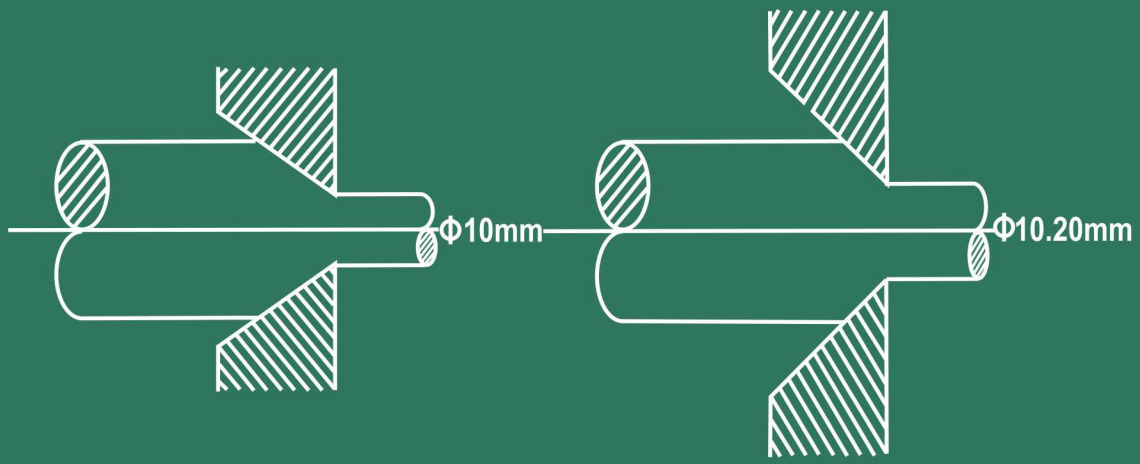
ISSN: 0794 - 7976



PROCEEDINGS

of the

NIGERIAN ACADEMY OF SCIENCE

Volume 6, 2013

Contents

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Vol. 6, Issue 1, 2013, pp. 1 - 3

PERSPECTIVES:

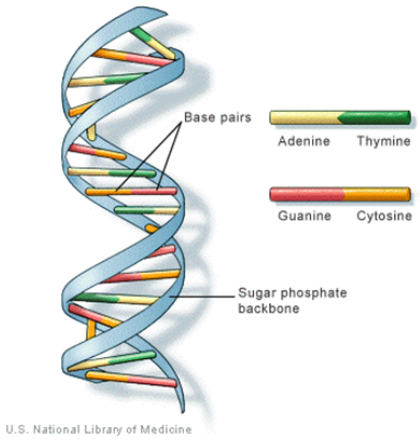
THE INCREASING CROSS-TALKS BETWEEN THE "DRY" AND "WET" SCIENCES

P.O. OKONKWO, FAS

In the early 1960s, the Higher School Certificate Course was the track to direct entrance to Nigerian universities. There was a clear dichotomy between those who opted for Additional Mathematics, Mathematics and Physics and those who followed the "wet sciences" of dissections, buffers, enzymes in Botany, Zoology and Chemistry. The would-be "dry scientists" toted around slide rules, mathematical sets, and pencils and were destined for careers in the computational sciences and engineering. Those in the "dry areas" acted as if they were smarter, and the two groups lived in different scientific worlds. Increasingly, however the two scientific worlds are having serious conversations.

Exactly sixty years ago, James Watson and Francis Crick announced to an astonished world that they had deciphered the structure of Deoxyribonucleic Acid (DNA), the building block of life, [1] . I remember as a young PhD student visiting the Cricks in Cambridge and gawking in awe at a five foot paper model of DNA on their porch and wondering to myself how anyone could have made such a stupendous discovery. Many now believe that the honors and Nobel Prize should have been extended to a brilliant, beautiful, but doomed X-ray crystallographer, Rosalind Franklin, whose data was delivered to the duo of Watson and Crick without her knowledge. Crick was a physicist, Watson a virologist, but without Franklin's data no one would have predicted the double helix and the genetic code. This was a case of physics talking to biology at the Cavendish laboratory where many things are discovered. Sadly, Ms. Franklin died of cancer at the age of 37. Before the discovery of DNA, there were many claimants to the discovery of the compound microscope. In my opinion, it was Leeuwenhoek who, in the late 17th century, first observed bacteria and yeasts in a drop of water

and presented his observations to the Royal Society of England and the French Academy, [2]. Without the microscope, microbiology would have remained in its infancy. There are now few areas of science where computational and dry sciences do not loom large. In discovery of new drugs, combinatorial chemistry is now routine. Many years ago, we were involved in treating large populations of river blindness patients with the drug ivermectin, [3]. The drug was magical in that a single tablet was effective in clearing skin and ameliorating eye lesions for up to a year, and yet the drug disappeared from the body within twenty-four hours. This phenomenon is common with chemotherapy where the curative agent disappears from the body before the destruction of the parasite or bacteria commences. I traveled to the University of Buffalo, USA in 2006, at the age of 64, to undergo a course in pharmacodynamic modeling in order to suggest an explanation for this phenomenon. This would have been unnecessary if we had had willing collaborators in computational sciences, or if I had had requisite courses in advanced calculus as a young man. Incidentally, it has just been announced that our ivermectin may also be useful in malaria prevention, [4]. In our universities now, students run away from dry sciences with the exception of the engineering sciences. A Vice-Chancellor had several professors of Mathematics, but no students. He even offered scholarships for new students, but there were no takers. The situation is quite grave. A plan is to be devised to rescue pure sciences as a whole. Mathematics should



be emphasized from kindergarten, and there should no longer be a gap between the dry and wet sciences. Therefore, as we celebrate 60 years of the discovery of the structure of DNA, (structure is shown above courtesy of U.S. Library of Medicine) let us inculcate the collaborative

spirit that engineered that iconic feat. Let us encourage the study of Mathematics and at the same time affirm the unity of all Science.

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Proc. Nigerian Acad. Sci.
Vol. 6, Issue 1, 2013, pp. 4 - 15

SALT INTAKE, SALT SENSITIVITY AND HYPERTENSION IN NIGERIANS: AN OVERVIEW.

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Abstract. It is widely recognized that a high dietary intake of salt can result in hypertension and various studies have confirmed this link. Epidemiological studies have shown that communities that consume large amounts of salt in their diet have a high incidence of hypertension. Studies in experimental animals show that giving high salt in the diet can result in high blood pressure. Some of the mechanisms responsible for this observation include enhanced constriction response as well as reduced relaxation of resistance vessels. There also appears to be sexual dimorphism in the responses. In humans, our experiments have reported elevated blood pressure in response to oral salt loading and this elevation or Salt Sensitivity may be related to increased salt retention. Some suggestions include genetic defect in the renal tubules in the handling of sodium ions, due to mutation in the Epithelial Sodium Channel (ENaC), which is common in blacks. Our studies with the drug, amiloride that blocks ENaC tend to confirm this, as well as experiments that test sympathetic nervous system mechanisms by the Cold Pressor Test (CPT) which confirm vascular hyperreactivity. Subsequently we hope to conclude genetic studies on ENaC polymorphism and mutations in our subjects. The eventual goal is the development of screening mechanisms to identify individuals that are salt sensitive and so advise on dietary salt restriction in order to reduce the incidence of hypertension.

1. Introduction

Salt or sodium chloride has been used over the years as food condiment as well as preservative. Over the millennia it has been available

Key words and phrases. Salt, Hypertension, Salt Sensitivity, Epithelial Sodium Channel (**ENaC**).

* Corresponding author.

from sources including sea water, rock salt and recently, manufactured industrially. The universal use of salt has also resulted in behavioural trends in which its consumption level varies in many different communities. Sodium in salt is the major cation in the body fluids and blood. Its osmotic property allows it to attract water along with it especially at the nephrons such that excessive salt intake can result in expansion of blood volume which can result in high blood pressure or hypertension.

Thus, there is extreme interest in the relationship between the amount of salt consumption in food and the level of arterial blood pressure. The recommended average daily intake is about 5g (or 86 mmol) per day, equivalent to about 1 teaspoon but actual consumption ranges between 1 g per day to as high as over 10 - 12g in some populations (Meyer, 2010). Epidemiological studies have shown a correlation between the level of salt intake and the incidence of hypertension. For example, communities that consume very little or no salt in their diet such as Eskimos, Kalahari tribesmen of Southern Africa and Yanomamo Indians in Brazil among others have incidence of hypertension which is virtually zero whereas those that consume a high salt in their diet such as the inhabitants of Northern Japan do have incidence of hypertension that is as high as 40% of the population (Oliver, Cohen, & Neel, 1975). Indeed the most well known community with regard to low salt intake are the Yanomamo Indians on the border of Venezuela and Brazil who have been reported to ingest as little as 0.46g/day (20mmol/day) of sodium (Food and Nutrition Board, 2004) and at the age of 50 years, the average blood pressure in this community is only 100/64 mmHg (Meneton, Jeunemaitre, De Wardener et al, 2005).

A large scale study that involved 52 centres in 32 countries and encompassing over 10,500 subjects, the INTERSALT study (INTERSALT 1988), found a correlation between the quantity of salt consumption and the level of blood pressure. Salt intake was estimated from the quantity of sodium excreted in urine in 24 hours which is termed 24 hours Urinary Na excretion. By contrast, another study that looked into the effect of salt restriction in the diet, the Dietary Approach to Stop Hypertension (DASH) showed that reduction of salt intake in the diet resulted in the lowering of blood pressure in both normotensive and hypertensive subjects (Sacks, Svetkey, Volman et al, 2001). The DASH diet which has been made popular in the United States involves the reduction in consumption of high salt-containing processed

food and replacements with fruits and germ cereals. The results show significant beneficial effects on not only blood pressure but also on cardiovascular well-being. A recent meta-analysis of studies on salt and blood pressure has estimated that reduction in salt intake of $5gm$ (1 teaspoon) could result in 25% fewer strokes and other cardiovascular events (Meyer, 2010).

The afore-mentioned observations became an impetus to embark on studies to find out the mechanisms by which high salt in the diet can result in elevation of blood pressure. Studies were then carried out on experimental animals in order to test the effects of high salt diet on blood pressure. Previously, Dahl (Dahl, Heine & Tassinari, 1962) had developed genetically-selected rats that developed hypertension when subjected to a high salt diet, the so-called Dahl Salt Sensitive (Dahl-SS) rats, as well as the subset of salt resistant strains or Dahl-SR rats. However, in our studies we have used normal or non-genetically selected Sprague - Dawley (SD) rats. If weanling SD rats of 4 - 6 weeks of age are fed a high salt diet containing 8% sodium chloride, for about 6 - 8 weeks, they often developed high blood pressure (Miyajima & Bunnang, 1985; Obiefuna, Ebeigbe, Sofola et al, 1991). Other studies involving chimpanzees (Denton, Weisinger, Mundy et al., 1995). or dogs (Hainsworth, Sofola, Knill & Drinkhill, 2003), fed with high salt diet have also reported elevated blood pressure in these experimental animals.

2. **Studies on Experimental Animals**

In our rat studies, high dietary salt intake resulted in high blood pressure which can be attributed to vascular mechanisms. We therefore set out to investigate the responses of isolated blood vessels of rats and dogs that have been fed a diet that has a high salt content. In arterial vessels, which we studied by using isolated aortic ring segments (Figs 1, 2), or the pressurized mesenteric artery preparation (Fig 3), a high salt diet resulted in enhanced constriction tone (Obiefuna, Ebeigbe, Sofola et al, 1991; Sofola, Knill, Hainsworth et al., 2002) as well as reduction in relaxation responses to agonists (Sofola, Knill, Myers et al, 2004), both factors that will increase vascular resistance and hence blood pressure. In addition, the veins which act as conduit vessels, that return blood to the heart, also show enhanced constriction tone after a high salt diet in the dog (Hainsworth, Sofola, Knill et al, 2003). The effect of this is that venous return to the heart will be increased leading to high cardiac output and hence high blood pressure.

The reduced relaxation response that we reported in arterial resistance vessels was shown to be mediated by changes in the signaling mechanism in the vessel where the usual vasodilator agent - the Endothelium Derived Relaxing Factor (EDRF) is replaced by another vasodilator agent, the Endothelium Derived Hyperpolarizing Factor (EDHF) (Sofola, Knill, Hainsworth et al., 2002). In these experiments, perfused and pressurized mesenteric vessels exhibited identical relaxation responses to acetylcholine but this response was reduced by the inhibitor of Nitric Oxide Synthase (NOS), N-methly L-arginine methyl ester (L-NAME) in rats fed a high salt diet, but abolished by blocking EDHF with apamin and charybdotoxin in both normal salt and high salt rats (Sofola, Knill, Hainsworth et al, 2002). We have also reported reduction in cyclic- AMP mediated relaxation responses in isolated aortic ring preparation (Sofola, Momoh, Igbo et al, 2003). Equally, the concurrent administration of potassium ions (K+) or the drug spironolactone, a potassium-sparing agent, has been shown to reverse or inhibit elevated blood pressure as well as the constriction responses of blood vessels to agonists following a high salt diet (Sofola & Adegunloye, 1998). This observation is important in that it has been well reported that intake of potassium e.g. in fruits as well as calcium as in skimmed milk, can reduce the tendency to develop high blood pressure, as shown as part of the recipe of the DASH diet (Sacks, Svetkey, Volman et al., 2001). In addition, we have reported that the male hormone, testosterone, whenadministerd exogenously, may actually reduce the tendency for blood vessels to contract and so prevent development of hypertension in contrast to the belief that this hormone contributes to the higher incidence of hypertension in males (Oloyo, Sofola, Nair et al, 2011). However, following orchidectomy, the elevation in blood pressure in response to a high salt diet is reduced suggesting that endogenous testosterone production contributes to blood pressure elevation via genomic mechanisms (Oloyo, Sofola & Anigbogu, 2011), in contrast to the vasorelaxant action of exogenously administered testosterone, acting via non-genomic mechanisms (Oloyo, Sofola, Nair et al, 2011).

3. **Salt Loading and Blood Pressure in Human Subjects**

Following several reports and experiments in laboratory animals, we have now shifted our focus to studies in human subjects. As mentioned earlier, dietary salt intake can be evaluated from the 24 hour urinary excretion of sodium ion. Experiments were carried out in which oral salt of 200 - 400 mmol (about 11 - 22g of salt) was given to subjects over a period of three days. Blood pressure and other parameters such

as serum levels of sodium and potassium as well as urinary excretion of these ions were then monitored (Azinge, Mabayoje, Sofola et al, 1999). The background to these series of studies is based on reports that blacks e.g. African Americans or native Africans do have a higher incidence of hypertension when compared with Caucasians. Furthermore, it has been shown conclusively that blacks tended to respond with a high blood pressure in response to salt than their Caucasian counterparts. The incidence of salt sensitive hypertension in normotensive and hypertensive Caucasians in the United States is about 29% and 56% respectively compared with 43% and 72% respectively in normotensive and hypertensive African Americans (Weinberger, 1996). In Nigeria, the incidence of hypertension has recently been reported to be about 32.8% (Ulasi, Ijoma & Onodugu, 2010). In a study in Britain, the incidence of hypertension in blacks living in South London has been reported to be as high as 50% (Cappucio, Cook, Atkinson et al). There thus appears to be a higher association between salt intake and hypertension in blacks. This may have some relationship to salt sensitivity.

Salt sensitivity in blacks has historical and scientific backgrounds. The historical background on bio-history of slavery suggests that surviving "slaves" after the transatlantic shipment did survive because of their possessing inherent sodium conserving mechanisms during heat exposure and this trait was then transferred to later generations (Wilson & Grim, 1991). However, lately it has been shown that some aspects of salt sensitivity in blacks is possibly related to defective Epithelial Sodium Channel (ENaC), which is the membrane channel mechanism that regulates the final adjustments for sodium reabsorbed at the distal tubules of the kidney thus regulating the final amount of sodium ions that are retained in the body. A defective channel that results in excessive sodium reabsorption will lead to its accumulation in the body and hence cause the tendency for blood pressure to increase. This defect in ENaC occurs in about 5% of hypertensive blacks in the United States compared with less than 1% of Caucasians (Baker, Duggal, Dong et al, 2002). The defect has been linked to a transmutation of T594M gene, where Threonine is exchanged for Methionine, in the β subunit of the genes. The ENaC is regulated by Aldosterone and is Amiloride-sensitive. Thus the drug Amiloride can be useful in cases of hypertension with defective ENaC (Baker, Duggal, Dong et al, 2002).

Our current studies are thus looking at:

- Salt Taste Threshold variability in individuals

- Salt sensitivity of blood pressure in normotensive and hypertensive Nigerians
- Blood pressure responses to neurally-mediated sympathetic challenges using the Cold Pressure Test and
- The role of ENaC in salt sensitivity in normotensive and hypertensive Nigerian subjects

Salt Taste threshold (STT) examines individual perception of salt taste at different salt concentrations. A high salt taste threshold will suggest tendency to a high salt consumption because of the reduced taste perception for salt which can then lead to an increase in its consumption and hence a rise in blood pressure. Some studies in our environment have reported correlation between a high salt taste threshold and hypertension (Obasohan, Ukoh, Onyia et al. (1992).

Salt sensitivity describes the propensity of individuals to show meaningful changes, increases or decreases, in mean arterial blood pressure (MABP)in response to sodium repletion or restriction respectively (Sanders, 2008). Hypertensive subjects are generally more salt-sensitive than normotensive subjects (Franco, Oparil, 2006; He, Gu, Chen et al, 2009). Salt sensitivity is useful in predicting target organ damage such as left ventricular hypertrophy, renal dysfunction, and increased mortality (Titze & Machnik, 2010). Salt sensitivity is determined when the Mean Arterial Blood Pressure (MABP) increases by $\geq$ 5mmHg following a salt load (Cooper & Hainsworth, 2002; Schmidlin, Forman, Sebastian et al, 2007). Preliminary results among our Nigerian subjects, following salt loading with 200mmol sodium daily for 5 days, have shown that salt sensitivity occurred in 52% of normotensive subjects and in 60.7% of age-matched hypertensive group of subjects respectively (Elias, Azinge, Umoren et al, 2011).

4. **Salt sensitivity and Salt Reactivity**

The Cold Pressor Test (CPT), determined from blood pressure response to cold immersion of the foot in ice slurry at $4°C$, was carried out in our normotensive and hypertensive subjects before and after salt loading with 200mmol of sodium daily for 5 days. The CPT allows categorization of vascular reactivity in subjects. Hyperreactivity occurs when the elevated blood pressure response to the CPT is $\geq$ 15mmHg, systolic or diastolic (Kasagi, Akahoshi, Shimaoka, 1995; Chen et al, 2008). Our recent preliminary results have shown that 71%

of normotensive subjects and 68.2% of hypertensive subjects are hyperreactive and these figures increased and reduced respectively following salt-loading. More subjects are being recruited to study this in more detail.

