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An Evaluation of Improved Local Blacksmith Process

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Abstract: Blacksmithing processes one the most ancient craft and forerunner of all metal forming processes in used is almost fading out in Nigeria because of the quality and quantity of the products. Base on this fact, this study was conducted on manufacturing processes and products in local blacksmith shops in view to improve the quality and quantity of the products. Questionnaires were administered to 70 local blacksmith shops in the south west of Nigeria to verify the manufacturing processes with its associated factors. Critical analysis of the probable solution to the problems as indicated by respondents from the questionnaire lead to redesigning and development of some equipment, which include: Heat treatment bath, close furnace and forging machine in the shop. The performance evaluation carried out on the equipment using two selected products (Chisel and Hammer head) showed that quality and productivity can be considerably improved using developed equipment. The sample from improved equipment showed remarkable increased in hardness, strength and ductility when compared to samples from traditional equipment. These equipment are also simple in design and can be fabricated from locally available materials.

Key words: Blacksmith, manufacturing processes, redesigning, product, quality

INTRODUCTION

Blacksmithing is an ancient indigenous technology, which is the progenitor of various metal forging operations in use today and can be found in virtually all-major culture of the world (Oke and Aderoba, 2000). Blacksmithing processes remain primitive and rudimentary that it is hardly employed as a viable means of commercial production of metal wares in Nigeria (Thomas, 1980).

For long, particularly during the pre-colonial era and even now, some of Nigeria local blacksmith are traditional producer of simple tools such as cutlasses, hoes, knives head pans, diggers and machetes and many fixtures and devices primary used for agricultural production. Other items produced through blacksmithing processes are domestic products, which include; kitchen wares, cooking utensils, basin, pails, which have found application in various homes. However, some blacksmiths are involved in the production of industrial products, which include. Hammer head, key, chisel punch, bolt and nuts etc. The forge product of blacksmithing is also very important and highly demanded by those in the construction industry (RMRDC, 2000). Oke (2005) also stress the important of blacksmith shop in the production of forge parts of automobile spare parts if the shop is the shop is mechanized and appropriate material is provided.

The major operations in blacksmith shops consist of heating of work pieces, hard forging operation and heat treatment processes. The production facilities consists of a forging facilities, which include anvil, hammer, chisels, fuller, drifts punches etc. Open furnace with bellow is another blacksmith production facility for heating operation. This furnace makes use of palm kernel shell/waste to heat the metal, which is mostly iron and the heated metal is forged manually into desired tool. Occasionally, a primitive heat treatment process is achieved by quenching the forged metal in a container containing palm oil, water or some vegetable oil solution.

Blacksmithing products have been recognized in the country from time immemorial and its importance, as an enterprise cannot be contested as one of the local skill necessary for sustainable development. Blacksmith skills was extremely important to early Arkansan, to make and repair tools, automobile spare parts, household implements and weapons (Oyenenye, 1984). The potential of blacksmiths for serious application sometimes demonstrated under unusual circumstances is beginning to find commercial application in satellite town of Nigeria urban centers where they serve as an adjunct to roadside mechanics (Eboh *et al.*, 1995). Although the advent of the imported farm implements and machineries spare parts distorted the activities of local producers, but the increasing scarcity of foreign exchange is now necessitating a change of direction to abandon indigenous products (Obikwelu, 1999).

It is quite important to note that the blacksmith skills is one of the basic skill required for producing innovative appropriate technological implements, but is unfortunate that, local blacksmith shop is about to be faced out due to the influence of western education and rural-urban drift

(Ezeadichie, 2002). The problem of flow of advance and improved western industrial products give blacksmiths little room to improve on their product in accordance with modern appropriate technology innovation (Atteh, 1992). The people are now neglecting the products of local blacksmith shops for the foreign products which suites the changing circumstances of time in term of quality and quantity. The situation has made the blacksmiths to be periodically engaged in the practice base on the demand of the products from individual customer.

