lawn mowers which we have patented towards possible application in difficult terrains as obtained in the University plantations. A rockie – boogie is a mechanism designed to traverse undulating terrains and also climb stair cases. It has six tyres. We will adapt our patented lawn mowers to this devise with the possibility of application on our Teak and Palm plantations where conventional mowers cannot be applied.

Conclusion

Mr Vice – Chancellor Sir, I have attempted in this lecture to present how the potentials in welding engineering processes can be optimized towards accelerated national development. The disparity between the formal and informal welding sectors in terms of practice regulations, training requirements and worth were highlighted. This lecture highlighted the uniqueness of steel as the most common welding material but the significance and welding procedures of a few other materials were discussed.

Recommendations

(1) In view of the large volume of imported vehicles into the country yearly, it is recommended that the Government should support investments in the automobile industry in form of low interest loan and protective policies in form of high import duties on vehicles or their components that are being manufactured locally.

(2) Towards the optimization of material joining towards national development, the informal sector of welding practice which comprises of road side welders and other metal fabricators should be recognized, regulated and supported by Government. Prospective certified welders in this sector should undergo formal training programmes after having a minimum education of School Certificate and welding practice controlled by an appropriate professional body such as Nigeria Institute of Mechanical Engineers.

(3) Power is the life blood of any welding based engineering outfit. It is recommended that a special location be made available in every town for those involved in welding works to set up their workshop with a dedicated power supply from the national grid with stable electricity supply.

(4) A nation could be industrialized without necessarily being a producer of Iron and steel. This is possible by importing the relevant raw materials for processing. Even though billions of dollars had been expended on Ajaokuta steel company in the past 40

years, the country should stop further expenditure on equipment towards making it work. Negotiations should be made with established steel production companies internationally towards outright sales of Ajaokuta steel company. Alternatively a concessionaire can be invited to run the company for a defined number of years. The complexity of operation of a steel plant does not allow for a successful operation as a governmental parastatal.

(5) The general notion about technological transfer is not realistic rather it demands forceful acquisition. The industrialized nations will not cheaply transfer their technology to any nation. It is recommended that creative ideas of metal products should be funded by Bank of Industries with single digit interest loans and further taking steps to protect such markets through import restrictions. Policies that will leave buyers with no alternative other than purchase of locally made goods are strongly advised.

Acknowledgements

I whole heartedly appreciate the Almighty God for being so gracious to me in this journey of life that despite my weaknesses, lifted me up to this level in life. I always testify of His unusual help during my Ph.D programme. I had some health issues during the critical years of the programme, yet He saw me through. To Him be all the glory.

Mr Vice – Chancellor sir, I want to specially appreciate you for granting approval for me to deliver this lecture barely a week after convocation when ordinarily some officers might want to take a break. My choice of

October for my Inaugural lecture was because I turned 60 years this month.

Special thanks goes to my parents Chief Samuel Olawepo Adedayo and Deaconess Aduke Adedayo. Their support, training, guide and encouragement had been tremendous. They live an exemplary disciplined and hard working life making them good reference standards for me concerning work, family life and community services.

I appreciate my uncle Mr Job Adedayo. He was a staff of ABU, Zaria at the time I was doing my undergraduate and post graduate studies at ABU. He was very selfless in his assistantships all through the period we were together in Zaria. As a student on several weekends I visit their house , take meals and get refreshed financially before going back to the campus. I wish to also thank my other Uncles and Aunties within the Adedayo family for diverse supports during my childhood years. May I particularly mention Mrs Bose Bolarin (Nee Bose Adedayo) who lived with my parents in Kaduna and supported my mother in various efforts at taking care of me. Another uncle of mine who is more as a father to us that deserves special appreciation is Dr. S.O. Oloruntoba. All my children were delivered safely in his hospital and at various times offered me major advises that had helped my advancements in life. I appreciate all my other uncles in the Oloruntoba family for their support all through the years. It is also worth mentioning the supports I received from the Abifarins while they were in Ibadan in the 70's and now in Abuja. I pray that the Lord bless you richly. I thank Antie Abiba of Alla - Isin whom I was told was among those that took care of me as a toddler. I appreciate deeply the love and care of those childhood years.