Results from our laboratory also show that salt sensitivity among normotensive and hypertensive subjects is positively correlated with systolic reactivity. Being a predictor of the tendency to develop hypertension, this Cold Pressor Test is being developed as a screening test for pre-hypertensive subjects among our populace.

Our current on-going work seeks to eventually develop scientifically based criteria for determining salt sensitivity in an individual and therefore the prediction of hypertension in Nigerians. If this is established, we can therefore carry out dietary counseling to susceptible individuals so as to reduce the tendency towards developing high blood pressure. Our experiments on the assessment of ENaC will also allow us eventually to develop a possible genetic marker for identifying those with defective ENaC gene. The ultimate is to be able to carry out real genetic studies in order to determine actual genetic profiling, identify genetic determinants and hopefully determine the genomic mechanism for salt sensitivity and hence of salt induced hypertension.

In conclusion, the large number of studies on experimental animals and man has linked a high intake of salt with the possibility of developing hypertension. However, not everyone will develop hypertension from the intake of salt but a large proportion of people that are salt sensitive will do so. Therefore a reduction in the quantity of salt in cooked food for both normotensives and hypertensives, avoidance of high consumption of processed food, development of the habit of NOT adding extra salt to table food, identification of salt sensitive individuals and their dietary counseling will go a long way in reducing significantly, the incidence of hypertension as a result of salt intake in Nigerians.

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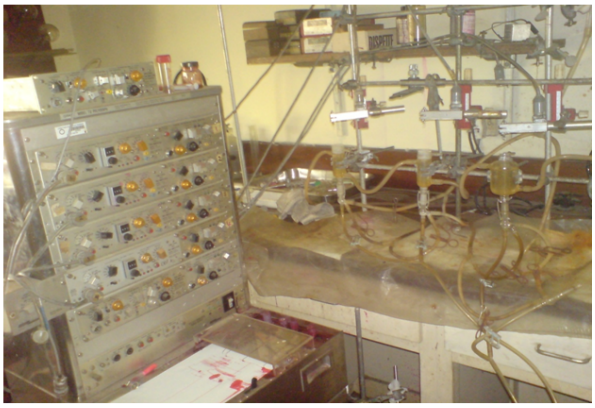

FIGURE 1. Grass Polygraph Model 7D Recorder and Organ Baths. The aortic rings are suspended in an array of organ baths which can record from 3 to 4 rings simultaneously

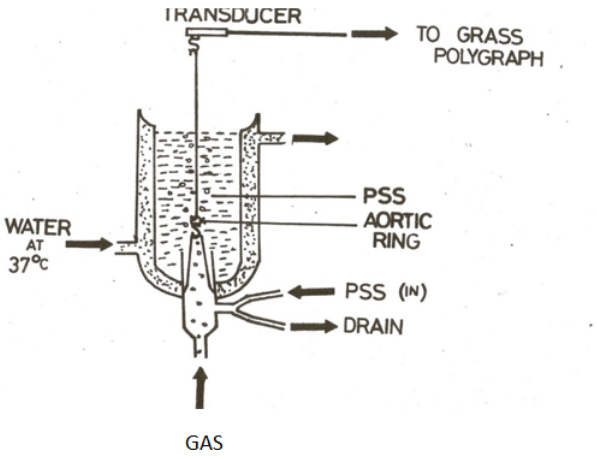

FIGURE 2. Schematic diagram of an Organ Bath. The aortic ring is suspended between a hook at the bottom of the bath and a Force transducer above and perfused with Physiological Salt Solution (PSS) at $37°C$ bubbled with $95\%O_2$-$5\%CO_2$ gas mixture. The Force transducer is connected to the Grass polygraph to record tension developed by the ring during experimentation

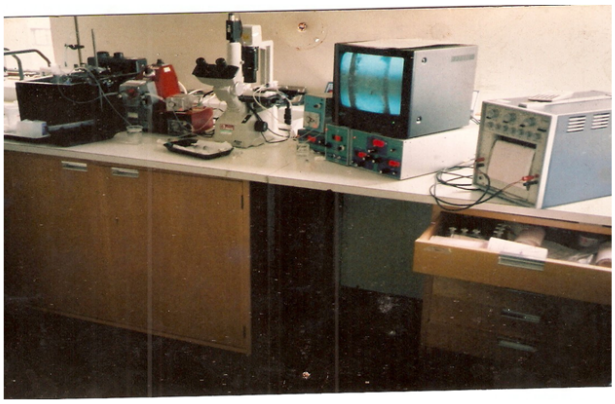

FIGURE 3. Pressurized vessel set up. The mesenteric artery is viewed with an inverted microscope (on the left), connected via a video camera, to a monitor which records the luminal diameter of the vessel digitally (displayed below the screen). Constriction of the vessel results in decreased diameter which can be measured.

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Proc. Nigerian Acad. Sci.
Vol. 6, Issue 1, 2013, pp. 16 - 32

PRECISION DIE DESIGN BY THE DIE EXPANSION METHOD

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Abstract. A new method for the design of precision dies used in cold forging, extrusion and drawing processes is presented. It is based on die expansion. It attempts to provide a clear-cut theoretical basis for the selection of critical die dimensions for this group of precision dies when the tolerance on product diameter (or thickness) is specified. It also presents a procedure for selecting the minimum-production-cost die from a set of design alternatives. The results show that as external die diameter increases, die expansion decreases while die strength increases. Also, as the degree of die compounding increases, die expansion decreases and die strength increases. Comparison of theoretical and experimental results shows good agreement especially at full die cavity filling stage. Die selection from a set of multi-layer dies is based on the die that has minimum Design Effectiveness Index (DEI) which gives the minimum-production-cost die. It is hoped that the design method, apart from providing solutions to simple design problems, can be applied as a first approximation to the solution of more complex problems, based on a clear-cut theory rather than the usual rule-of-thumb method. Thereafter, more sophisticated computer-based methods may be applied for refinement.

1. Introduction

Precision dies are dies used to produce net or near-net shapes which require little or no post-forming processing such that they may be used in the as-formed state. Thus, precision dies find application in metal forming operations (such as in forging, extrusion, drawing and press-work), metal-casting (die-casting, lost-wax casting, etc) and polymer

Key words and phrases. (Engineering) Die Design, Die expansion, Product tolerance.

processing (injection molding, compression molding, etc). This work however is restricted to metalworking precision dies.

Die design, no matter the area of application, depends heavily on experience gathered over the years. There are usually no fixed rules for the design of dies as different approaches could lead to the same result though in differing degrees of success. However, certain principles developed over the years through practical experience exist which when applied could lead to acceptable products produced at competitive costs. Thus, a good number of works exist in which these principles have been outlined. Examples include the works of Lantrip et al[1], Lange[2], Thomas[3], ICFG[4,5] and Smith[6].

With the widespread use of the computer, there is now the tendency to de-skill die design in order to reduce associated cost and lead time. The following methods have been applied: computer-aided design/computer-aided manufacturing (CAD/CAM) (Akgerman and Altan[7], Yu and Dean[8], Nategh and Bakhshi-Jooybari[9]), the finite-element method (FEM) (Rowe et al[10], Kobayashi et al[11]), and intelligent knowledge-based systems (IKBS) or expert systems (Sevenler[12], Osakada and Yang[13], Hartley et al[14], Bakhshi-Jooybari et al[15, 16]).

Despite these improvements based largely on experience, it is still important to provide some theoretical basis for die design or some aspects of it, which will aid the universal application of principles. For example, such principles could be used across a range of processes such as forging, extrusion and drawing without having to devise unique rules for each separate process. This work presents a new method for the design of the precision dies used in cold-forging, extrusion and drawing processes. The method is based upon die expansion, and attempts to provide a clear-cut theoretical basis for the selection of critical die dimensions for this group of precision dies when the tolerance on product diameter (or thickness) is specified. It also includes a procedure for selecting the minimum-production-cost die from a set of design alternatives.

2. **The Die Expansion Method**

Design Philosophy: Understandably, precision-formed products are usually made in the cold state, specifically at room temperature where the dimensions of product can be controlled precisely. Heat expansion of dies and scaling of products are eliminated. In the cold-working state, deformation loads are usually very high and metal flow

is small compared to those encountered in hot-working. Axisymmetric shapes lend themselves to cold-forming because they require no extensive redistribution of material. Therefore, we can safely state that most precision metal working dies are used for producing axisymmetric products.

A critical dimension of all axisymmetric products is the diameter of the wall, 2a, which is in contact with the die wall during forming, where a is the radius of the product. During forming, the die deforms elastically. Thus, the die wall expands as shown in Figure 1 all dies just like any other solid metal expands when loaded.

In all completely closed cavity forming operations, when the load is removed the die stresses are relieved and the die wall recovers but not fully due to the internal pressure still acting on it from the workpiece. It is known in practice that, the die wall does not recover fully on removal of the forming load because some force is required to eject the workpiece from the die; and re-loading the workpiece into the die after ejection also requires a load to do so. Additionally, measurement of workpiece diameter after ejection shows that it is usually greater than the die bore.

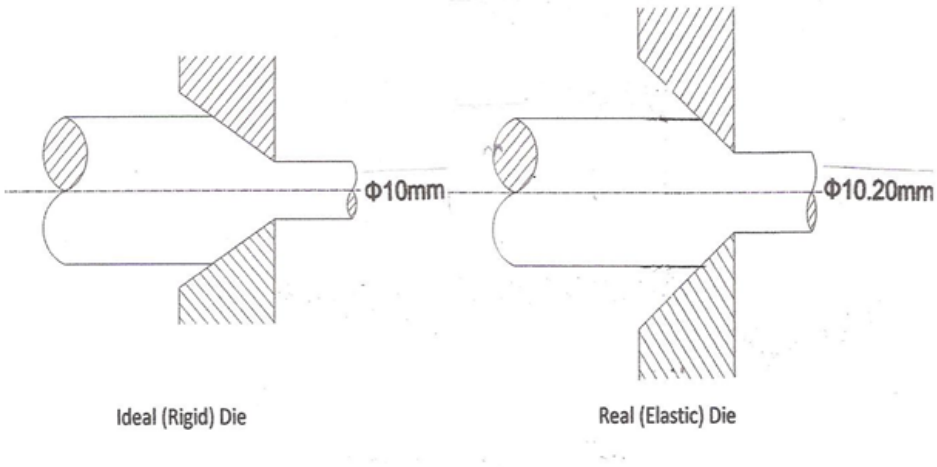

FIGURE 1. **Comparison of ideal (rigid) and real (elastic) dies under same impressed load**

For open die extrusion and drawing processes, where there is always an impressed forming load as the product is being continuously formed, the product flows out with the expanded diameter of the die orifice.

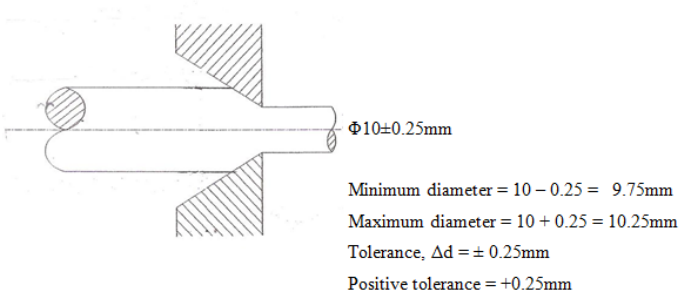

FIGURE 2. **Tolerances on a particular product**

These additional dimensions to the nominal dimensions of the formed products arising from die expansion are causes of inaccuracies in the final dimensions of products. These inaccuracies in product dimensions brought about by die expansion can be transferred to tolerances specified on the product as shown in Figure 2. Thus, by limiting these inaccuracies to the positive tolerance on workpiece dimension, the die dimensions may be selected. This is what the die expansion method for precision die design seeks to achieve[17, 18].

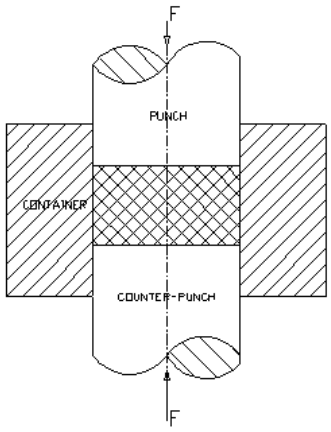

FIGURE 3. **A completely closed cavity die**

In completely closed cavity-die processes (Figure 3), the method may also be extended to select the dimensions of the punch and counter-punch by considering the positive tolerance on product thickness or height.

The design method is derived for cylindrical dies with plain bores. Figure 4 shows how the method may be applied to rectangular blocks in which a cylindrical die has been fitted, and to a die with a complex internal feature. Depending on particular applications, the method may also be used as a first approximation, on which FEM and IKBS may be used for refinements or detailed studies, for example, the use of the simulation software - SimufactForming [19].

Scope of the Method: The die expansion method of die design may be applied to the following processes:

(*i*) Completely - closed cavity die forging as shown in Figure 5 and their variants.
(*ii*) Extrusion processes as shown in Figure 6.
(*iii*) Drawing processes such as rod or wire and tube drawing as shown in Figure 7.
(*iv*) Cold compacting in powder metallurgy products similar to Figure 5.

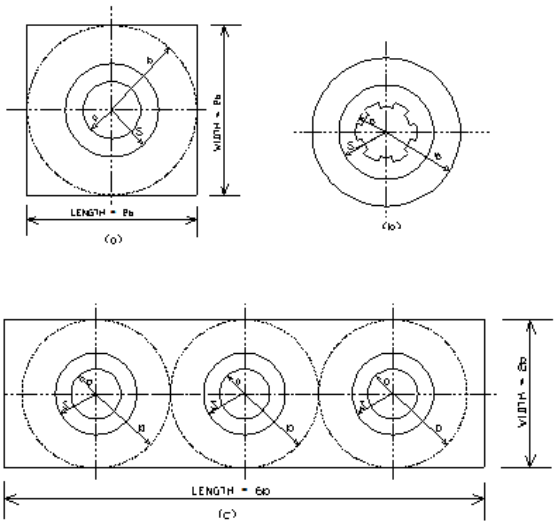

FIGURE 4. **Extension of the design method to other forging dies**

Design: The **Die Expansion Method** has evolved over the past 20 years from work on precision die design starting in 1987 with the development of a model by Ibhadode and Dean [20] to explain the increase in the diameter of a forging over its die bore after ejection in a completely closed cavity die. Further work was done by Ibhadode [21, 22, 23, 24, 25, 26, 27, 28]. The die consists essentially of a punch, counterpunch

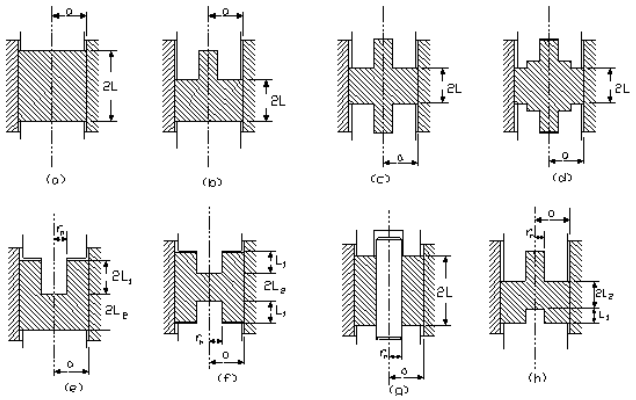

FIGURE 5. **Closed cavity die forging**

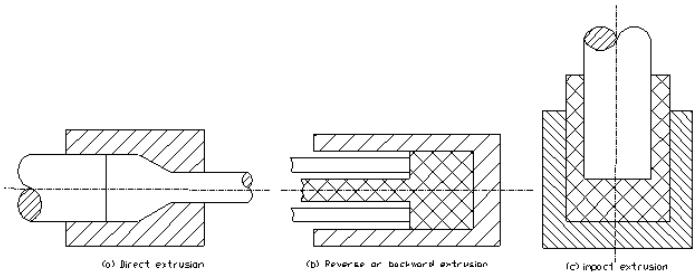

FIGURE 6. **Extrusion processes**

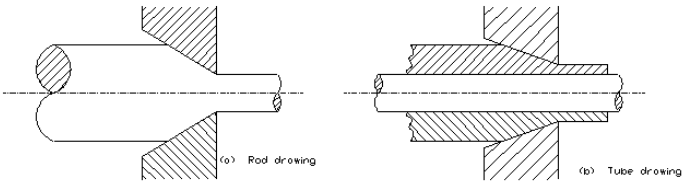

FIGURE 7. **Drawing processes**

and die container. During forming, the container expands under the forming load F by Δa_F at the die bore of diameter $2a$. For processes in which the exiting product is under pressure such as in wire/rod/tube

drawing and extrusion processes, the impressed die expansion on the exiting product is Δa_F. For processes in which the final product is obtained after the release of the forming load as in forging processes, there is a residual die expansion Δa_0 at the bore after release of the forming load. Thus, the final product is impressed with this residual die expansion Δa_0.

The **Die Expansion Method** of design requires that these inaccuracies brought about by die expansion be limited to the positive tolerance specified on the product diameter, δd. Thus, the condition to be satisfied (apart from strength criterion) is

$$\Delta a(\Delta a_F \; or \; \Delta a_0, \text{ whichever is applicable }) \leq +\Delta d/2 \tag{1}$$

Equation (1) is the first governing equation.

It is known that as the external diameter of the die container $2b$, increases the die expansion Δa decreases while the die strength increases. It is also known that as the number of cylinders or layers of the die container increases, the die expansion Δa also decreases. (Similarly, the die strength increases). The decrease in Δa occasioned by increase in number of cylinders or layers is much more effective than by mere increase of the external diameter of a single-cylinder or layer die container. This is also true for the die strength. All dies irrespective of design method must have sufficient strength to withstand deformation loads. Therefore, the other governing equation is

$$\sigma_{all} = \sigma_{o0.2}/SF \tag{2}$$

where σ_{all} = allowable stress, that is, the maximum stress that can be allowed in the die, $\sigma_{o0.2} = 0.2\%$ proof stress of the die material which is constant for the die material used and SF = Safety Factor.

By the use of Equations (1 and 2), the appropriate die dimensions and number of cylinders or layers of cylinder making up the die container can be selected. As the number of cylinders making up a die container increases, the die expansion Δa decreases; however, the cost of the die C increases. Thus, it is important to know the minimum cost of die that will give an acceptable die expansion.