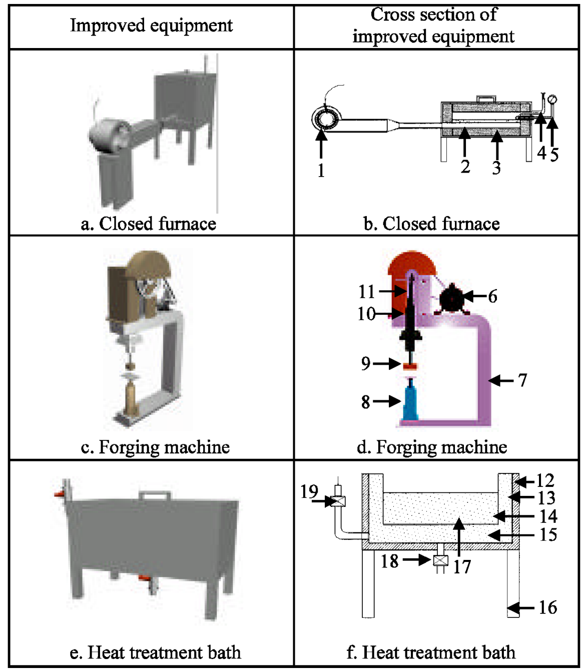
It was stressed that, development of indigenous technology for developing small-scale industry in which blacksmith shop is included is important for fast development of complex technology industries in Nigeria (Okopo and Ezeadichie, 2003). Oni and Lawal (2006) also stated it clearly that development of this type small-scale manufacturing industries is the cornerstone of sustainable economic self reliance.

For reasonable development of local blacksmith shops in Nigeria there is a need to know the quality level of the products as related to the foreign products in other to know how to improve the production processes to enhance the quality of the products in the shops. This study, therefore, investigated the production processes of blacksmith shops in comparison with standard smith forging to identify the problems encountered during production processes. Base on the identified problems the manufacturing process is redesigned to improve the quantity and quality of the by-products of the shop.

FEATURES OF REDESIGNED EQUIPMENT FOR LOCAL BLACKSMITH SHOP

Based on the problems observed in traditional blacksmithy the equipment that were developed to improved the quality and productivity include: Close furnace with air duct, Heat treatment bath and forging machine. All the dimensions used in the design are based on the analysis of questionnaire of the dimension of the products produced in the local blacksmithy. The average maximum length of the product is 65cm and the maximum width is 15cm.

Close furnace: The furnace in Fig. 1a is box type furnace made of following parts furnace chamber made of firebrick clay, steel casing, pyrometer, air duct firing tray and angle iron.The furnace chamber lining is made of fire blended brick clay with chemical composition 50.9% SiO_2, 31.08% Al_2O_3, 1.55% TiO, 0.0001% Na_2O, 0.289% K_2O.The clay was blended to have desired properties which include thermal conductivity of 0.9W/mK, refractiveness



Legends description:
1: Air duct
2: Firing tray
3: Firebrick clay
4: Exhaust
5: Pyrometer
6: Electric motor
7: Frame
8: Hydraulic jack
9: Detachable mass
10: Connecting rod
11: Arm
12: Partical board
13: Air duct
14:Quenchant container
15: Water
16: Angle iron
17: Quenchant
18: Outlet value
19: Inlet valve

Fig. 1: Improved and local blacksmith equipment

temperature of 1600°C, surface shrinkage of after firing of 2.50%, bulk density of 1.75g cm^{-3} and porosity of 35.97%. The pyrometer is made of 2 dissimilar wires (chromel and alumen) with working temperature range of 1100°C. An air duct was developed with close furnance to speed up the rate of complete combustion of the fuel (palm kernel shell) within the furnace. The stress of blowing air is also removed with the incorporation of air duct in the design. This close furnace was designed to solve the problem of inappropriate heating to reduce the time for heating a work piece and to minimize fuel wastage. The furnace actually improve the quality and the quantity of the product with the incorporation of pyrometer that monitoring the temperature in the furnace which enable the furnace to carry out effectively heat treatment processes like annealing, normalizing and tempering. The design of the furnace allows heat in the furnace to be uniformly distributed, this eliminate the problem of inhomogeneity in the properties of the products, which is the greatest shortcoming in local blacksmithy heating operation. Fuel wastage is also drastically reduces to the minimum and part heating of the work piece is completely eliminated with this design.