Special gratitude goes to my late father – in – law and mother – in – law, Most Snr Apostle Justus Adeoye and Lady Evangelist Serah Adeoye. The last communication we had about a week before his transition at the University of Ilorin Teaching Hospital in 2012 was "*Segun Yio da fun oo*". They had always supported my family in prayer and offered pieces of advice at various moments. My sister in law, Mrs Nike Bakare, I say thank you for all the support you rendered at the early stage of my marriage by assisting in domestic works and taking care of our children.

I appreciate my cousins, the Olatundes, for the support and good relationship we have enjoyed together over the years. Their home in Lagos has always been opened to all in respect of accommodation and hospitality. God bless you richly.

I acknowledge my Spiritual father, Bishop David Oyedepo, President and Founder of the Living Faith Church Worldwide. His bible teachings and books had guided greatly towards my success journey. I thank Bishop David Abioye, Bishop Thomas Aremu for their spiritual teachings that has guided me and other Resident pastors that have served as my pastor in Ilorin. My special thanks goes to Pst. Israel a former resident pastor of my church who at various times prayed for me and guided me spiritually. I also wish to appreciate the present state pastor, Pst (Dr). Rotimi Daniels for his spiritual guide and covering. I thank Pst. Temidayo Eseyin for his support on various family and career advancement matters. The Pastorate of Living Faith Church, Gaa – Imam, Ilorin to which I presently belong and Deacon's Assembly members I express deep appreciation for the fellowship we enjoy. I thank Rev. Adeloye and Rev. Taiwo who were my former pastors at Zion Baptist Church, Adewole, Ilorin for your prayers.

I acknowledge all my teachers in primary and secondary schools some of whom I may not be able to capture their names correctly. Of special recognition is my former principal at Baptist Grammer School, Isanlu – Isin, Late Mr S.A. Adepoju. He is an exceptionally committed Principal and missionary of whom we the products of that school adore very much till today for the seeds of discipline he sowed into us. I say thank you. I thank my senior at school, Dr. Segun Ige for his academic guide and mentorship in the last two years of my secondary school life. I thank Mr Ezekiel Adewumi who was my classmate and also a very reliable friend. He took the risk of running out of the hall while examination was on-going when he spotted that my seat was empty to wake me up in the hostel.

My former lecturers at Ahmadu Bello University, Zaria I appreciate you all for a very sound engineering training you gave me without which I could not have been a Professor today. Of particular note are Prof. C.O. Folayan (Late) who wrote the preface of my second book on Engineering graphics, Prof. S.Y. Aku , Dr. P. Mathew, Dr. K.P. Zachariah, Dr. J.O.T. Adewara(B.Eng. Project Supervisor), Dr. G. Makarem, Prof. Y.K. Oyinlola, Mr. W.K. Neyman, Mr. Z.J. Brezena, Mrs Grigorova who taught me Engineering Drawing and laid a good foundation for me, a subject in which today I am also an author.

I thank Professors D.S. Yawas, F.O. Anafi, M. Dauda and other academic staffs of Mechanical Engineering Department, Ahmadu Bello University, Zaria for taking the pains to facilitate my second sabbatical leave

in 2017/2018 session. They created a very conducive environment for me to carry out my duties unhindered.

I am very grateful to Prof. M.B. Adeyemi now retired for recommending me for appointment at the University of Ilorin and further supervising my Ph.D degree programme. He gave me a welding related topic which this lecture revolves around. I acknowledge my current Head of Department Dr. I.O. Ohijeagbon for your encouragement and support on all academic and administrative matters, I thank all my senior colleagues (past and present) in the Department of Mechanical Engineering for various inputs you made into my career progression. Professors J.A. Olorunmaiye, F.L. Bello-Ochende (Late), J.S.O. Adeniyi, H.D. Olusegun, O.A. Fakinlede, A.G.F. Alabi and J.A. Omoleye. Other colleagues such as Prof. O.A. Lasode who sacrificed to read through the manuscript of this lecture and offered valuable suggestions , Professors I.K. Adegun , K.R. Ajao, Drs. J.O. Aweda, T.K. Ajiboye, A.S. Adekunle, S. Abdulkareem and H.A. Ajimotokan. All other staff of Mechanical Engineering I say thank you, I enjoy working with you all. I also want to thank Prof. S.F. Ambali of veterinary medicine and Prof. Babatunde of English Department for thoroughly reading through and making valuable corrections.

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presently of Federal University of Agriculture, Abeokuta for his support.

If for any reason I have omitted some personalities that have contributed to my life in the above listings, please accept my apology, it is not deliberate but constrained by time and space.