The die production cost C, is made up of

(*i*) Die material cost C_d

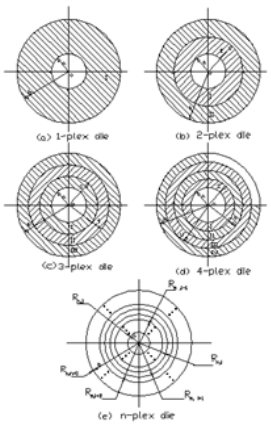

FIGURE 8. **Selection of degree of die container compounding**

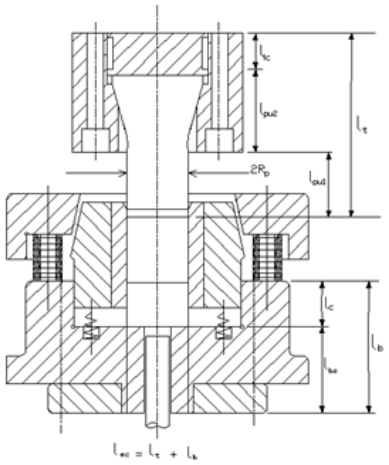

FIGURE 9. **A real duplex $(2 - plex)$ die**

(*ii*) Machining cost C_m

(*iii*) Die assembly cost C_a

Thus

$$C = C_d + C_m + C_a \tag{3}$$

The die material cost is the sum of the cost of each blank for making each cylinder. The machining cost includes the actual cutting cost, idle machine cost, tool changing or replacement cost, and tool and

regrinding cost. The machining parameters include cutting speed, feed rate and depth of cut for each machining operation. The die assembly cost includes set-up cost, actual press-fitting cost, press unloading cost, and cost of removal of assembled cylinders from the press. The press-fitting parameters include press speed, shrinkage pressure and Coulomb friction. The heat treatment cost is considered negligible. A procedure is developed for selecting the minimum production cost die. Figures 8 - 11 show the various forms of die container configurations considered.

For the design of punch and counterpunch (anvil) in precision forging dies, an Additional design equation is used given as

$$\Delta x \leq +\Delta H \tag{3}$$

where Δx = total elastic displacement of die after unloading and $+\Delta H$ = positive tolerance on product thickness.

This new method of die design is presented in a new book by Ibhadode[29].

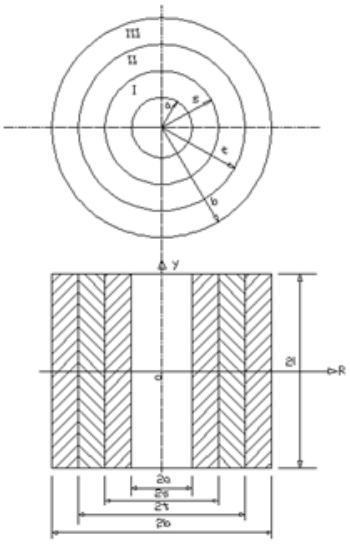

FIGURE 10. **A triplex** $(3 - plex)$ **die**

3. Results and Discussion

Comparison of Experimental and Theoretical Results

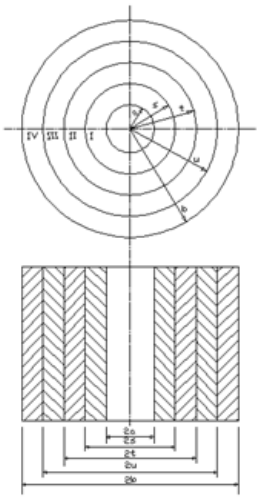

FIGURE 11. **A triplex $(4 - plex)$ die**

Forming Load: Figure 12 shows the plots of die expansion $(\Delta a/a)$ against punch pressure P. The experimental results were obtained by forging commercially pure aluminum billets measuring $\emptyset 50 \times 40mm$ high in a duplex forging die with bore diameter $63.5mm$. Forging was done incrementally from $600kN$ to $1800kN$ on a $3000kN$ Denisson compression testing machine. After each increment of forging, the workpiece was ejected and the dimensions $2h$ (workpiece height), $2l$ (workpiece-die wall contact length) and the diameter of the forged workpiece $2(a + \Delta a)$ were measured.

The experimental curve indicates that die expansion $(\Delta a/a)$ increases with punch pressure. The figure shows that a maximum die expansion of 0.00125 or 0.125 percent was obtained. For any nominal forging dimension, this would result in a height reduction of about 0.25%. So depending on the part tolerance required, die container expansion could have a significant effect on product accuracy.

Figure 12 also shows a comparison between theoretical and experimental die expansion curves. The theoretical curves for workpiece - die wall friction factors, $m_w = 0, 0.5$ and 1 are shown. The theoretical curves vary over a narrower range of die expansion than the experimental curve. They all predict higher die expansion at lower punch pressures. However, as punch pressure increases the divergence between the theoretical and experimental curves decrease. Agreement is

particularly good for $m_w = 0.5$ at full filling pressure. This is good as formed products are used in the full filling stage.

The theoretical curves indicate that die wall friction influences the final diameter of a formed product. The higher the friction, the higher the die expansion. The experimental curve tends to cut across different friction levels as punch pressure increases. This may be due to the fact that frictional stress increases with pressure.

The experimental curves also show that full die cavity filling was not yet quite achieved at the final load of $1800kN$ (pressure $= 0.52kN/mm^2$) as $2h - 2l = 3mm$. For full filling, $2h - 2l$ should be zero.

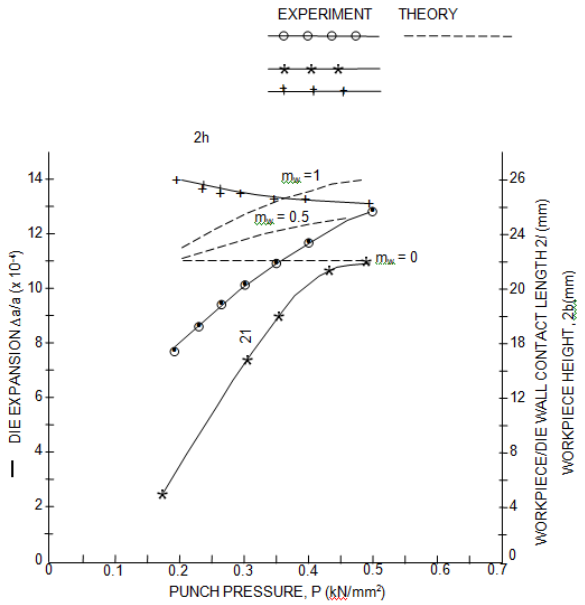

FIGURE 12. **Plots of die expansion against punch pressure**

Degree of Die Compounding: Figure 13 shows the experimental and theoretical plots of die expansion $\Delta a_n/a_1$ (relative to die expansion for the $1-plex$ die) against $n-plex$. Four separate dies were made. These were $1-plex$ (monoplex), $2-plex$ (duplex), $3-plex$ (triplex) and $4-plex$ (quadruplex) dies, having a constant material volume. The interface diameters of the multiplex dies were selected using the particular design equation. Each die had an internal radius $a = 17.5mm$ and outer diameter to internal diameter ratio, $b/a = 2.51$. Commercially pure aluminum billets of initial dimensions $\emptyset 30mm \times 35mm$ high were forged at $450kN$ in each of the dies on a $600kN$ Avery compression

testing machine. After each forging, the workpiece was ejected from the die and its forged diameter was measured. The difference in diameters between the forged diameter and the die bore was taken as the diametral die expansion $2\Delta a$. The die expansion $2\Delta a$ was also obtained from the appropriate equation (for $n = 1, 2, 3$ and 4) for each of the forging, using the experimental conditions.

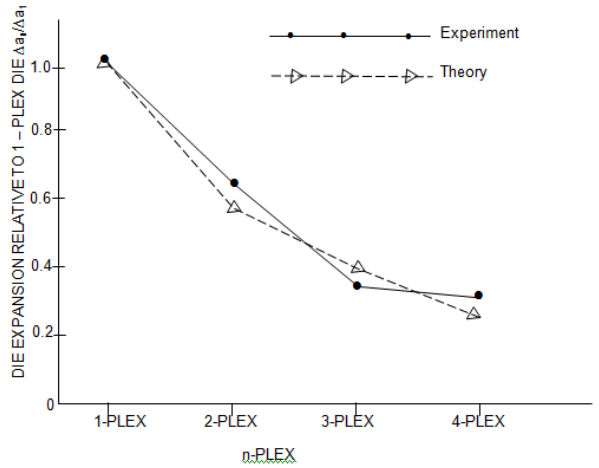

FIGURE 13. **Plots of die expansion against degree of die compounding**

Figure 13 shows that as the degree of die container compounding, (that is, $n - plex$) increases, the die expansion reduces experimentally and theoretically. The experimental results show that the relative die expansion of the $2 - plex$, $3 - plex$ and $4 - plex$ dies are 624%, 37% and 32% of that of the $1 - plex$ die respectively. Similarly, the theoretical results predict 54%, 40% and 26% reductions correspondingly. Thus, the theoretical and experimental results compare fairly well. Discrepancies may have arisen from machining errors on die bores for the different dies, and on interface diameters which are responsible for setting up shrinkage stresses for given interference diameters. The theory shows that the shrinkage stress (pressure) p_s, is a decisive factor in determining die expansion.

4. **Case Study**

Figure 14 shows an H-shaped forging to be made in a die. It is required to select an appropriate die container that can be produced at minimum cost.

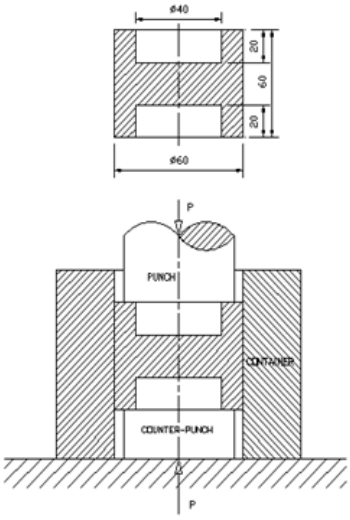

FIGURE 14. **H-forging in die**

Data

- Product to be made of low carbon steel with yield stress = $0.25kN/mm^2$.
- Tolerance on outside diameter of product, .
- Tolerance on web thickness,
- Initial dimension of billet is $50mm$ diameter $\times 61mm$ high.
- Required forging load is $4500kN$.
- Die container, punch and counterpunch are to be made from a material with 0.2% proof yield strength, = 2.kN/mm2, modulus of elasticity, E = 225kN/mm2, and Poisson's ratio,

Problem 1: Using a safety factor, $SF = 1.05$, design the following types of die container that may be used to form the product: monoplex, duplex, triplex and quadruplex.

Container Design Values: Application of the design method to die container gives the following design solutions

- $1-plex$ die: $2a = 60mm, 2b = 900mm$
- $2-plex$ die: $2a = 60mm, 2b = 144mm$
- $3-plex$ die: $2a = 60mm, 2b = 132.9mm$
- $4-plex$ die: $2a = 60mm, 2b = 128.7mm$

Satisfaction of design requirements: The four designs satisfy

- maximum die stress be less than or equal to the allowable die stress ($\sigma_{all} = 1.9048kN/mm^2$)
- die expansion be less than or equal to the specified product tolerance on diameter ( ).

Problem 2: Select the die container that gives the minimum design effectiveness index (DEI) where

$$DEI = \frac{\text{Poduction Cost Die}}{\text{Margin of safe Design of Die}} \tag{5a}$$

where

$$\text{Margin of Safe Design } (MSD) = \frac{\sigma_{all} - \hat{\sigma}_{\theta}}{\sigma_{all}} \times \frac{\Delta d - 2.\Delta a}{\Delta d} \tag{5b}$$

After carrying out the design for the four dies, we arrive at Table I showing the *Design Effectiveness Indices* for the dies.

From Table I, the triplex die $(3-plex)$ has the minimum Design Effectiveness Index, $DEI = \$7,317.88$. Next to it, is the duplex $(2-plex)$ die with a DEI of $\$11,221.57$. Based on these values, the triplex $(3-plex)$ die is selected.

Table I Design Effectiveness Indices (DEI) for dies

n − plex	**Die Cost, C**($)	**MSD**	**DEI**($)
$1-plex$	10,883.99	0.000394	27,624,340.10
$2-plex$	481.54	0.050189	9,594.53
$3-plex$	580.93	0.079431	7,313.64
$4-plex$	667.14	0.022470	29,690.25

However, the difference in $DEIs$ of the duplex and triplex dies is not appreciable compared to those of the $1-plex$ and $4-plex$. Based

on prevailing circumstances, for example, easy availability of stock bar sizes, cost, etc, the duplex die could also be used.

The monoplex die has an unusually high DEI of over $27 million. The design of the monoplex die was pursued to its logical conclusion for the purpose of illustrating the use of the design method

Benefits of the New Die Design Method

(*i*) It allows for cost-effective design of dies by producing a die design that gives precise dimensions of products produced in them at minimum cost.

(*ii*) It is able to use the expected tolerance on product as input into the design process. This gives it the inherent ability to produce precision die designs. Conventional die design methods do not have this ability.

(*iii*) For processes requiring the use of punch and counterpunch in the dies, the method gives the ability to the designer to predict punch and counterpunch dimensions from a knowledge of the tolerances expected on the products to be produced in the future die.

5. Conclusion

A new method for designing precision dies based on die expansion has been presented. It provides a clear-cut theoretical basis for the design of axisymmetric dies. It is able to select the outside diameter of die container, degree of die container compounding, punch and counterpunch (anvil) dimensions in precision forging dies and minimum production cost of die.

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Proc. Nigerian Acad. Sci.
Vol. 6, Issue 1, 2013, pp. 33 - 50

PLASMA ARC GASIFICATION FOR WASTE MANAGEMENT AND SUSTAINABLE RENEWABLE CLEAN ENERGY GENERALIZATION

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(Sponsored by K.M. Onuoha, FAS)

Abstract. Plasma gasification in waste to energy is one of the novel applications that were introduced many years ago. Landfill sites and incineration continue to be the primary methods used to dispose wastes with significant negative impact on the environment. Landfill releases methane which is 21 times more dangerous as a greenhouse gas than carbon dioxide. Incineration is often pushed as an alternative to land filling. However, it is a known fact that incinerator ashes are contaminated with heavy metals, unburned chemicals and new chemicals formed during the burning process. These ashes are then buried in landfill or dumped in the environment. Rather than making waste disappear, incinerators create more toxic waste that pose a significant threat to public health and the environment. Sustainable and successful treatment of MSW should be safe, effective, and environmentally friendly. In this application, plasma arc gasifies the carbon-containing materials in the waste to produce synthesis gas (syngas) composed primarily of carbon monoxide and hydrogen, which can be used to produce energy through reciprocating engine generators - gas turbines and steam boilers in integrated gasification combine circle (IGCC), and/or liquid fuels. The in-organic waste materials are vitrified and runs out of the vessel's bottom as glass-like slag and reusable metal. The double benefit of waste management and energy production is realized from plasma gasification process.

1. Introduction

Camacho, the former NASA scientist, used plasma technology to transform waste to energy in 1973. He showed that the process would

Key words and phrases. Plasma physics, plasma gasification, waste to energy, syngas.

produce useful gas that could be used for producing various forms of energy, and vitrified rock-like byproduct that could be used as construction aggregate (Camacho, S. L. 1996). The harmful attributes of landfills to environment are revealed (Youngchul B, Moohyun C, Soon-Mo H, and Jaewoo C, 2012). Consequently, the issues related to landfills, created an atmosphere for academia and industry to extend their research frontiers for new solutions that would be environmentally friendly.

Although plasma technology was introduced in the 1950s, adaptation of this technology to large-scale waste destruction, including gasification of waste and recovery of energy from the generated gas is new. Plasma gasification of municipal solid waste (MSW) is a fairly new application that combines well-established sub-systems into one new system (Dodge E. 2009).

In Plasma Gasification (http://www.recoveredenergy.com/ d_plasma.html) the MSW is gasified in an oxygen-starved environment to decompose waste material into its basic molecular structure. As opposed to incinerators, the waste does not combust in the gasifying plant. Plasma may be created in a variety of ways, including passing a gas between objects with large differences in electrical potential, as in the case of lightning, or by exposing gases to high temperatures, as in the case of arc welding or graphite electrode torches. Plasma arc torches utilize a combination of these techniques (Anyaegbunam F.N.C., 2013). A relatively small quantity of ionized gas is produced by an "arc igniter" and introduced between the electrodes contained in the body of the torch. The extremely intense energy produced by the torch is powerful enough to disintegrate the waste material into its component elements. The subsequent reaction produces syngas and byproducts consisting of a glass-like substance used as raw materials for construction and also re-useable metals. Syngas is a mixture of hydrogen and carbon monoxide (Blees, Tom 2008) and it can be converted into fuels such as hydrogen, natural gas or ethanol. The Syngas so generated is fed into a heat recovery steam generator (HRSG) which generates steam. This steam is used to drive steam turbine which in turn produces electricity. The cooled gas is then compressed and used to drive a gas turbine which in turn produces additional electricity. The integrated gasification combine circle (IGCC) energy thus produced is used partly for the plant load, while the rest can be sold to the utility grid. Essentially the inorganic materials such as silica, soil, concrete,

glass, gravel, including metals in the waste are vitrified and flow out the bottom of the reactor. There are no tars, furans or ashes enough to pollute the environment.

Municipal solid waste is believed to be a source of renewable energy, and plasma arc gasification technology is one of the leading-edge technologies available to harness this energy (Pourali, M. 2010). The Waste is a sustainable fuel source and increasing day by day as population increases. Therefore Plasma Gasification may be proven as a sustainable source of clean energy and environmentally safe solution for waste management.

1.1. **Waste Handling and Treatment.**

In most developing countries, wastes are commonly dumped in open dumps uncontrolled landfills where a waste collection service is organized. Developed countries, on the other hand have well organized waste management systems. Open dumping of waste cannot be considered as a long-term environmental method of disposal. The dangers of open dumping are many; health hazards, pollution of ground water, spread of infectious diseases, highly toxic smoke from continuously smoldering fires and foul odors from decomposing refuse. There is no defined method of waste handling and treatment but several million tons of MSW have been deposited in open dumpsites over the years. A new technology such as Plasma Gasification Technology may prove to be an environmentally friendly solution for the treatment of wastes.

1.2. **Plasma Technology.**

Plasma, often referred to as the "fourth state of matter", is the term given to a gas that has become ionized. An ionized gas is one where the atoms of the gas have lost one or more electrons and have become electrically charged. The sun and lightning are examples of plasma in nature. Important properties of plasma include the ability to conduct an electric current and to respond to electromagnetic fields. The term "plasma" was coined (Langmuir I., 1928) perhaps, because the glowing discharge molds itself into the shape of the Crooks tube. The presence of a non-negligible number of charge carriers makes the plasma electrically conductive so that it responds strongly to electromagnetic fields, (Patel M. L, Chauhan J. S, 2012).

Artificial Plasma may be created by passing a process gas, which serves as a dielectric, between objects with large electrical potential differences. The potential difference and subsequent electric field causes ionization of the gas and electrons are pulled toward the anode while the nucleus (Chen, Francis F., 1984) pulled towards cathode. The current stresses the gas by electric polarization beyond its dielectric strength into a stage of electrical breakdown. The presence of this ionized gas allows the formation of an electric arc between the two electrodes, and the arc serves as a resistive heating element with the electric current creating heat which creates additional plasma that allows the arc to be sustained. A major advantage of the plasma arc as a resistive heating element is that it is formed in a gas and cannot melt or fail as can solid heating elements. Interaction between the arc and process gas introduced into the torch causes the temperature of the gas to be very high and the hot gas can exit the plasma torch at about $10,000°C$.