Heat treatment bath: Heat treatment bath in Fig. 1e is designed to allow proper hardening of products with less distortion and internal stress and is made up of the following parts: outer water container, inner quenching container, particle board, pipe, control valve, heating element (2000W) and thermometer. The inner container consists of quechant, which can be brine, oil of different type and water depending on the property required of the product, which is surrounded, by water flowing from over head tank. The water in the outer container is usually heated through the heating element to maintain the temperature of the quechant in the inner container at around 60-65°C necessary for hot quenching. Valves are used for controlling inflow and out flow of water from the outer container to maintain the temperature of quenchant at room temperature during normal quenching. The particles board maintains the temperature of the water in the outer container to allow maximum heat flow to the inner container. All the incorporated parts actually help in stabilizing the property of the products there by avoid unnecessary cracking of the product as result of high distortion that normally lead to failure the products during operation.

Forging machine: The forging machine Fig. 1c is made up of the following parts steel casing, angle iron bar, connecting rod, hydraulic Jack, electric motor, bearing and detachable masses. The principle of operation is base on the fact that the impact force on the work piece is factor of potential energy due to the varying detachable mass of the hammer. The hydraulic jack serves as the base or table on which the forging is taken place is adjusted to accommodate the work pieces according the sizes. The developed forging machine helps in forging the product within the stipulated time and forging temperature thereby preventing inhomogeneous deformation of the products.

MATERIALS AND METHODS

Site studies: Questionnaires were used as the instrument for the research, these questionnaires were administered to local blacksmith shops in all state capitals that make up south west of Nigeria which include: Ekiti, Lagos, Kwara ,Ogun Ondo, Osun and Oyo States. Visitations were made to some blacksmith shops in all the states to carry out physical assessment of the blacksmith shops and manufacturing processes in the shop to ascertain the level of development of the product produced in the shop. The questionnaire used was divided into 7 sections. The 1st section dealt with ownership details, the 2nd section also addressed training processes in the blacksmith shop, while the 3rd section dealt with post training requirements. The 4th sections further dealt with the professional practices of the blacksmith, the 5th section also addressed marketing and financial operations. Moreover, the sixth section investigated the relationship of blacksmith shop sector and other body and the last section analysis the personal perception of the operators of the shop and their customers towards the operation the products of the shop. Twenty copies of questionnaire were distributed each to the seven states for completion for period of six months. One Hundred and twenty five copies of these questionnaires were duly completed and returned by the respondents from all the seven states. It was on these numbers that the findings were based. The statistical methods used for the description of the responds contained in the administered questionnaire were simple percentage and bar chart and pie chart. The redesign and developed blacksmith facilities was base on the responds from the questionnaire.

Specimen preparation: Mechanical test, microstructure and material composition were carried out on the products of local blacksmith shop in each state and the products of blacksmiths shop with redesigning equipment on two selected products to analysis properties of the products produced in the local blacksmith shop. The same test was carried out on imported products to serve as control. The selected blacksmith products used for the experiment are hammer head and chisel. Sets of blacksmith products were bought from the 7 state capitals, viz: That made up the south west of Nigeria which include; Ado, Ikeja, Ilorin, Abeokuta, Akure, Oshogbo and Ibadan. Mechanical, microstructure and material composition tests were carried out in the Metallurgy and Material Engineering Department of Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria.

Samples of selected blacksmith products from different locations and improved designed equipment products and their corresponding imported were machined into shapes and sizes suitable for mechanical testing and metallography examination. The mechanical tests preformed are hardness and tensile tests.

For hardness test, specimens of blacksmith products from each state, redesigned equipment products and imported smith products were grounded using emery paper of grades 220, 320, 400 and rough polished on glycerol-lubricated silicon carbide paper. This was done to produce a very smooth surface. The grinding and polishing were done slowly to avoid heating and oxidation and all the damages arising from specimen preparation were totally eliminated during grinding and polishing processes (Askeland, 1993) Brinell Hardness test was used and area of impression of load was determined. A load 750 kg was pressed on each test. specimen for 10 sec with the aid of an indenter of 5 mm diameter.