Last but not the least, I want to thank my darling wife, Mrs Yemisi Adebimpe Adedayo for her tremendous support and understanding over the years. My girls Fisayo (Now Mrs Areo), Damilola and Faith, you all have been most wonderful; I say thank you for being part of my life, I couldn’t have wished for a better family structure if given another chance.

I thank you all for your rapt attention and may the Almighty God bless you all.

References

[1] Welding Careers. www.gowelding.orgaccessed on 18 / 7 / 2019

[2] en.m.wikipedia.org accessed on 18 / 7 / 2019

[3] The History of Welding (Millerwelds). www.millerwelds.com accessed on 17 / 7 / 2019

[4] How Products are made. www.madehow.comaccessed on 18 / 7 / 2019

[5] Devarasiddappa D. (2014). "Automotive Applications of Welding Technology - A Study" International Journal of Modern Engineering Research Vol. 14, Issue 9, pp. 13-19

[6] Adewoye K.R., Awoyemi A.O., Babatunde O.A., Atoyebi O.A., Salami S.K., Issa F.Y. (2014). Effect of health education intervention on the awareness and use of personal protective equipments among small scale electric arc welders in Ilorin, Nigeria. Indian Journal of Occupational and Environmental Medicine, Vol. 18, pp.3-8

[7] Birir K. J. (2015). Investigation of welding quality in the Kenyan Informal Sector. M.Eng Thesis, University of Nairobi, Institute of Nuclear Science and Technology (unpublished).

[8] Parmar R.S. (2004). Welding Engineering and Technology, Romesh Chander Khana Publishers, India

[9] **Adedayo S.M.** (2001). "Measurement of Residual Stresses due to Slab Milling", *Nigerian Journal of Science*, Vol.35, pp.81 – 85

[10] **Adedayo S. M.** and E. O. Odepidan (2002). "Effect of welding speed on Mechanical Properties of an arc-welded steel plate". *Journal of Applied Science and Technology*, Vol. 2 (1), pp.40 – 43.

[11] **Adedayo S. M.** (2002). "Effect of welding speed on Residual Stresses of an arc-welded steel plate", ***Nigerian Journal of Technological Development***; Vol. 2 (1), pp. 69 - 75.

[12] **Adedayo, S. M.** and S.O. Momoh (2010). "Effect of Initial Preheat on Mechanical Properties and Microstructures of Arc-welded Steel plates " ***Indian Journal of Science and Technology***, Vol. 3(12), pp.1224-1228.

[13] Babatunde S.A. and **S.M. Adedayo** (2013). "Effect of Multi – pass on Mechanical Properties of an Arc – welded C25 steel plate." ***Journal of Applied Science and Technology***, Vol.18 (1 & 2), pp.35 - 39

[14] **Adedayo S.M.** and V.O. Oyatokun (2013). "Effect of Saline Water Cooling on Service Quality of a Welded AISI 1013 Carbon Steel Plate". ***International Journal of Engineering***, Vol.11 (2), pp.27 – 30.

[15] Odebiyi O.S., Oseni G.L. and **S.M. Adedayo** (2013). "Effect of Parallel Heating on Properties of a Welded AISI 8438 Steel Plate". ***International Journal of Engineering***. Vol.11 (3), pp.321 – 324.

[16] Yahaya T, **Adedayo S.M.** (2015). Effect of Post - Weld Soaking Temperature on Mechanical Properties of AISI 1018 Steel Plate Welded in Aqueous Environment, ***Proceedings of the 13th, International Conference on Mechanical and Materials. Engineering (ICMME),*** pp.684–688. Published by World Academy of Science. Engineering and Technology.

[17] Sieyondji L. and **S.M. Adedayo** (2010). "Effect of Pressure and Die Temperatureon Residual Stresses Distribution across a Squeeze Cast. Aluminium Cylinder. ***International e–Journal of Engineering. Mathematics: Theory and Application.*** Vol.8 (No 1), pp. 38 – 45.

[18] **Adedayo S.M.,** Adekunle A.S. and Ajiboye, A. (2014). "Effect of Tempering Temperature on Microhardness and Residual Stresses of Quenched C25 Carbon. Steel Hollow Cylinder." ***Journal of Production Engineering,*** Vol.17, pp.13 – 20.

[19] **Adedayo S.M.** and Babatunde S.A. (2012). "Two Dimensional Finite – Difference Simulation of Temperature in Quenched Solid Steel Cylinders", ***Journal of Engineering Research,*** Vol.17 (4), pp.1–13.