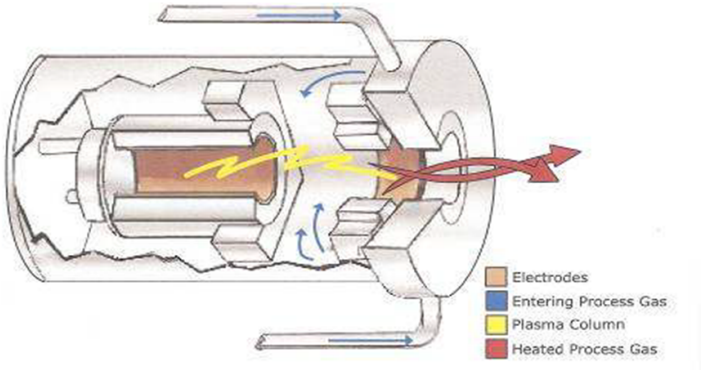


FIGURE 1. **Plasma Tourch**

The ability to increase the temperature of the process gas up to ten times higher than those attainable by conventional combustion makes plasma arc technology ideally suited for high temperature process applications such as gasification.

2. Materials and Methods

Waste in Abuja-Nigeria is considered as a test case for this study. Information on waste collection and handling is supplied by Abuja environmental protection board (AEPB) and also from various municipal area councils in the Federal Capital Territory. Some workers at AEPB were interviewed to gather relevant information on the status of MSW collection and disposal. Various open dumpsites were visited and waste

samples collected and analyzed. Useful information is also gathered from AEPB website: (www.environmentalprotectionboard.gnbo.com.ng) Data collection and analysis is based on the information about the six municipal area councils of Abuja with respect to 2006 population census. A survey is conducted on the status of solid waste generation in each of the municipal area councils. The area councils provided information based on collection and transportation. The data collected from the area councils and those obtained on their websites were analyzed and corrections made on average basis of the size of the area council. The sampling was done at the dumpsites and analysis done for the composition of MSW in each area council as per established guidelines issued by the United Nations Environment Program (UNEP).

2.1. **Municipal Solid Waste Generation and Characterization.**

Solid waste generation studies are based on the information supplied by the local area councils. There are no regulations or standards to guide the collection and monitoring of the MSW. Less than 50% of the waste generated is collected. The MSW generation in Abuja is shown in Table 1. The rate of MSW generation in Abuja is about $0.67 kg/cap/day$.

Table 1. Municipal Solid Waste Generation in Six Area Councils of Abuja

MUNICIPAL AREA COUNCILS	POPULATION	MSW /MT/d	Per capita waste Generation/kg/d
ABUJA	2,245,000	1527	0.68
ABAJI	58,444	38	0.65
BWARI	227,216	150	0.66
GWAGALADA	157,770	104	0.66
KWALI	85,837	55	0.64
KUJE	97,367	44	0.67
TOTAL	2871634	1918	0.668

Table 2. Waste Stream Composition

	ABUJA	ABAJI	BWARI	GWAGALADA	KWALI	KUJE
Putreserible	53.2	52..5	50.8	51.9	54.5	55.0
Plastics	7.2	8.2	8.1	7.8	6.8	7.6
Paper	14.0	12.4	14.3	13.5	12.1	13.8
Textile	4.1	3.5	2.6	4.0	4.6	2.7
Metal	5.0	4,5	5.1	5.2	4.9	3,9
Glass	3.5.	3.9	4.0	4.2	4.3	4.1
Others	13.0	15.0	15.1	13.4	12.8	12.9

The food consumption of residents of Abuja and the municipal area councils is essentially carbohydrate and vegetables just as in most part

of Nigeria. This partly gives rise to higher percentage of organic component of the MSW. The AEPB does not provide separate solid waste management for the seven classifications of available solid waste. The majority of substances composing municipal solid waste include paper, vegetable matter, plastics, metals, textile, rubber and glass. Table 2 shows a comparative analysis of municipal solid waste composition in the six Municipal area councils of Abuja. It can be seen that great majority of the total solid waste generated in Abuja is organic as in most developing countries.

2.2. **Plasma Gasification Process.**

Gasification is a process that converts carbon-containing materials, such as municipal solid waste (MSW), coal, petroleum coke, or biomass, into a synthesis gas (syngas) composed primarily of carbon monoxide and hydrogen. Gasification occurs (Anyaegbunam F.N.C., 2013) when a carbon-containing feedstock is exposed to elevated temperatures and/or pressures in the presence of controlled amounts of oxygen which may be supplied by air, oxygen enriched air (essentially pure oxygen), or steam. The global gasification reaction is written as follows; waste material is described by its global analysis, $CHxOy$), (Youngchul B, Moohyun C, Soon−Mo H and Jaewoo C, 2012):

$$\mathrm{CH}_x\mathrm{O}_y + w\mathrm{H}_2\mathrm{O} + m\mathrm{O}_2 + 3.76m\mathrm{N}_2 \rightarrow a\mathrm{H}_2 + b\mathrm{CO} + c\mathrm{CO}_2 + d\mathrm{H}_2\mathrm{O} + e\mathrm{CH}_4 + f\mathrm{N}_2 + g\mathrm{C},$$

where w is the amount of water per mole of waste material, m is the amount of O_2 per mole of waste, a, b, c, d, e, f and g are the coefficients of the gaseous products and soot (all stoichiometric coefficients in moles). This overall equation has also been used for the calculation of chemical equilibrium occurring in the thermal plasma gasification with input electrical energy. The concentrations of each gas have been decided depending on the amount of injected O_2, H2O, and input thermal plasma enthalpy. The detailed main reactions are as follows:

$\mathrm{CH}_4 + \mathrm{H}_2\mathrm{O} \rightarrow \mathrm{CO} + 3\mathrm{H}_2$ (CH_4 decomposition-endothermic)
$\mathrm{CO} + \mathrm{H}_2\mathrm{O} \rightarrow \mathrm{CO}_2 + \mathrm{H}_2$ (water gas shift reaction-exothermic)
$\mathrm{C} + \mathrm{H}_2\mathrm{O} \rightarrow \mathrm{CO} + \mathrm{H}_2$ (Heterogeneous water gas shift reaction-endothermic)
$\mathrm{C}+\mathrm{CO}_2 \rightarrow 2\mathrm{CO}$ (Boudouard equilibrium-endothermic)
$2\mathrm{C} + \mathrm{O}_2 \rightarrow \mathrm{CO}$

The H_2 and CO generated during the gasification process can be a fuel source. Therefore, plasma gasification process has been combined with many other technologies to recover energy from the syngas.

2.3. **Plasma Gasification of Municipal Solid Waste (MSW).** Plasma gasification is an efficient and environmentally responsible form of thermal treatment (Dighe Shyam V., 2008) of wastes which occurs in oxygen starved environment so that waste is gasified, not incinerated. Westinghouse Plasma Corporation (WPC) has developed a plasma gasification system (Patel M. L, Chauhan J. S, 2012; Anyaegbunam F.N.C, 2013) which uses plasma heat in a vertical shaft cupola adopted from the foundry industry. The plasma gasification process is illustrated in Figure 2 below. The heart of the process is the plasma gasifier; a vertical refractory lined vessel into which the feed material is introduced near the top along with metallurgical coke and limestone. Plasma torches are located near the bottom of the vessel and direct the high temperature process gas into a bed of coke at the bottom of the vessel. Air or oxygen is introduced through tuyres located above the torches. The high temperature process gas introduced through the torch raises the temperature of the coke bed to a very high level to provide a heat reservoir and the process gas moves upward through the gasifier vessel to gasify the waste. The power of plasma gasification makes it environmentally clean technique. Plasma Gasification Plant (PGP) projects (Evans Steve D, 2009) are being developed by many gas plasma technology companies, and real benefits are obtained from this technology for the Municipal Solid Waste (MSW) disposal. (Plasma Gasification Plant Benefits for Municipal Waste Management, EzineArticles.com, available at http://www.articlesbase.com/literaturearti-//cles/plasma-gasification-plant-benefits-for-municipal-waste-management-850915 . html, accessed during December 2011). Additional heat

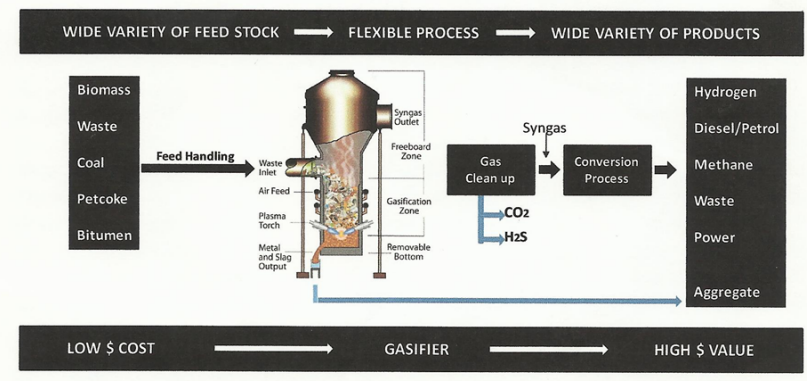


FIGURE 2. **Plasma gasification process**

is introduced from the reaction of the carbon in waste with the oxygen introduced through the tuyres to produce carbon monoxide in the gasification process. The hot product gas, passing upward though the waste breaks down organic compounds and dries the waste at the top of the gasifier. As the waste moves downward through the gasifier vessel, inorganic materials such as metal, glass and soil are melted and produce a two phase liquid stream consisting of metals and a glass-like (vitrified) residue that flows to the bottom of the vessel. Discharge of the molten material into water results in the formation of metal nodules and a coarse sand-like material.

2.4. **Environmental Sustainability of Plasma Gasification.** Plasma gasification represents a clean and efficient option to convert various feed stocks into energy in an environmentally responsible manner (Nedcorp Group, 2009; Anyaegbunam F.N.C., 2013). In the plasma gasification process, heat nearly as hot as the sun's surface is used to break down the molecular structure of any carbon-containing materials - such as municipal solid waste (MSW), tires, hazardous waste, biomass, river sediment, coal and petroleum coke - and convert them into synthesis gas (product gas) that can be used to generate power, liquid fuels or other sustainable sources of energy.

The Georgia Tech PARF lab conducted several tests (Pourali, M. 2010) using their prototype plasma gasification units. The main supplies of the furnaces were artificial combination of materials to simulate typical average constituents of MSW based on US EPA. For the Ex-Situ experiments the MSW constituents were used and for In Situ experiments, soil was added to the MSW constituents to simulate a real landfill. The summary of the PARF lab experiment results are as follows:

1. The percentage weight loss of the MSW after plasma processing is 84% for ex-situ experiment where the MSW constituents alone were used, and 59% for in-situ experiment where soil was added to MSW to simulate a real landfill or dumpsite. And weight loss was significantly less than for ex-situ experiments.
2. The percentage volume reduction of the MSW after plasma processing was 95.8% for ex-situ experiments and 88.6% for in-situ experiment. Again, given that significant amount of soil was added to the mix in in-situ experiment, obviously, the soil was melted (vitrified) but did not gasify and consequently the volume reduction was reasonably different comparing with ex-situ experiment.

3. Toxicity Leaching text results for heavy metals (Arsenic, Barium, Cadmium, Chromium, Lead, Mercury, Selenium and Silver) present after plasma gasification process are below detectable levels (BDL) in both experiments, and also far below the permissible standards established by US EPA.
4. Output Gas Composition: Table-3 shows the output syngas compositions for experiment without soil and with soil respectively in parts per million:

Table 3. Output Gas Composition

Output Gas	Ex-Situ Experiment without soil (PPM)	In-Situ Experiment with soil (PPM)
Hydrogen (H2)	>20,000	>20,000
Carbon Monoxide (CO)	100,000	>100,000
Carbon Dioxide (CO2)	100,000	90,000
Nitrogen Oxides (NOx)	<50	100
Hydrogen Sulfide (H2S)	100	80
Hydrogen Chloride (HCL)	<20	225
Hydrocarbons	>5,000	>4,500

PPM = parts per million.

2.4.1. **Low emissions.**
Less than 0.01 NG/NM3 of Dioxins/Furans emission results in PG. The pollutants (No_x, So_x and particulate matter are significantly low in PG Process see (Fig.3). Sulfur reports as Hydrogen Sulfide (H_2S) Easier to clean than So_x. Tars are cracked prior to leaving Plasma Gasifier.

Commparison on waste-to-Energy Criteria Pollutants

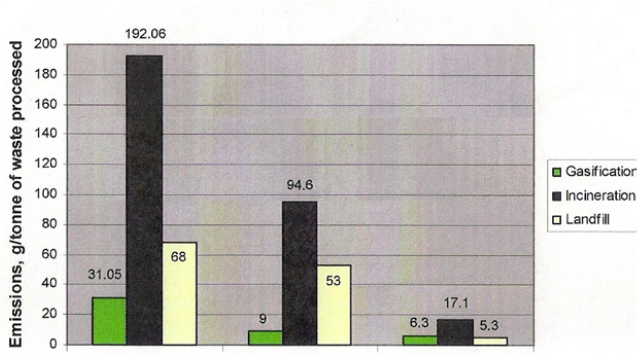
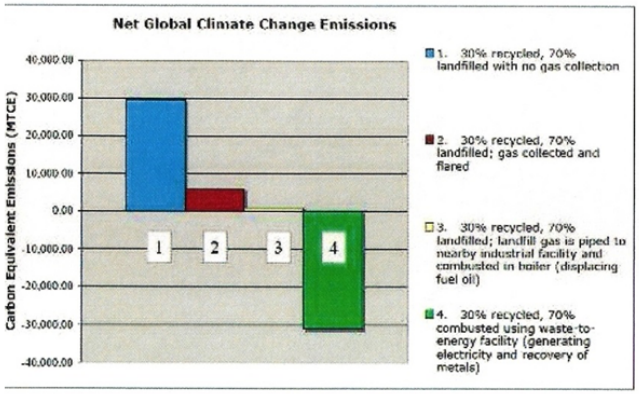


FIGURE 3. **Emissions in grams per ton of waste processed by different processes**



Data Source: Thorneloe SA, Weitz K, Jambeck J. Application of the U.S. Decision Support Tool for Materials and Waste Management. WM Journal 2006 August.

FIGURE 4. **Net climate change emissions for Plasma gasification are negative compared to other waste management options**

The rate of Carbon dioxide emission (Circeo L. J, 2012) per MWH of electricity produced shows (EPA document: www.epa.gov/ceanenergy-/emissions.htm) that while incineration of MSW emits 2,988 pounds of CO2 per MWH of electricity produced, plasma gasification emits only 1,419 pounds per MWH. (Westingouse Plasma Corporation, CO_2 conversion-Nedcorp Group, 2009). Each plasma gasification application will have a different environmental profile, (Nedcorp Group, 2009)

but in general terms a plasma gasification facility will have very low emissions of NO_x, SO_x, dioxins and furans. In summary, when compared to conventional incineration or traditional gasification technologies, the Plasma Gasification technology and its plasma torch systems offer the following benefits listed in table 4:

Table 4. Plasma Gasification Compared to Incineration and Other Gasification Processes

Feedstock Flexible	Ease of Operation	Environmental Benefits	Flexible Product Delivery
A wide range of opportunity fuels can be accepted with limited pre-processing requirements	The Gasification Reactor Operates at ambient pressures allowing for simple feed system and online maintenance of the plasma torches	Operation is environmentally responsible creating a product gas with very low quantities of NOx, SOx, dioxins and furans	Syngas composition (H2 to CO ratio, N2) can be matched to downstream Process equipment by selection of oxidant and torch power consumption
Multiple Feed Stocks can be combined	Plasma Torches have no moving parts resulting in high reliability. Torch consumables are quickly replaced off line by plant maintenance personnel	Inorganic components get converted to glassy slag safe for use as a construction aggregate	Multiple gasification reactors are used for larger projects increasing availability of the gasification system

2.5. **Plasma Gasification an environmentally friendly sustainable solution for Municipal Solid Waste Management.**

As we have seen from our Abuja test case, AEPB still practice dumping of the MSW in the outskirt of the township and open dumping creates huge Environmental Problems. The quantity and composition of the waste contribute much to the selection of the management solution. In fact, waste management is multi-disciplinary issue and involves various environmental, economic and community aspects. Hence, certain criteria should be satisfied for any waste management method desired.

2.5.1. **Waste management criteria.**

There is an emerging global (Rathi Sarika, 2007, Patel M. L, Chauhan J. S, 2012) consensus to develop local level solutions and community participation for better MSW management. Emphasis has been given to citizens' awareness and involvement for better (Beukering, 1999) waste management. A number of studies were carried out in the past

to compare different methods of waste disposal and processing for different places. (Maimone, M., 1985) concluded that composting was the best option of waste management. (Powell, J.C., 1996) concluded that refused derived fuel was the best option. It can be inferred from the literature that no one method in isolation can solve the problem of waste management. The present study is an attempt to establish that the best feasible method of waste management shall involve plasma gasification method which will not only achieve environmental sustainability but also sustainable renewable energy solutions. The suitability of a particular technology for the treatment of MSW depends on a number of factors which include techno-economic viability, environmental factors, sustainability, accessed during December 2011), (Varma, R. Ajayakumar, 2009) and geophysical background of the location. The Plasma Gasification Process (Lisa Zyga, 2012,) seems to be a realistic solution for the MSW management. It is a process, that can get rid of almost any kind of waste by eliminate existing landfills, open dumps, and produce a clean renewable energy.

2.5.2. **Land requirement Criteria.**
The land and transportation facilities are basic requirement for MSW management. As per the provisions of (Municipal Solid Waste Management and Handling) Rules, 2000, the landfill site shall be large enough to last for 20-25 years (Patel M. L, Chauhan J. S, 2012). It is the general experience that the land requirement for development of the MSW landfill site is around 0.2 ha/MT of MSW generation per day with minimum requirement of 2.0 ha land area. The projected minimum land requirement for Plasma Gasification Process (PGP), (Nedcorp Group, 2009) is dependent on the processing capacity of the plant and ancillary processes that maybe included in the overall plant design. However, a standard IGCC configured plant having a capacity of 1000 M.T per day would require about 2.0 Hectares (5Acres) of land. Increasing the capacity of the plant to 3000 M.T. per day would increase land requirement to about 4.0 Hectares.