Table1: Hardness test results

	Brinell Hardness Number (BHN)																	
	Imported product (control)						Product from improved equipment						Product from locally made equipment					
Trials	1	2	3	4	5	AVE	1	2	3	4	5	AVE.	1	2	3	4	5	AVE.
Hammer head	295.2	295.2	295.2	295.2	295.2	295.2	286.4	286.4	286.4	286.4	286.4	286.4	251.2	247.3	255.3	245.8	250.3	250
Chisel	262.6	262.6	262.6	262.6	262.6	262.6	251.65	251.55	251.6	251.5	251.7	251.6	229.2	228.7	220.9	225.6	227.8	226.4

Table 2: Tensile test results

Sample	Products	Ave ultimate stress (kn m^{-3})	Ave fracture stress (kn m^{-3})	Ave percentage elongation (%)
Hammer head	Imported (control)	620	480	11.80
	Improved equipment	570	445	10.50
	Local blacksmith equipment	501	420	0.80
Chisel.	Imported (control)	549	425	17.30
	Improved equipment	521	418	15.20
	Local blacksmith equipment	445	378	0.95

Table 3: Material test results

		Products																		
Sample	elements	c	si	s	p	mn	ni	cr	mo	v	cu	w	as	sn	co	al	pb	ca	zn	fe
Hammer head	Imported	3.80	1.49	0.06	0.03	0.52	0.08	0.20	0.02	0.01	0.23	0.01	0.02	0.03	0.01	0.01	0.14	-	0.02	93.4
	Improved equipment	2.70	0.47	0.05	0.09	-	0.02	0.40	0.15	-	0.6	-	-	0.03	-	-	0.03	0.03	0.03	96.60
	Local blacksmith equipment	2.70	0.47	0.05	0.09	-	0.02	0.40	0.15	-	0.6	-	-	0.03	-	-	0.03	0.03	0.03	96.60
Chisel	Imported	1.30	0.40	0.02	0.02	0.65	0.07	0.20	0.05	0.01	0.01	0.10	0.04	0.01	0.01	0.01	0.03	-	-	97.50
	Improved equipment	1.17	1.05	0.02	0.09	0.52	0.08	0.06	0.01	0.01	0.01	0.1	0.03	0.01	0.01	0.01	0.03	0.01	-	96.80
	Local blacksmith equipment	1.17	1.05	0.02	0.09	0.52	0.08	0.06	0.01	0.01	0.01	0.1	0.03	0.01	0.01	0.01	0.03	0.01	-	96.80

$$BHN=2F/\pi D[D-\{(D^2-d^2)\}^{1/2}] \quad (1)$$ (Askeland, 1993)

Where: BHN = Brinell Hardness Number ,F= load in kilogram, D = Ball Diameter in (millimeter) and d = Diameter of impression in (millimeter) The average value of five hardness test trial data from each state was taken and recorded with their corresponding imported smith products and products from redesigned equipment in Table 1.

For tensile test, the specimens of blacksmith products from each state, redesigned equipment products and their c orresponding imported products were turned on lathe machine to standard tensile pieces. These "dog-bone" shape specimens have specifications of 5 mm diameter at the middle. Tensile test pieces were tested to fracture on extensometer. The dimension of the gauge zone was determined before and after the fracture. The loads at necking and at fractured were determined as well. The percentage elongation, ultimate and fracture stress were calculated using Eq. 1-3, respectively.

$$E = (L_f - L_o)/L_o \quad (2)$$

$$(\sigma_u)=F_N/A_F \quad (3)$$

$$(\sigma_F)=F_F/A_F \quad (4)$$

Where:
E = % Elongation, L_f = Final length of tensile specimen, σ_u = Ultimate stress, L_O = Original length of tensile specimen, σ_F = Fracture stress ,F_N= load at Necking, F_F = Load at fracture and A_F= Cross sectional area at Necking/Fracture. The average value of five tensile test trial data from each state was taken and recorded with their corresponding imported smith products and products from redesigned equipment in Table 2.