[20] **Adedayo, S. M.** (1999). "Computation of the Effects of Preheat and Multipass on temperature Distribution in Arc-welded Steel Plates", ***Nigeria Journal of Pure & Applied Science,*** Vol. 14, pp. 1999 –1013.

[21] Olabamiji, T.S. and **S.M. Adedayo** (2016). "Finite Element Modeling of Temperature Cycles in Axi – Symmetric Flash Butt – Welded Thin Steel Rods and Experimental Validation" ***Journal of Engineering Research***, Vol.21 (1), pp.31 – 40

[22] Bamigboye, J.T. and **S.M. Adedayo** (2018). "Two–Dimensional Finite Element Modeling of Transient Temperatures in Flash Butt Welded bars" ***Technical Journals*** Vol. 23(2), pp.17-23

[23] Adeyemi, M.B. and **S. M. Adedayo** (2009). "Vegetable Oils as Quenchants for Hardening Medium Carbon Steel". ***Journal of Applied Science and Technology (JAST),***Vol.14 Nos 1 & 2, pp. 74 -78.

[24] **Adedayo, S.M.**, Adekunle, A.S. and Oladimeji, T. (2014). Effecting Quench Agitation by Immersion Speed Variation of C 30 Carbon Steel and Mechanical Properties Variation in ***Transactions on Engineering Technologies*** (World Congress on Engineering 2014). Gi-Chul Yang, Sio-Long Ao, Leo Gelman (editors). pp.201 – 211, London.

[25] **Adedayo, S.M.** and Onitiri, M.A. (2012). "Mechanical Properties of Iron – Ore Tailings filled Polypropylene Composites." ***Journal of Minerals and Materials Characterization and Engineering***, Vol.11 (7) pp. 671 – 678.

[26] Onitiri, M.O. and **Adedayo, S.M.** (2015). "Compressive behavior of Polypropylene filled with Iron – Ore

Tailings" ***Journal of Engineering, Design and Technology.*** *Vol.13 (2), pp.198 - 212*

[27] Ige, J.A., **S.M. Adedayo** and K.O. Abdulrahman (2016). "Design, Construction and Testing of a 3.04m/60 kg/ 50W, 24V D.C. Capacity Electrically Powered Sliding Residential Gate" ***Journal of Research Information in Civil Engineering***, Vol.13 (1), pp.790 – 800.

[28] Olawuyi, A.A. and Alayande, A.O. (2002). "Design and Construction of an Electrically. Powered Lawn Mower", Final Year Student's Project, Department of Mechanical Engineering, University of Ilorin, Ilorin, Nigeria (unpublished)

[29] Azeez, A.B. (2006). "Design, Construction and Testing of a Lawn Mower Powered by Petrol Engine", Final Year Student's Project, Department of Mechanical Engineering, University of Ilorin, Ilorin, Nigeria, (unpublished)

[30] Abolarinwa, E. and **S.M. Adedayo** (2018). "Design, Development and Testing of an Orthogonal Shaft Transmission Lawn Mowing Machine", ***Leonardo Electronic Journal of Practices and Technologies***, Issue 32, pp.173-182

[31] **Adedayo, S.M**. and Jolayemi, O.O: A Push – Type Twin – Bladed Internal Combustion. Engine Powered Shrub/Lawn Mowing Machine; Patent No: RP: NG/PT/NC/2019/3441 Date of Patent: 16th January, 2019

[32] Awe, A., **Adedayo, S.M.** and Olabamiji T. (2019). Design, Development and Performance Evaluation of a 5-Ton Capacity Brinell Hardness Testing Machine Presented at the 3rd International Conference of Engineering for a Sustainable World (ICESW), Covenant University, Ota, 3rd – 8thJuly..

[33] Lawal, R.A. (2003). Design, Construction and Testing of a Laboratory Beam Deflection Apparatus Final Year

Student's Project, Mechanical Engineering Department, University of Ilorin, Nigeria. (Unpublished).
[34] Adejuwon, A.N. (2003). Design and Construction of a $0.256m^3$ capacity Fire and Burglar proof system. Final Year Project, Mechanical Engineering Department, University of Ilorin, Nigeria, (Unpublished).
[35] Amoo, A. O. (2003). Design and Construction of an Adjustable Height Ladder, Final Year Project, Mechanical Engineering Department, University of Ilorin, Nigeria (Unpublished).