2.5.3. **Sustainability Criteria.**
The sustainability of any project depends up on the capital cost, running & maintenance cost, availability of raw materials and payback cost. Capital costs for a plasma gasification plant are similar to those for a municipal solid waste incineration power plant, but plasma gasification plants are more economical because the plant's inorganic byproduct can be sold to the market as bricks and concrete aggregate. Plasma gasification plants also produce up to 50% more electricity than other

gasification technologies, (Pourali, M. 2010) hence, reducing the payback period. Nedcorp group plasma gasification system using Westinghouse Plasma Corporation plasma touches uses 2 to 5% of energy input to produce 80% of energy output (Anyaegbunam F.N.C., 2013). The raw material or fuel for the plant is readily available in abundance and increasing by the day. Typical plasma gasification for waste to energy plant with a feedstock of 3,000 MT of MSW per day is estimated to cost over $400 million for installation and will generate about 120MW of electricity (Pourali, M. 2010). Most of the Plasma Gasification Plants require 120 Kwh of energy per ton of MSW and 816 kwh electricity is generated from the process. It is also projected (Pourali, M. 2010) that each ton of MSW can produce 1.20MWh of electricity if an integrated gasification combine circle (IGCC) is used. As the technology continues to gain acceptance, the cost will decrease significantly. Thus, theoretically, plasma IGCC plant at 45% efficiency can generate about 1,035MWh of electricity from 1918MT of MSW.

2.5.4. **Syngas-to-Liquids Alternative.**
Plasma gasification of MSW also generates several sustainable energy outputs including liquid fuels, Fig.2. Rising fuel costs and a desire for energy independence have revived interest in another market for gasification technology: the production of liquid transportation fuels. Commonly called Fischer-Tropsch (FT) liquids, after the German inventors of the primary chemical conversion process (indirect liquefaction), STL can help increase fuel supply diversity and energy security. In STL, clean synthesis gas (syngas) from plasma gasification of waste or coal is converted to a liquid hydrocarbon or alcohol for use as fuel or otherwise. First, the syngas must be cleaned of sulfur and other impurities before it is reacted into its liquid fuel form. The FT process is one possible conversion path. FT catalysts are used to facilitate the formation of hydrocarbons or alcohols from the carbon monoxide (CO) and hydrogen (H2) in the syngas. The end product of the process can be determined by changing the catalyst, feed composition, and reactor conditions such as internal temperature and pressure. The main products of the FT process are typically straight-chain, saturated hydrocarbons, of the form CnH2n+2 (this class of molecule are called paraffin), from which gasoline and diesel can be refined. Fuel gases like methane and liquefied petroleum gas (LPG; mostly propane and butane) are usually also formed in small amounts by STL but are generally discouraged by the process designers. Different catalysts can facilitate the formation of alcohols like methanol, ethanol and propanol that can be used as fuel or fuel additives. Methanol to Gasoline (MTG)

is another alternative path for STL production. In this route, syngas is reacted to form methanol, from which gasoline is then formed.

3. **Results and discussion**

Municipal Solid Waste Management is a great challenge to the Waste Managers, Scientists and Engineers. The quantity of Municipal Solid Waste generation is increasing and availability of land for the landfills or open dump disposal is decreasing day by day and hence most of the latest efforts focus on "Zero Waste" and/or "Zero Land filling" disposal methods. It is depicted from the data interpretation that; that average Municipal Solid Waste generation from the six municipal area councils of Abuja is about 1918MT/day (Table-1). The percentage of plastic waste present in municipal solid waste is about 8% on average. The Plasma Gasification Process of Municipal Solid Waste is a proven technology in which the weight is reduced by about 84% and the volume of organic matter reduced by more than 95%. The vitrified glass generated as residue from Plasma Gasification Process is also environmentally safe for toxicity leaching. The vitrified glass can be used for the construction work. The reaction processes in the gasifier produce mainly syngas (Hydrogen and Carbon monoxide). The PGP out-put gas is environmentally safe. Plasma Gasification technology and its plasma torch systems when compared to incineration or traditional gasification offer unique environmental benefits. Operation is environmentally responsible creating a product gas with very low quantities of NO_x, SO_x, dioxins and furans. Inorganic components get converted to glassy slag safe for use as a construction aggregate. The fuel gas emissions are also within prescribed limit, thus, the process is environmentally safe in terms of rate of Carbon dioxide emission (Circeo L. J, 2012) per MWh of electricity produced in comparison to different processes such as incineration and land filling. The land requirement for management of Municipal Solid Waste through landfills would be around 384ha for 1918MT/day. However, processing of 3000MT/day by plasma gasification process will require only about 4ha of land, (Nedcorp Group, 2009). The reduction in the space required for the MSW management by PGP is very significant. This is positive for the fast growing Cities where land resources are limited. The Plasma Gasification Processing (PGP) plants will generate renewable energy such as power and liquid fuels and these can be used by the local utility through national grid or sold to chemical companies. The PGP plants conserve fossil fuels by generating electricity and liquid fuels from MSW. It has been estimated that one ton of MSW decomposed in a gasifier rather

than land filled reduces greenhouse gas emissions by 1.2 MT of carbon dioxide. Hence, there will be reduction of over 2300 MT/day of land filled greenhouse gas emissions for the 1918 MT of MSW which, in addition, can also produce about 1035MWh of electricity with Plasma gasification IGCC configuration.

The Municipal Solid Waste management is a challenge due to its increasing quantity and limited land resources. This is the reason that most of the latest efforts focus on "Zero Waste" and/or "Zero Landfilling" which is certainly expensive (Shekdar Ashok V., 2009) for weaker economies. Developing countries, though poor should develop area-specific solutions to their problems (Henry et al., 2006) in the MSW management. Application of Plasma Gasification Process (PGP) in waste to energy, relieves the pressure on distressed landfills, and offers an environmentally benign method (Tom Blees, 2008) of disposing MSW. Municipal solid waste is considered as source of renewable energy, and plasma gasification technology is one of the leading-edge technologies available to harness this energy. In recent years, the US government officially declared the MSW as a renewable source of energy, and power generated through the use of MSW is considered green power and qualified for all eligible incentives. Plasma technology, therefore, is an economic and abundant source of renewable energy, and a reliable source of power.

4. **Conclusion**

Considering many applications of Plasma Gasification Process, the profit potential of plasma conversion (Blees Tom, 2008) is tremendous. Private companies could build facilities in developing countries and it would naturally be in their financial best interest to develop the garbage collection infrastructure to support their business, indirectly the collection system will be improved. Thus, the multiple benefits of waste management by plasma gasification can be exploited.

Plasma gasification converters represent the ultimate in recycling process; making virtually 100% of the waste a household normally produces into usable and even valuable end products. There would be no need to have two garbage pickups running,- one for trash and one for recyclables that people have perhaps been conscientious enough to separate. The plasma gasification process of MSW has all the merits of adoption, even though there are many disagreements among scientists and policy makers on these matters, there is, however, consensus

that alternative sources of energy that are sustainable, environmentally friendly and regionally available must be the best choice. However, skepticism about the technology, lack of historical data, volatile price of crude oil, a mislabeling of plasma gasification technology as another type of incineration and a lack of government sponsored development and projects in plasma gasification, have contributed to the lack of progress in the development and utilization of this technology.

The sustainability of any solid waste management system depends (Pradhan U. M, 2008) on numerous factors; however, the most important factor is the will of the people and governments to change the existing system and develop something better. For any technology to be successful, the government should take the required initiatives and sincere commitment to drive the process of development.

Acknowledgement

I am grateful to the staff of Abuja Environmental Protection Board (AEPB), and of the six municipal area councils of Abuja who provided me with relevant information, without of which this study might not be possible.

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Proc. Nigerian Acad. Sci.
Vol. 1, Issue 1, 2013, pp. 51 - 56

PRINCIPLE OF EMAGNETODYNAMICS FOR COMPOSITE MAGNETIC POLE

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Abstract. It is shown in this paper that geometry provides the key to the emagnetodynamics principle of operation of the machine (invented by Dr. Ezekiel Izuogu) which has an unexpected feature of driving a motor with static magnetic field. Essentially, because an array of like magnetic poles of the machine is arranged in a half circular array of a cylindrical geometry, the array creates a non-pointlike magnet pole that may be represented by a "magnetic current loop" at the position of the pivot of the movable arm. As a result, in three-dimensional space, it is possible to characterize the symmetry of the stator magnetic field **B** and the magnetic current loop **J** as a geno-dual (cube-hexagon) system by a 6-vector **(J,B)** (with $\mathbf{J}.\mathbf{B} \neq \mathbf{0}$) comprising a 4x4 antisymmetric tensor analogous to the conventional electric and magnetic 6-vector $(\mathbf{E}, \mathbf{B})$ (with $\mathbf{E}.\mathbf{B} \neq \mathbf{0}$) comprising the 4x4 antisymmetric tensor of classical electrodynamics. The implications are discussed.

1. Statement of the problem

The conventional electric motor works on the principle that force is exerted on a current-carrying conductor in a magnetic field This is the Lorentz force on a moving electric charge which together with Maxwell's electromagnetic field equations constitute the laws of classical electrodynamics [1]. However, Ezekiel Izuogu [2] has invented a motor made up of an array of magnets and a vane (see, Fig. 1 below) with unexpected principle of operation, named emagnetodynamics and described in the following words

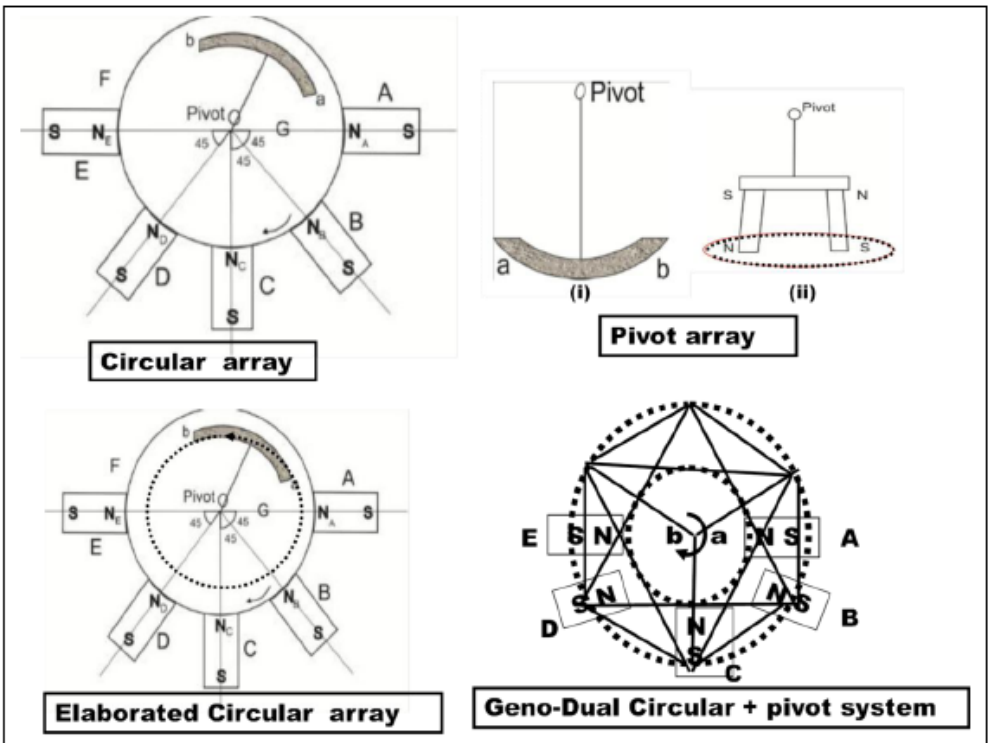

Fig. 1: [Top left] Soft iron sheet (ab) spins like a current-carrying conductor in a magnetic field. [Top right] (i)Composite magnetic pole made of a slab of soft iron core & (ii) Composite magnetic pole (Magnet made of poles of two permanent magnets); [Bottom left] elaboration of circular array; & [Bottom right] the combined circular and pivot to reflect its three-dimensional cube-hexagon ("geno-dual") symmetry.

"Acertain force is exerted on a composite magnetic pole when it is placed under the influence of an array of like magnetic poles".

2. PROOF OF THE STATEMENT

In order to prove this statement, we begin by elaborating the geometrical arrangement of the circular array of magnetic poles in combination with the pivot in the machine to enable us visualize the three-dimensional cube-hexagon ("geno- dual") symmetry of the material

components of the machine as shown in Fig. 1. Next we pose the question: What is the energy/driving force for such a geno-dual system? To answer this question, we introduce a six-vector (**J,B**) system which may be represented by 4x4 antisymmetric tensor analogous to the six-vector(**E,B**) system of Maxwells electromagnetic field as follows:

$$||G_{\mu v}|| \equiv \begin{pmatrix} 0 & J_1 & J_2 & J_3 \\ -J_1 & 0 & B_3 & -B_2 \\ -J_2 & -B_3 & 0 & B_1 \\ -J_3 & B_2 & -B_1 & 0 \end{pmatrix} \sim ||F_{\mu v}|| \equiv \begin{pmatrix} 0 & E_1 & E_2 & E_3 \\ -E_1 & 0 & B_3 & -B_2 \\ -E_2 & -B_3 & 0 & B_1 \\ -E_3 & B_2 & -B_1 & 0 \end{pmatrix} \quad (1)$$

Now, the usual Maxwell's equation which are 3-vector equations, relating the electric field, **E**, magnetic field, **B**, and a conserved electric current $\mathbf{J^e}$, when rewritten in 4-vector notations takes the form

$$\partial^t F_{\mu v} = J^e_\mu \quad (2)$$

and has conventional dual symmetry with respect to interchange of electric and magnetic quantities, ($\mathbf{E} \to \mathbf{B}, \mathbf{B} \to -\mathbf{E}.\mathbf{J^e} \to \mathbf{J^m}$) where J^m is the magnetic analog of the electric current, while the usual Lorentz force takes the form

$$\mathbf{f^e} = \mathbf{eE} + \mathbf{J^e} \times \mathbf{B} \quad (3)$$

Finally, to include the effect of gravity, we incorporate the space-time metric and curvature, by introducing (in addition to Eq.(2)) the determinant equation [3]

$$Det||F_{\mu v} - \lambda \eta_{\mu v}|| \equiv \lambda^4 - (R_{\mu v \rho \sigma} F^{\mu \rho} F^{v \sigma})\lambda^2 + (\epsilon_{\mu v \rho \sigma} F^{\mu \rho} F^{v \sigma})^2 = 0, \quad (4)$$

where, with $||\eta_{\mu v}|| \equiv diag(+1, -1, -1, -1), R_{\mu v \rho \sigma} \equiv (\eta_{\mu v}\eta_{\rho \sigma} - \eta_{\mu \rho}\eta_{\sigma v})$, we have

$$R_{\mu v \rho \sigma} F^{\mu \rho} F^{v \sigma} - 2\epsilon_{\mu v \rho \sigma} F^{\mu \rho} F^{v \sigma} = \begin{cases} \mathbf{E^2} \\ \\ \mathbf{B^2} \end{cases} \Rightarrow \begin{cases} \mathbf{E^2} - \mathbf{B^2} \pm 2\mathbf{B}.\mathbf{E} = 0 \\ \\ \mathbf{B^2} - \mathbf{E^2} \pm 2\mathbf{E}.\mathbf{B} = 0. \end{cases} \quad (5)$$

For the corresponding magnetic pole array, we have the analog of Eq.(4),

$$Det||G_{\mu v} - \lambda \eta_{\mu v}|| \equiv \lambda^4 - (R_{\mu v \rho \sigma} G^{\mu \rho} G^{v \sigma})\lambda^2 + (\epsilon_{\mu v \rho \sigma} G^{\mu \rho} G^{v \sigma})^2 = 0, \quad (6)$$

where

$$R_{\mu v \rho \sigma} G^{\mu \rho} G^{v \sigma} - 2\epsilon_{\mu v \rho \sigma} G^{\mu \rho} G^{v \sigma} = \begin{cases} \mathbf{J^{m2}} \\ \\ \mathbf{B^2} \end{cases} \Rightarrow \begin{cases} \mathbf{J^{m2}} - \mathbf{B^2} \pm 2\mathbf{B}.\mathbf{J^m} = 0 \\ \\ \mathbf{B^2} - \mathbf{J^{m2}} \pm 2\mathbf{J^m}.\mathbf{B} = 0 \end{cases} \quad (7)$$

under the dual transformation ($\mathbf{J^m} \to \mathbf{B}, \mathbf{B} \to -\mathbf{J^m}$). This is the result we are after. To complete our proof, we draw an analogy between our

model of the array of magnetic poles with London's superfluid model of a superconductor (p.412-414 of [4]) in terms of Feynman's wave function (Anderson [5]) for a superfluid, for which an expression for the superfluid velocity $\mathbf{J^m}$ in the presence of an electromagnetic vector potential, $\mathbf{A}$, is given by the London equation

$$\mathbf{J}^m = (2e\hbar/mc)\mathbf{A}, \mathbf{B} = \text{curl}\mathbf{A} = \text{curl}(\zeta\mathbf{J^m}), \zeta = (mc/2|e|\hbar) \quad (8)$$

which leads to the Meissner effect in a superconductor (p. 412 of [4]). It shows how a magnetic current loop $\mathbf{J}^m$ could be associated with a magnetic field $\mathbf{B}$ in such a system.

The importance of geno-dual symmetry of the magnetic pole array (and the consequential non-vanishing of the $\mathbf{J^m}.\mathbf{B}$ term in Eq.(7) above) is provided further by antiferromagnetic ordering of MnO below the Curie point (see p. 359 of [4], and also [6]), sketched in Fig. 2. The magnetic unit cell comprises eight chemical unit cells, and the antiferromagnetic coupling is between second nearest manganese neighbors, such as A and B, via the intervening oxygen, O. The array has geno-dual symmetry as explained in the caption. In this case, the analog of the $\mathbf{J^m}.\mathbf{B}$ term is the Heisenberg exchange (Eq.(10.29) of [4]) $H_{ex} \propto (\mathbf{S}_A.\mathbf{S}_B)$.

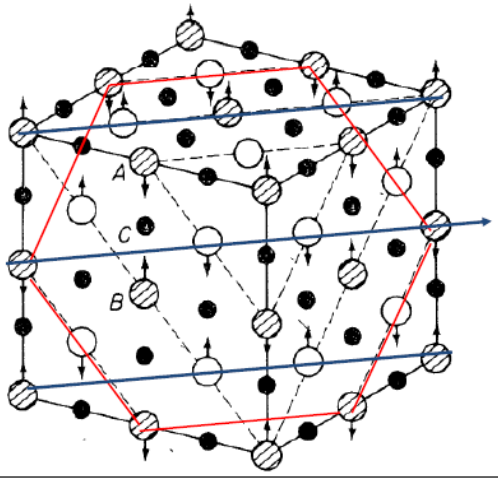

Fig. 2: Characterization of geno-dual symmetry of Antiferromagnetic Ordering in MnO by a cube(up-spin) & Hexagon(down-spin) magnetic unit cell[6]

3. DISCUSSION AND CONCLUSION

The puzzling aspect of Engr. Dr. Izuogu,s observation of emagnetodynamic phenomenon stems from the fact that a pointlike magnetic monopole has not been observed. But Engr. Dr. Izuogu's array is non-pointlike and hence representable as a magnetic current loop, which follows from the correspondence principle [3]

$$\text{points} \Leftrightarrow \text{particles}, \quad \text{lines} \Leftrightarrow \text{fields}, \quad \text{planes} \Leftrightarrow \text{currents},$$

between points, lines and planes of the tetrahedron of reference of projective 3D space and particles, fields and currents of Maxwell-type gauge field theories (as shown in Fig. 3) which was employed in Eq.(1) above. Another puzzling question has to do with energy conservation in

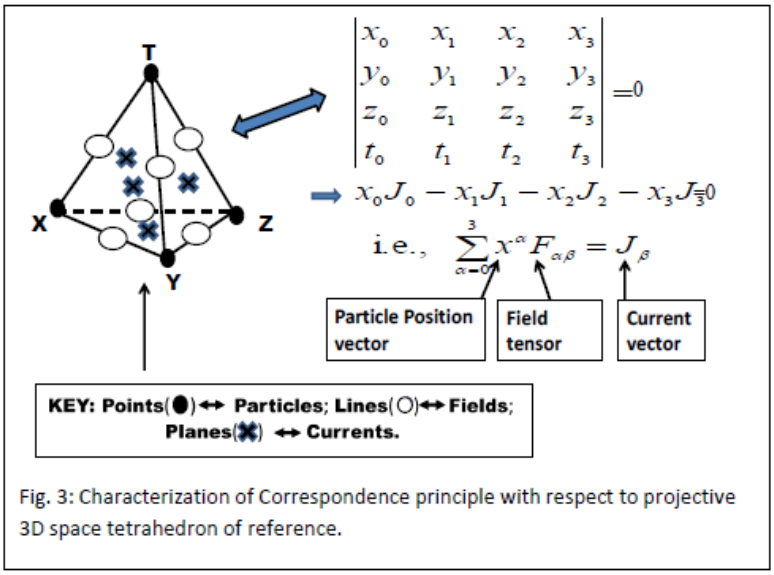

Fig. 3: Characterization of Correspondence principle with respect to projective 3D space tetrahedron of reference.

the new machine: Can the emagnetodynamic machine run perpetually, contrary to the 2^{nd} laws of thermodynamics that forbids the construction of a "perpetual motion machine"? The answer to this question is that the emagnetodynamic machine is not an isolated system insofar as gravity comes into play through the inertia of the pivoted vane and plays a role in crossing the "dead end" at each half-cycle of the vanes motion.

We are, therefore, led to the conclusion that emagnetodynamics phenomenon is allowed both theoretically and in practice, and should be incorporated into the body of knowledge of the physical universe.

ACKNOWLEDGEMENT

I am deeply grateful to Engr. Dr. Izekiel Izuogu for sharing with me information about his patented discoveries, especially the equipment associated with Fig. 1, and for useful discussions concerning its elaboration on which this paper is based.

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Proc. Nigerian Acad. Sci.
Vol. 6, Issue 1, 2013, pp. 57 - 68

AMPLITUDE SPECTRUM AND EDGE DETECTION ATTRIBUTES FOR CHANNELS DISCRIMINATION AND GEOMETRY IN OTUMARA FIELD, NIGER DELTA, NIGERIA

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(Sponsored by B.C.E. Egboka, FAS)

Abstract. Geological interpretation of seismic data traditionally fulfill two main objectives: solving geometry of structures with possible hydrocarbon accumulations and correlation of recorded seismic amplitudes with lithology, with the latter based on factors largely depending on interpreters' previous experiences. Upon the transformation of seismic data into frequency domain using the Fast Fourier Transform, the phase spectra indicate lateral geologic discontinuities while the amplitude spectra delineates temporal bed thickness variability, thus making the spectral decomposition technique an effective tool in discriminating geobody within a 3D seismic data such as channel fills and associated lithofacies. From its inception, spectral decomposition has been used in highlighting channels. In many tertiary basins such as the Niger Delta, there is a direct correlation between strong amplitude, greater porosity and the presence of hydrocarbons. We have employed such frequency attribute complimented with similarity, illustrating real possibilities in identifying stratigraphic features of interest.

1. Introduction

The study of frequency content of seismic data provides better understanding to geoscientists in the interpretation of seismic data. Isofrequency process is a very powerful tool in reservoir studies. Spectral Decomposition provides isofrequency slice which is known to eliminate most limitations encountered in seismic data to reveal geological information. The concept behind spectral decomposition is that the seismic reflection from a thin subsurface layer produces a characteristic frequency response that is indicative of the temporal bed thickness in

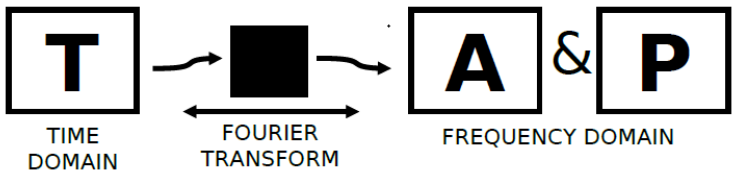
time. This quick and effective novel seismic technique was originally pioneered through research at BP and Amoco in the 1990's; an imaging innovation that over the years have provided interpreters with high resolution detail for imaging, mapping bed thickness, giving better definition helpful in the determination of stratigraphic architecture and structural features within 3D seismic surveys by breaking down seismic signal into its component frequencies as can be seen in fig.1.

Figure 1 shows the optical analogue of spectral decomposition where white light is decomposed into its spectral components. In actuality, the velocity of glass is dispersive, such that Snell's Law gives a different refraction angle for each frequency. A broadband seismic volume can be broken into constituent narrow band volumes. In this case, the analysis window is the length of the entire seismic trace (After Aarre et al., 2012).

In this study, Spectral Decomposition is employed for observing the response of lithofacies associated with channels helpful in discerning their existence and geometry.

2. **Methodology**

The basic Fourier theory suggest that a given signal can be synthesized as a summation of sinusoidal waves of various amplitudes, frequencies and phases; transforming a time domain signal to the 'frequency domain' where it is equivalent to an 'amplitude spectrum' and a 'phase spectrum'.



Initially, spectral-decomposition analysis was done within a fixed-sized analysis window (by using a short-window, discrete Fourier transform

(SWDFT)) (Liu and Marfurt, 2007). The equation for the short window discrete Fourier transform can be written as (Mallat, 1999)

$$U_{SWDFT}(\tau, f) = \frac{1}{\sqrt{2\pi}} \int u(t) W(t-\tau) e^{-i2\pi f t} dt$$

where:

$$\begin{aligned} u(t) &= \text{the time domain seismic data,} \\ \tau &= \text{the center time of the window function} \\ W(t-\tau), f &= \text{frequency and} \\ U_{SWDFT}(\tau, f) &= \text{the time-frequency function} \end{aligned}$$

The defined window $W(t-\tau)$ can be either a tapered or untapered rectangular window, Gaussian window, Hamming window, or Hanning window (Mallat, 1999). While Partyka *et al.* (1999) used a tapered window; Mallat (1999) uses a Gaussian window of the form

$$W(t-\tau) = e^{-\sigma^2 (t-\tau)^2}$$

Where: σ = a constant value controlling the window size, with larger values resulting in smaller time windows.

Geological Background

The study area covers 420 km^2 and is situated in the Niger Delta of West Africa which is located in the Gulf of Guinea at the formal triple junction of the South Atlantic rifting (Delhaya-Prat, et. al, 2009). The passive continental margin basin developed in the Early Cretaceous and its evolution can be divided into rifting and drifting phases. Covering an approximate areal extent of 70,000km^2, it is viewed as a long-lasting system supplied by Niger and Benue rivers. Both rivers have extensive drainage basins which delivered a high sediment supply accommodated by large growth faults. The resulting succession of deltaic, interslope and abyssal plain deposits has reached a thickness of approximately 12km (Delhaya-Prat, *et al.*, 2009). In the course of tectonic history of the basin - which have been extensively dealt with in relevant literatures, subsidence within the resulting depobelts ceased episodically, at which time alluvial sands advanced rapidly across the delta top, concurrent with a seaward shift in deposition and subsidence (Cohen and McClay, 1996).

Data availability and quality

The data set used for this research is a conventional 3D seismic volume (Fig 2) with range of 11228 to 12110 and 2673 to 3434 in the inline

and crossline direction respectively. TWTT range between 0-3000ms.

The reflectors are nearly parallel, being offset by normal growth faults which run across the section at specific intervals. Events within 496 to 1184ms (TWT) show little displacement at both sides of the faults. At intervals beyond 1184ms, the reflectors become quite chaotic close to and behind the faults. Furthermore intervals from 1800 to 3000ms, is characterized by chaotic, discontinuous and low amplitude reflections in the Eastern zone; these become relatively continuous, high reflections towards the western zone away from the first fault plane.

3. **Results and discussion**

The workflow adopted entailed firstly, looking for a typical local amplitude bright spot, dim spot, or something that looks geological often called FLT (Funny Looking Things); seismic attributes (energy and similarity) were generated for the entire seismic volume for this purpose. Once a 'FLT' is identified it becomes the focus of the interpretation (Fig 3), employing the use of one or several seismic attributes with the selected set constrained by the feature of interest under investigation. The facies interpretation made was anchored on such understanding that lithology influence on amplitude can often be recognized by the pattern of amplitudes as observed on horizon slices and by understanding how different lithologies occur within a depositional system (Avseth et al, 2005). This link when established between amplitude characteristics and depositional patterns makes it easier to distinguish lithofacies variations in amplitude maps. Brown et al. (1981), who was amongst the first to interpret depositional facies from 3D seismic amplitudes also used this technique to recognize buried river channels from amplitude information.

A frequency cross section of phase and amplitude showed that the signal below 75Hz is relatively meaningless (Fig 4). Hence, the study was constrained to iso-frequencies above the identified threshold. Animating through the spectral amplitude maps generated by spectral decomposition analysis between the range of 10 to 75Hz and comparing against that of the original seismic volume, the best definition of the seismic anomaly was observed at 10Hz and 20Hz over a time window of ± 28 depicting spatial patterns corresponding to reasonable geological model. This frequency attribute which returns the amplitude spectrum (FFT) was complimented by edge-detecting attribute in reaching

acceptable deductions from the horizon slice at 1424ms, while channel CH1 is highlighted by the peak frequency and peak amplitude in different color.

4. **Channel Morphology**

Two channels were identified within the study area. A broad relatively braided channel designated CH1(Fig 6a) and a second sinuous channel denoted CH2 (Fig 9b), both inferred from the geometric arrangement of the channel sand body. Energy attribute extracted over a time slice at 692ms (Fig 5c) gave the first insight into the possible presence of channel CH1 in the North-western part of the study area. The anomalously high amplitude contrast between the NW-SE trending feature (Fig 6a) as compared to the original seismic suggests a very sandy system.

The behavior of the channel was interpreted as resulting from the nature of basin topography and the nature of the substrate during the active periods of the channels. The positively high amplitude reflections which define a linear feature in the spectrally decomposed horizon map at 20Hz best depict braid bars with the degree of braiding $\langle 5\%$. Also cutting across the flow path is a relatively extensive structural ridge which is best resolved in the color blended display map (Fig 7a)- to enhance the visibility of the superimposed geologic features by spectral enhancement and gives the best output of spectral decomposition anomaly. Red, Green, Blue (RGB) blended amplitude map at three discrete frequencies was developed; the choice of frequencies is such that they represent the low, middle and high frequency of the seismic bandwidth around the horizon (the zone of interest (Fig 8)) as expressed in the amplitude spectrum. The low frequency is selected as being the first peak, while the high frequency as the last peak.

The homogeneity noted between the northern and southern margin as opposed to the distinct and striking difference along the channel's flow direction avails us insight into the depositional environment. The margins can best be defined as overbank regions characterized by such fine sedimentary fills as silt and clay, mostly responsible for its low amplitude reflectivity as observed in both the energy and spectrally decomposed maps. However, the somewhat discontinuous, alternating but relatively inconspicuous array of events along the central portion of the slice in Fig 6a, tells something of a rather paralic event typical of the Agbada formation in the Niger Delta involving marine, coastal

and fluvial marine deposit. Based on seismic facies characteristic only, basically amplitude and reflection continuity, the base of the three distinct formation boundaries when delineated, place horizon slice 692ms at the uppermost formation (Benin Fm) which consist of shallow massive continental sand sequence extending up to about 2500m. These discrepancies resulting from solely utilizing the 3D seismic volume will best be validated by integrating with well data.

The second channel CH2 is sinuous and has one of its meandering arm extending beyond the survey area (Fig 9) and the degree of sinuosity lie between the range of 1.06 to 1.25. Of little help was the use of similarity attribute in delineating its edges, however, based on the arrangement and configuration of the channel-associated-deposit, the flow path to a very great degree of confidence was mapped. These lithofacies include the two point bar deposits, showing up in the energy and frequency slice at 10Hz. A massive sand body is clearly seen to close against the E-W trending major fault F2, and constrained also by two minor faults in the North Western region (Fig 9a & 9b).

5. **Conclusion**

Spectral decomposition has become a useful and important technique & tool for extracting stratigraphic information from seismic data. In this paper, a case study is presented, where spectral decomposition was used successfully to image & map the channel sands and establish the presence and morphology of the channels in the Otumara Field, Niger Delta. We are encouraged to think that integration with well control will further validate these findings and identify the possible hydrocarbon prospect of these channel fills.

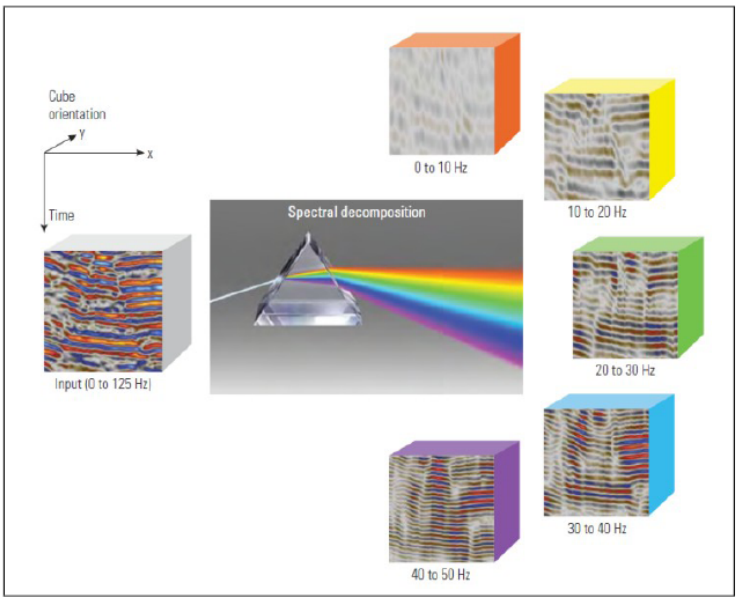


FIGURE 1. Fourier components of a broadband seismic pulse (After Aarre et al., 2012).

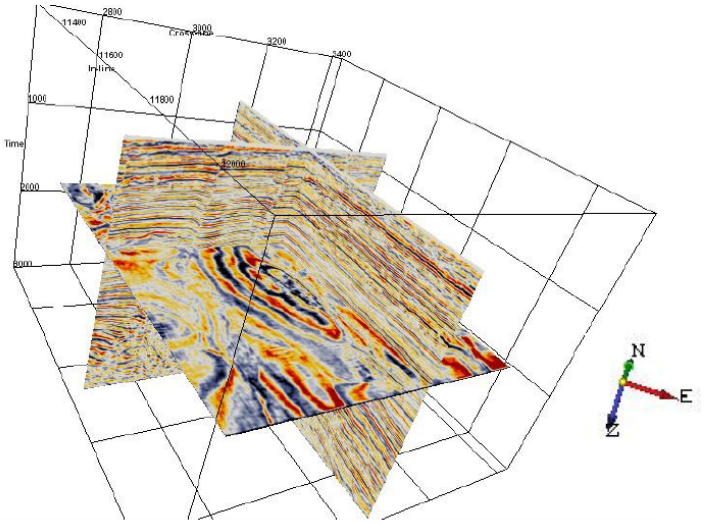


FIGURE 2. 3D seismic volume of the study area.

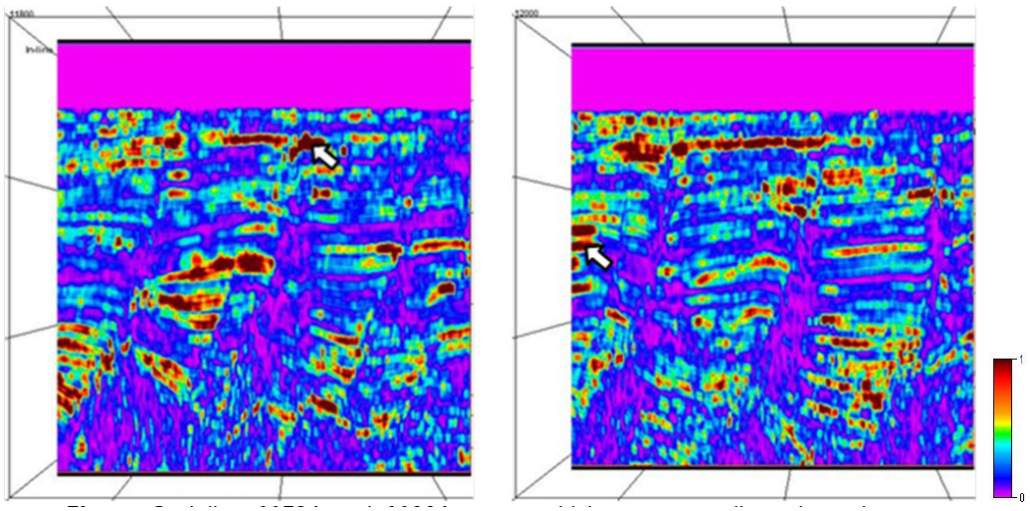
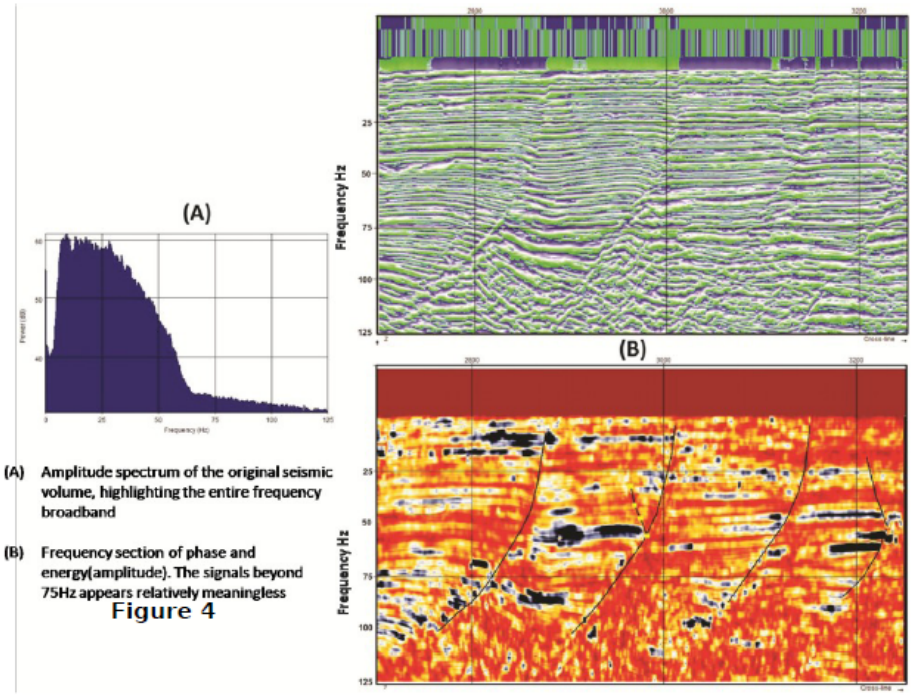


FIGURE 3. Inline 11724 and 11904 across which energy attribute have been extracted; the white arrow points toward the bright spots.



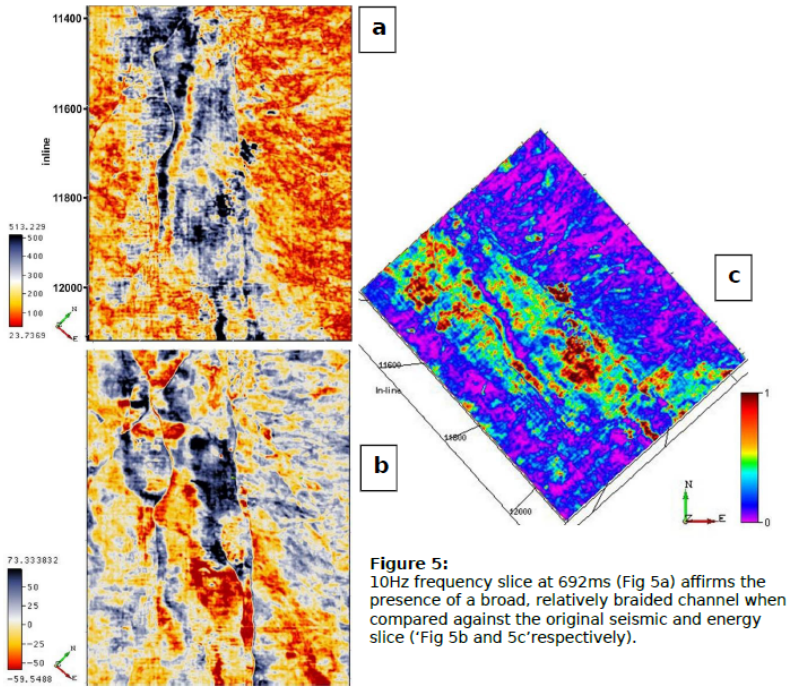


Figure 5:
10Hz frequency slice at 692ms (Fig 5a) affirms the presence of a broad, relatively braided channel when compared against the original seismic and energy slice ('Fig 5b and 5c'respectively).

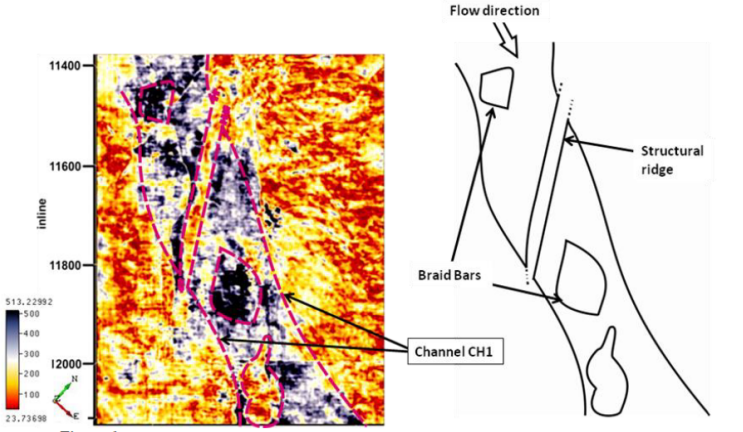


Figure 6a:
20Hz frequency slice at 692ms; the south-eastern end of the channel is more clearly highlighted. The structural ridge noted in Fig 7a shows up as the narrow linear structure trending across the channel path.

Figure 6b:
Interpreted line drawing

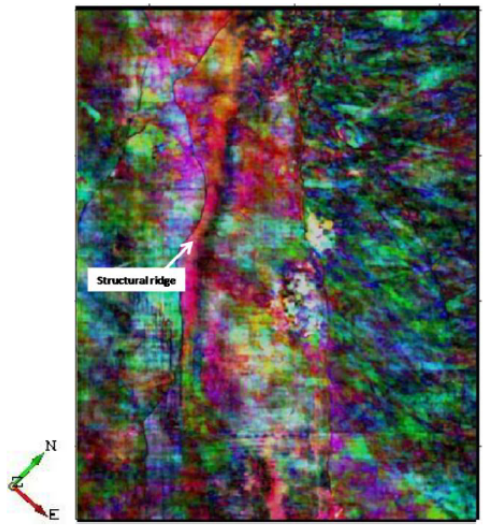


Figure 7a: RGB color blended display at horizon slice (692ms). Note the distinct difference between the northern and southern margins from the central area. Interpreted also is the NNW – SSE trending structural ridge.

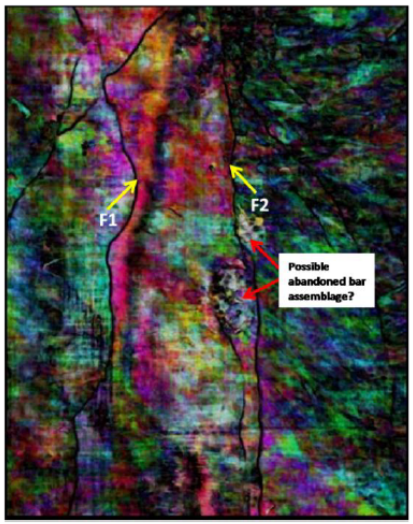


Figure 7b: Color blended display (z-slice at 692ms) co-rendered with similarity, more clearly resolve the major faults (F1 & F2) and a myriad of local fractures and joints.

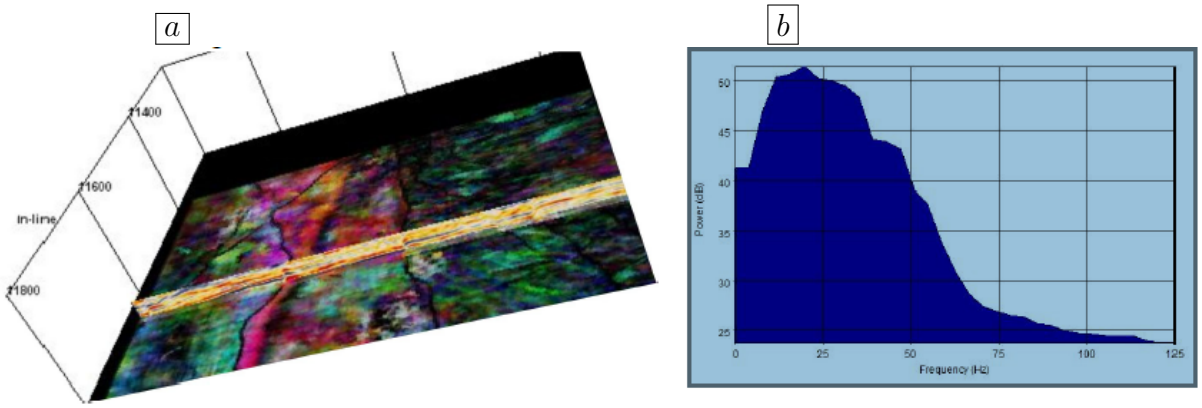


Figure 8: Three iso-frequencies of the seismic bandwidth around the zone of interest (8b) blended in the RGB display (8a).

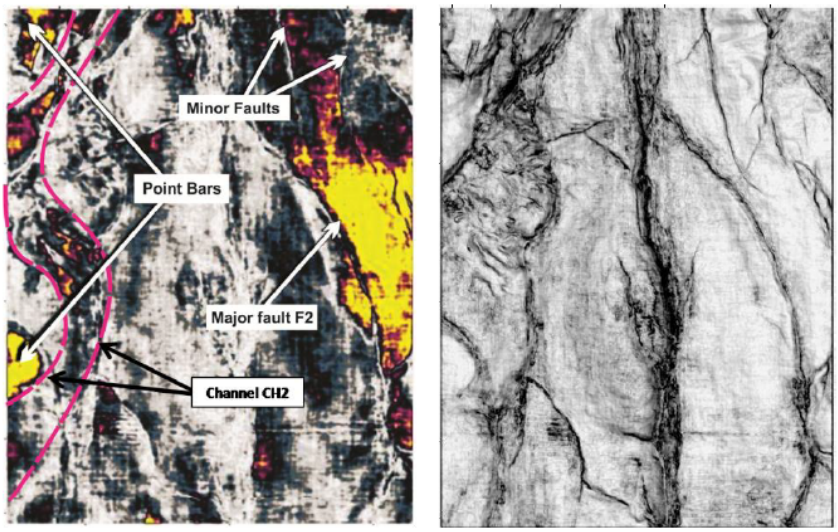


Figure 9: Horizon slice at 1424ms (a) Energy map (b) 10Hz frequency slice showing the channel outline (c) Similarity map

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Proc. Nigerian Acad. Sci.
Vol.6, Issue 1, 2013, pp. 69 - 75

AN EFFICIENT ALGORITHM FOR ZEROS OF BOUNDED GENERALIZED PHI-QUASI-ACCRETIVE MAPS

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Abstract. This is a research announcement of the following result. Let E be a real normed linear space in which the single-valued normalized duality map is Hölder continuous on balls and let $A : E \to E$ be a bounded generalized Φ-quasi-accretive map. A Mann-type iterative sequence is constructed and proved to converge strongly to the unique zero of A. In particular, our Theorems are applicable in real Banach spaces that include the L_p spaces, $1 < p < \infty$. The Theorems are stated here without proofs. The full version of this paper, including detailed technical proofs of the Theorems will be published elswhere.

1. INTRODUCTION

Let E be a real normed linear space with dual E^*. A mapping A with domain $D(A)$ and range $R(A)$ in E is called *accretive* if for all $x, y \in D(A)$, there exists $j(x-y) \in J(x-y)$ such that

$$\langle Ax - Ay, j(x-y)\rangle \geq 0, \tag{1.1}$$

where $J : E \to 2^{E^*}$ is the normalized duality map on E. The operator A is said to be $m-$*accretive* if A is accretive and the range of $(I + sA)$ is all of E for some $s > 0$. It can be shown that if $R(I + sA) = E$ for *some* $s > 0$, then this holds for *all* $s > 0$. The operator $-\Delta$, where Δ denotes the Laplacian is an $m-$accretive operator.

The accretive operators were introduced independently in 1967 by Browder [1] and Kato [5]. Interest in such mappings stems mainly from

Key words and phrases. Accretive- type operators; Uniformly continuous maps, phi-hemicontractive maps.
2000 *Mathematics Subject Classification* 47H06, 47H09, 47J05, 47J25.

their firm connection with the existence theory for nonlinear equations of evolution in Banach spaces. It is well known that many physically significant problems can be modelled in terms of an initial value problem of the form $\frac{du}{dt} + Au = 0,\ u(0) = u_0$, where A is accretive in an appropriate real Banach space. Typical examples of such *evolution equations* are found in models involving the heat, wave or Schrödinger equation (see e.g., Browder [2]). At equilibrium, $\frac{du}{dt} = 0$, so that the evolution equation reduces to the equation:

$$Au = 0, \tag{1.2}$$

whose solutions correspond to the equilibrium state of the system.

Let H be a real Hilbert space and let $f : H \to \mathbb{R}$ be a convex functional. Consider the *subdifferential,* $\partial f : H \to 2^H$ defined by

$$\partial f(x) = \left\{x^* \in H : f(y) - f(x) \geq \langle y - x, x^* \rangle \ \forall\ y \in H\right\}.$$

It is known that ∂f is a maximal monotone ($m-$ monotone) operator (e.g., Rockafellar[8]) and that $0 \in \partial f(u)$ if and only if u is a critical point of f. Thus, if we set $A := \partial f$, then $0 \in \partial f(u)$ reduces to the inclusion

$$0 \in Ax,\ x \in H, \tag{1.3}$$

whose solutions correspond to the critical points of f.

Since the operator A in equation (1.2) or inclusion (1.3) is generally nonlinear, considerable research efforts have been focused on iterative methods for approximating solutions of (1.2) or (1.3), assuming existence, when the operator A is of the accretive (or monotone) type.

Let $N(A) := \{x \in E : Ax = 0\} \neq \emptyset$. An operator $A : D(A) \subset E \to E$ is called *generalized $\Phi-$quasi-accretive* if, for any $x \in D(A), x^* \in N(A)$, there exists $j(x - x^*) \in J(x - x^*)$ such that $\langle Ax - Ax^*, j(x - x^*)\rangle \geq \Phi(||x - x^*||)$.

Remark 1.1. The class of generalized $\Phi-$quasi-accretive mappings is the most general for which the equation $Au = 0$ has a *unique* solution.

The most general results for approximation of fixed points of *uniformly continuous $\Phi-$ pseudo-contractive-type mappings* seem to be the following theorems.

Theorem G1 ([7], Theorem 2.1) *Let E be a real normed linear space,*

K be a nonempty subset of E and $T : K \to E$ be a uniformly continuous $\Phi-$pseudo-contractive-type operator, i.e., there exist $x^* \in K$ and a strictly increasing function $\Phi : [0,\infty) \to [0,\infty),\ \Phi(0) = 0$ such that for all $x \in K$, there exists $j(x-x^*) \in J(x-x^*)$ satisfying $\langle Tx - x^*, j(x-x^*)\rangle \leq ||x-x^*||^2 - \Phi(||x-x^*||)$. (a) If $y^* \in K$ is a fixed point of T, then $y^* = x^*$, and so T has at most one fixed point in K; (b) Suppose there exists $x_0 \in K$ such that both the Ishikawa iterative sequence $\{x_n\}$ with error and the auxiliary $y_n = (1-\beta_n)x_n + \beta_n Tx_n + v_n,\ n \geq 0$, $x_{n+1} = (1-\alpha_n)x_n + \alpha_n Ty_n + u_n$, are contained in K, where $\{u_n\},\ \{v_n\}$ are two sequences in E and $\{\alpha_n\}, \{\beta_n\}$ are two sequences in $[0,1]$ satisfying the following conditions: $(i)\alpha_n, \beta_n \to 0\ (n \to \infty)$ and $\sum \alpha_n = \infty$; $(ii)\ ||u_n|| = o(\alpha_n)$ and $||v_n|| \to 0 (n \to \infty)$. **If $\{x_n\}$ is a bounded sequence in K,** *then $\{x_n\}$ converges strongly to x^*. In particular, if y^* is a fixed point of T in K, then $\{x_n\}$ converges strongly to y^*.*

Remark 1.2. The conditions on $\{u_n\},\ \{v_n\}$ and $\{x_n\}$ in the Theorem 2.2 of [7] are as in Theorem G1.

Theorem C1 ([6]**, Theorem 7.2.1, p.248)** *Let E be a real normed linear space, K be a nonempty convex subset of E such that $K+K \subset K$, and $T : K \to K$ be a uniformly continuous and $\phi-$hemi-contractive mapping. Let $\{\alpha_n\},\ \{\beta_n\}$ be two real sequences in $(0,1)$ satisfying the following conditions: $(i)\alpha_n,\ \beta_n \to 0\ (n \to \infty)$; $(ii)\sum \alpha_n = \infty$. Assume that $\{u_n\}, \{v_n\}$ are two sequences in K satisfying the following conditions: $u_n = u_n^{'} + u_n^{''}$ for any sequences $\{u_n^{'}\}, \{u_n^{''}\}$ in K with $\sum ||u_n^{'}|| < \infty;\ ||u_n^{''}|| = o(\alpha_n)$ and $||v_n|| \to 0$ as $n \to \infty$. Define the Ishikawa iterative sequence with mixed errors in K by $x_0 \in K$, $y_n = (1-\beta_n)x_n + \beta_n Tx_n + v_n,\ n \geq 0$, $x_{n+1} = (1-\alpha_n)x_n + \alpha_n Ty_n + u_n$. If $\{Ty_n\}$ is bounded, then the sequence $\{x_n\}$ converges strongly to the unique fixed point of T.*

Remark 1.3. The conditions in $\{u_n\}, \{v_n\}$ in Theorem 7.2.2 of [6] are as in Theorem C1. In that theorem, the sequence $\{Ty_n\}$ is required to be bounded.

Remark 1.4. (1) Theorems G1 and C1 are important generalizations of several results. We observe that the class of mappings considered in theorem C1 is a *proper subclass* of the class of mappings studied in theorem G1 in which $\Phi(s) = s\phi(s)$. However, the requirement that $\{x_n\}$ be bounded imposed in theorem G1

is stronger than the requirement that $\{Ty_n\}$ be bounded imposed in theorem C1. Furthermore, the boundedness of the sequences $\{x_n\}$, $\{Ty_n\}$ or $\{Sy_n\}$ imposed in these papers ([6], [7]) are difficult to verify, *ab initio*, in any possible applications.

(2) It is well known that if an algorithm is applicable in establishing that the sequence of the algorithm converges strongly to a solution of a problem, the discussion of a more cumbersome algorithm for the same problem is completely undesirable unless, of course, if the cumbersome algorithm has significant advantages over the simpler one. For example, if the cumbersome algorithm converges significantly faster, or has a better error estimate. In particular, whenever the Mann algorithm works, any discussion of the so-called Ishikawa method is totally unecessary.

(3) The addition of *bounded* error terms to either the Mann or the Ishikawa-type recursion formula leads to no generalization. The proofs of theorems in this case amount virtually to uneccessary repetitition of the computations employed in the case when no error terms are included (see e.g., [3], Theorem 9.1, p.130). In fact, in Theorems G1 and C1 and other theorems of [6] and [7], the conditions imposed on the error terms are *impossible* to verify in any possible application because those terms are not known precisely.

(4) Existence theorems are generally proved in reflexive real Banach spaces. Consequently, it suffices to approximate solutions in such spaces.

(5) It is known that uniformly continuous maps defined on normed linear spaces are bounded (see e.g., a proof in Chidume *et al.*, [4]).

Let E be a real normed linear space in which the single-valued normalized duality map is Lipschitzian on balls and let $A : E \to E$ be a bounded generalized $\Phi-$quasi-accretive map.

We announce here that we have been able to construct an efficient Mann-type iterative algorithm and prove that the sequence of our algorithm converges strongly to the unique zero of A. Our theorems are applicable in q uniformly smooth real Banach spaces, $q > 1$. These spaces include the L_p spaces, $1 < p < \infty$.
More precisely, the following theorems are obtained.

2. Main results

Theorem 2.1. *Let E be a real normed linear space in which the single-valued normalized duality map is Hölder continuous on balls and let $A : E \to E$ be a bounded generalized $\Phi-$quasi-accretive map. For arbitrary $x_0 \in E$, define a sequence $\{x_n\}$ by*

$$x_{n+1} = (1 - \alpha_n)x_n + \alpha_n S x_n \ n \geq 0, \tag{2.1}$$

where $S : E \to E$ is defined by $Sx = x - Ax \ \forall \ x \in E$, and $\{\alpha_n\}_{n=1}^{\infty}$ is a sequence in $(0, 1)$ satisfying the following conditions: $(i) \lim_{n\to\infty} \alpha_n = 0$; $(ii) \sum_{n=1}^{\infty} \alpha_n = \infty$. Then, there exists $\gamma_0 \in \mathbb{R}^+$ such that if $\alpha_n \leq \gamma_0 \ \forall \ n \geq 0$, $\{x_n\}$ converges strongly to the unique solution of the equation $Au = 0$.

Theorem 2.2. *Let E be a q-uniformly smooth real Banach space, $q > 1$, and $A : E \to E$ be a bounded generalized $\Phi-$quasi-accretive map. For arbitrary $x_0 \in E$, define a sequence $\{x_n\}$ by*

$$x_{n+1} = (1 - \alpha_n)x_n + \alpha_n S x_n \ n \geq 0, \tag{2.2}$$

where $S : E \to E$ is defined by $Sx = x - Ax \ \forall \ x \in E$, and $\{\alpha_n\}_{n=1}^{\infty}$ is a sequence in $(0, 1)$ satisfying the following conditions: $(i) \lim_{n\to\infty} \alpha_n = 0$; $(ii) \sum_{n=1}^{\infty} \alpha_n = \infty$. Then, there exists $\gamma_0 \in \mathbb{R}^+$ such that if $\alpha_n \leq \gamma_0 \ \forall \ n \geq 0$, $\{x_n\}$ converges strongly to the unique solution of the equation $Au = 0$.

Corollary 2.3. Let $E := L_p$, $1 < p < \infty$ and $A : E \to E$ be a bounded generalized $\Phi-$quasi-accretive map. For arbitrary $x_0 \in E$, define a sequence $\{x_n\}$ by

$$x_{n+1} = (1 - \alpha_n)x_n + \alpha_n S x_n \ n \geq 0, \tag{2.3}$$

where $S : E \to E$ is defined by $Sx = x - Ax \ \forall \ x \in E$, and $\{\alpha_n\}_{n=1}^{\infty}$ is a sequence in $(0, 1)$ satisfying the following conditions: $(i) \lim_{n\to\infty} \alpha_n = 0$; $(ii) \sum_{n=1}^{\infty} \alpha_n = \infty$. Then, there exists $\gamma_0 \in \mathbb{R}^+$ such that if $\alpha_n \leq$

$\gamma_0 \ \forall \ n \geq 0$, $\{x_n\}$ converges strongly to the unique solution of the equation $Au = 0$.

Remark 2.4. Our results in this paper, under the setting of our theorems, are significant improvements of Theorems G1 and C1 and a host of other recent results in the following sense:

1. Since uniformly continuous maps defined on normed linear spaces are bounded, it follows that the class of *bounded* mappings considered in our theorems is much larger than the class of *uniformly continuous* maps considered in Theorems G1 and C1
2. The recursion formula of the Mann-type considered in our paper is much simpler and more efficient than the Ishikawa-type recursion formulas considered in these papers.
3. The boundedness of the sequence $\{x_n\}$ of the cumbersome Ishikawa-type recursion formula, and for the restricted uniformly continuous maps imposed in Theorem G1 and in Theorem 2.1 of [7] is dispensed with in our theorems for the more general class of bounded maps, and superior Mann-type iteration formula. Similarly, the boundedness condition on the sequence $\{Ty_n\}$ imposed in Theorems C1 and on $\{Sy_n\}$ imposed in Theorem 7.2.2 of [6] is dispensed with in our theorems.

The full version of this paper including the technical proofs of the above theorems and corollary will be published elsewhere.

Prototype of the iteration parameter in all our theorems is $\alpha_n = \frac{\gamma_0}{1+n} \ \forall \ n \geq 0$.

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Proc. Nigerian Acad. Sci.
Vol. 6, Issue 1, pp. 76- 86, 2013

NIGERIAN ENERGY BILLING IN A DEREGULATED ECONOMY FOR SELF RELIANCE AND SUSTAINABLE DEVELOPMENT

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Abstract. Electric energy which is placed on top of the energy stratification and its uses at home, industry, agriculture, and in transport is indispensable. Tariffs are ways in which electric utilities derive their income from customers through effective electricity bills. This paper examines and analyses the energy billing in a deregulated economy in terms of its benefits for sustainable development especially for its capacity in eliminating subsidies, improvement in public financing and sale of assets. It as well shows its improvement of macro performance in generation of energy, transmission and distribution system. Moreover electric energy and billing are cost effective as well as competitive with improved service to consumers while at the same time encouraging private investment, lower consumers' tariffs. various tariffs system such as flat demand rate, straight rate, block rate, Hopkinson rate, Doherty rate, Wright rate and further proposed two important tariffs demand rate known as Zarma, and Otokpa demand rate. Recommendations were made and finally conclusion were also made that energy is very sensitive to either remain in the hand of government or private alone. Both have a good role to play collectively.

1. Introduction

Electric energy companies in the world incurred lose due to low tariff, high generation, and transmission and distribution losses and as a result many countries in the world have undertaken comprehensive review of the sector to make electric utility more responsive to public needs, improve and private sector participation in electric power generation, transmission and distribution.

In Nigeria, the electricity was in the hand of National Electric Power Authority (NEPA) and is now the Power Holding Company of Nigeria (PHCN) to generate, transmit, distribute and market to the general public, electricity in Nigeria is distributed via the National grid system. Power is not decentralized; this body implements different energy policies. Before the deregulation reform, PHCN had a monopoly in generation, transmission and distribution, but currently the generation and distribution section are under a serious reforms. The tariffs system is formulated and monitor by the Nigeria Electricity Regulatory Commission with the following mandates:

1. To determine the tariff for electricity, wholesale, bulk, grid or retail in the country.

2. To determine the tariff payable for the use of transmission facilities.

3. To regulate power purchase and procurement process of transmission facilities in the nation.

4. To promote competition, efficiency and economy in the activities of the electricity industry.

5. To perform other functions, as conferred by the Federal Government as regards operation of Power system in the country, safety standards, power quality standards, National Power Policy etc.

Energy billing and customer information system in a deregulated power sector may be different from the present day billing system where consumer receives monthly bill for electricity consumption and meter rent, since generation, transmission and distribution function may be performed by different companies, it is advisable that billing for each of theses are shown separately on each consumer's bill (Nicholgon, K.E. *et al.* 200). Additional segmentation for metering function and customer service may also be made by Distribution Company or Retail Company. Other information of the electric bill are profile code, customer name and address, rate in kilowatt hour (KWH) and total amount changed and consumed by customers.

2. TARIFF

Tariffs are different methods of charging customers (Gupta, B.R, 2000). A good electric tariff should fulfill the following objectives and requirements.

1. Must have a satisfactory net return on the capital investment.
2. Cost of metering, billing, collection and miscellaneous services must be recovered.
3. Cost of operation, supplies, maintenance of losses must be recovered.
4. It should be simple and comprehensive to the public.
5. Cost of capital investment in generation, transmission and distribution equipment must be recovered.
6. Should be uniform over large population.
7. It should provide incentive for using power during the off-peak hours.

3. COMPARISON OF ELECTRIC UTILITY COMPANIES WITH OTHER FIRMS IN NIGERIA

In Nigeria electric business enjoy monopoly, and it is subjected to government control especially as regards to fixation in tariff, the amount of voltage and frequency is specified by electricity rules, PHCN directly sell the commodity to the consumer's and there are no middle men like whole-sale dealers and retailers. Generally, electric utility trading required huge investment and return on investment is low, duplication of facilities or competition is uneconomical and this lead to monopoly.(Roley, T.A 1977).

TARIFF SYSTEM

A lot of tariffs have been proposed over the years and are in use. They are generally derived from the following equation

$$A = Cx + dy + f,$$

where

$A =$ Total amount of bill for a certain period (one month)
$x =$ maximum demand during the period (KW or KVA)
$y =$ total energy consumed during the period (KWH)
$c =$ unit charge for maximum demand (Naira/Kw, Cr Naira/KVA)
$d =$ unit cost of energy, (Naira for KVA)
$f =$ constant charge, (in Naira).

A standard or general bill consists of three parts, one depending on maximum power demand, the second on total energy consumed and the third being a constant figure (Barely, E.E 1974).

1. FLAT DEMAND RATE

The flat demand rate can be expressed in the form of $A = Cx$, this implies that the bill depend on unit charge for maximum demand in naira per kilowatt and maximum demand during the period in kilowatt.

It is the earliest form of tariff and the bill in those days was based on the total number of lamps installed in the premises and currently this tariff is restricted to sign lighting, signal system, street lighting and in irrigation farms where the number of hours are fixed and energy consumption can be easily predicted. This charge is made according to the horse power of the motor installed based on the rated capacity and the cost of metering equipment and meter reading is eliminated by the use of this form at tariff (Gupta, B.R. *et al.* 1975).

2. STRAIGHT METER RATE

This tariff is in the form of $A = dy$ and is a function of total energy consumed during the period in kilowatt hour and the unit cost of energy in naira per kilowatt hour. This implies that this charges depend on the energy used and is used in residential and commercial customers because of its simplicity (Gupta, B.R *et al.* 1975) on the other hand, its main challenge is that customer who does not use energy has zero bill though it caused the utility company to incurred a definite expenditure due to its readiness to serve him and discourage the use of electricity.

3. BLOCK METER RATE

This tariff is a modification of straight meter rate based on

sliding scale where a certain unit rate is for a certain block of energy and for each succeeding block of energy, the corresponding unit charge decrease and is expressed in the form of $A = dy, +dzy2 + \cdots + dn[y - +y2 + \cdots + tyn + \cdots + yn - 1)]$ where $d1, d2, d3$ are unit charges for energy blocks of magnitude $y1, y2, y3$ etc. Generally the charge and energy consumption are divided into three blocks, a high rate for the initial certain number of energy units, lower rate for the next certain number of energy units and still lower for the remaining energy units (Roley, T.A 1977). This tariff is commonly used for residential and commercial customers. In Nigeria, this tariff is in a reverse form to restrict the energy consumption and as a result the unit energy charges increases with increase in energy consumption.

4. HOPKINSON DEMAND RATE

This tariff favour the utility company and is in the form of $A = Cx + dy$. It includes a demand charge based on the maximum demand plus a charge based on energy consumed; the factors c and d may be constant or may vary as per sliding scale. It is mainly used for industrial customers and introduces the problem of measuring the maximum power demand of the customers. The maximum demand can either be taken as a certain fraction of the corrected load or measured by a maximum demand meter (Gupta, B.A *et al.* 1991). The demand charges are based on KVA of maximum demand; these in most cases discourage customers from using low power factors.

5. DOHERTY RATE

This rate is mainly for industrial customers that uses heavy electrical machine. The tariff is in form of $Cx + dy + f$ that has three component. This rate favours the electric utility because the rate recovers maximum demand irrespective of the amount of energy consumed and considers total energy consumed during the period and unit cost of energy.

6. WRIGHT DEMAND RATE

This tariff is generally specified for those industrial customers who have a control over their maximum demands and may be in the form of $Cx + dy$ but offers an inducement to a customer to keep his maximum demand at a low value and energy charge

for a reduction in maximum demand low. This implies an improvement in load factor.

7. TARIFFS PROPOSAL FOR RESIDENTIAL CUSTOMERS IN NIGERIA

There is a lot of inconsistency in the billing system from time to time and they is a need for stability within the sectors say a review in every four years. In a developing country like Nigeria, the tariff system should be in either in the form of

$$A = Cx + f, \qquad (1) \text{ Zarma}$$

where x= maximum demand during the period in kilowatt, C = unit charge for maximum demand in naira per kilowatt. f = monthly charges for metering and other constant

or

$$A = dy + f \qquad (2) \text{ Zarma},$$

where d = unit cost of energy in naira per kilowatt hour y = total energy consumed during the period in kilowatt hour. f = monthly charges for metering and other constant

$$\int_a^b f(x)dx \qquad \text{Otokpa}$$

where $f(x)$ is the integration value of cost of generation, transmission, and distribution and must be charged based on the building types such hut, one bedroom, bungalow, Duplex, high rising and sky scrapers.

The mode of payment in Nigeria is either post paid or prepaid metering.

1. Post paid is the process whereby customers are allowed or given access to the electrical energy and at the end of the specified period, electrical utility company calculate and bring the tariff in form of bill and give to both industrial and residential customer. This system does not favour the electric utility companies because of long history of bad debt incurred by influential customers and government offices while the prepaid system is in the form of billing system where customer pays and procures for both monthly charges and electrical units ahead/or before

access is given to them for usage. The billing below is a sample of prepaid tariff in Lagos, Nigeria.

PHCN EKO DISTRIBUTION ZONE
VAT NO: LCV25230601

Date : 30/11/2011 12:22:33
Customer: Awotundu S.A
Location No: MUS9043130382-01
Meter No: 01325914628
Address: 10 Karimu Street, Mushin
Debt Collected : =N=0.00
Monthly Charges: =N=325.00
Charges VAT : =N=15.47
Cost of units: =N=629.56
Total units: 86.2kwh = N=7.30/kwh
Unit VAT = N= 29.97
Total paid =N=1000.00
Electricity Token PIN: 53809614709795095316
GNO: M30N00188169
Operator : C.P. Anyasie
SGC: 600292 Tariff: 1 KRN:1

SOURCE: PHCN EKO distribution zone, Lagos.
November, 2011

PHCN EKO DISTRIBUTION ZONE
VAT NO: LCV25230601
Credit token

Date: 08/06/2012 13:26:05
Consumer: Awotundu S.A
Location No: MUS9043130382-01
Meter No: 01325914628
Address: 10 Karimu Street, Mushin
Debt Collected : =N=0.00
Monthly Charges: =N=575.00
Charges VAT : =N=27.37
Cost of units: =N=379.56
Total units: 29.5kwh = N=12.87/kwh
Unit VAT = N= 18.07
Total paid =N=1,000.00
Electricity Token PIN: 3427318548590960 6477
GNO: M30N00213047
Operator : Akanbi Akintunde A
SGC: 600292 Tariff: 1 KRN:1

Source: PHCN EKO distribution zone, Lagos.
June 2012

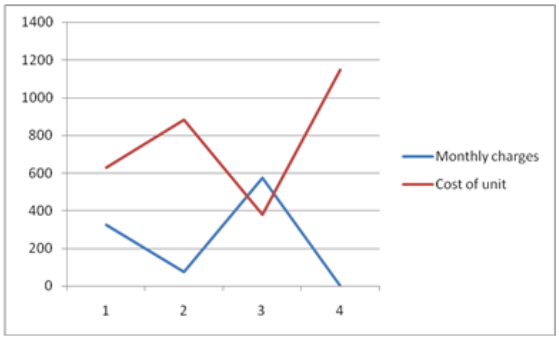
PHCN EKO DISTRIBUTION ZONE
VAT NO: LCV25230601
Credit Token

Date : 17/04/2012 14:58:10
Customer: Awotundu S.A
Location No: MUS9043130382-01
Meter No: 01325914628
Address: 10 Karimu Street, Mushin
Debt Collected : =N=0.00
Monthly Charges: =N=75.00
Charges VAT : =N=3.57
Cost of units: =N=879.56
Total units: 120.5kwh = N=7.30/kwh
Unit VAT = N= 41.87
Total paid =N=1,000.00
Electricity Token PIN: 0797 2944 1467 6416 5019
GNO: M30N00206526
Operator : Akanbi Akintunde A
SGC: 600292 Tariff: 1 KRN:1

Source: PHCN EKO distribution zone, Lagos.
April, 2012

Analytical deduction for ₦1000

Date	Monthly charges	Cost of unit	Total unit	Vat
30/11/2011	325.00	629.56	7.30	29.97
17/04/2012	75.00	879.56	7.30	41.87
08/06/2012	575.00	379.56	12.87	18.07
23/06/2012	0.00	1,145.48	13.87	



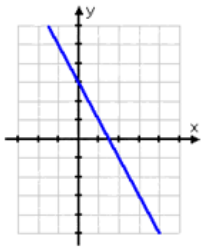


Figure 1.2: graph of Monthly charges against unit cost

The extrapolation of monthly charges against unit cost showed a straight line curve intercepting at both y and x axis. This revealed a progressive increase in total unit in Naira/kilowatt hour (N/kwh)

4. BENEFITS OF DEREGULATION

Currently, electricity department and energy are still controlled strictly by government. The technical departments of generation, transmission distribution operations are funded by the government. This is capital intensive and return on investment is slow, and it is now realized that this system is unwisely, uneconomical, and is not consumer friendly. Complete deregulation of the sector can bring in the following advantages.

1. Elimination of subsidies: public fund in the form of tax payer's money are squandered on subsidies which are in most cases not given proper account of.
2 . Improve public finance through sale of assets.
3. Improve performance of generation, transmission, and distribution system by introducing competition between different power players.
4. Improve and better service to consumers

5. Attract private investment and lower customer tariffs through efficient operations.

5. RECOMMENDATION

1. Deregulation should be carefully planned and carried out in a way and manner that the implementation will not have negative effect on the public.
2. Sales of public asset should be done in a transparent manner.
3. Only companies with the technical knowhow and financial strength should be allowed to participate on the initial take off of the deregulation process.
4. The scope of Nigerian deregulation should be such a way that will accommodate individuals, research institute, and all tiers of government.
5. Government should set up value added network (VAN) in form of energy parliament where energy senators and customers will interact both electronically and physically in such a way that will enable customers to maintain electronic mail.
6. There is an urgent need for legislative framework that will mandate all the tiers of government to establish a bureau of energy office for effective energy audit.
7. Energy is a springboard to economy development, therefore, government should establish energy development fund (EDF) to support this sector.

6. CONCLUSION

Energy is very sensitive to either stay in the hand of government or private alone. Both have a good role to play. Government is not a good business manager, therefore, should be restricted to the role of policy maker and should not be involve in commercial activities. In Nigeria, if the above recommendation is adhered to, electric energy requirement will be achieved and maintained.

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This journal is being supported by TETFUND 2012 special intervention under the higher Educational Book development fund (Batch 2)