For metallography examination, the surface of a sample of each of the specimen was ground perfectly flat and mirror like surface using grade 220, 320 400, 500 and 600 emery papers ranging from coarse to fine. Polishing was done using alumna (Al_2O_3) paste (6μm down to 1 μm) extended with distilled water into slurry. Submicorn diamond was finally used to produce a mirror surface finish at end of polishing operation. The entire surface of the specimen was dipped into the enchant (Nital, 2% HNO_3 and 98% methyl alcohol) for about 10 sec after which the surface was washed with water and dried (Higgin, 1993). The specimens were taken to electronic microscope for metallography examination and the picture showing the arrangement of grain structure were taken and these are shown in Fig. 2a-f.

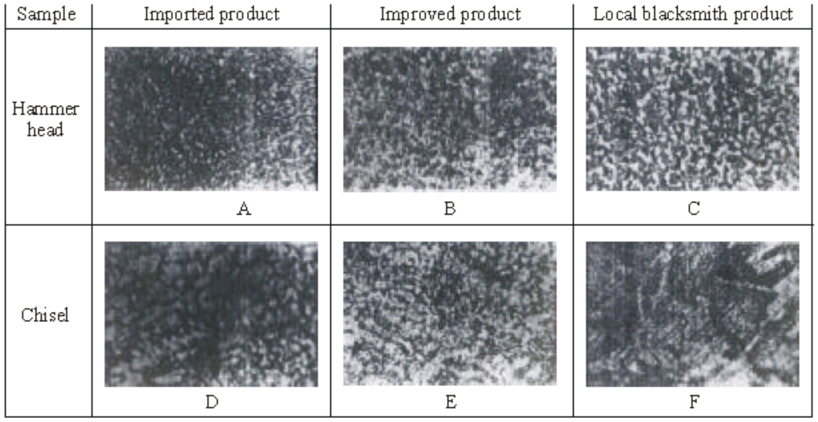


Fig 2A-F : Metallographic structure of smith products

For material composition analysis, the ground and polished surface was washed and subjected to the chemical composition analysis using metalscope and the result is shown in Table 3.

RESULTS AND DISCUSSION

Analysis of questionnaires: The result of the questionnaire and personal interview revealed that most of the blacksmiths were encourage by their family because blacksmithing is a family business while few (about 20%) actually created interest to engage in the business. Actually from the result of the questionnaire the age of the people involving in the business ranges from 40-60 years which shows that young people do not go into the business any longer because of the stress involved. It was discovered from the findings that no newly established blacksmith shops for the past 15 years. This is an indication that blacksmithing may soon fade out if it is not mechanized and modernized to reduce the stress involved in the processes and to improve the products to meet the acceptable standard.

During the period of visitation which covers period of 6 months the blacksmiths and their apprentice were observed fashioning varieties of domestic household utensils, Agricultural and industrial products. It was discovered from the result of the questionnaire that all blacksmiths in all the considered state states are involved the in production of agricultural products, about 69% of blacksmiths produce domestic/household utensils products while about 22% in average produce industrial products as shown in bar chart in Fig 3. Looking through all the products produced in local blacksmith shops during the study, it was discovered that 42% of the products produced in local blacksmith shops are Agricultural products and 25% domestic/house hold utensils while about 33% are industrial products as shown in a pie chart in Fig 4. This is in indication that if blacksmith shop is developed and mechanized its contribution will be felt by all area of human endeavors

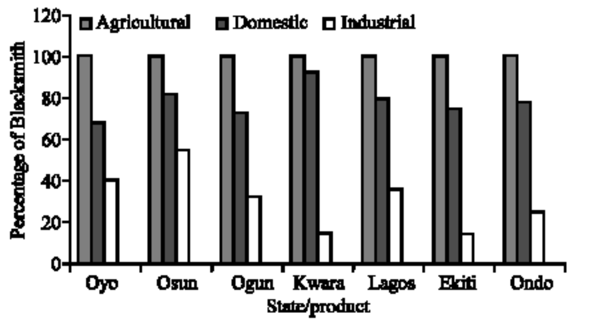


Fig. 3: Percentage of blacksmiths involving in producing different smith product in each state

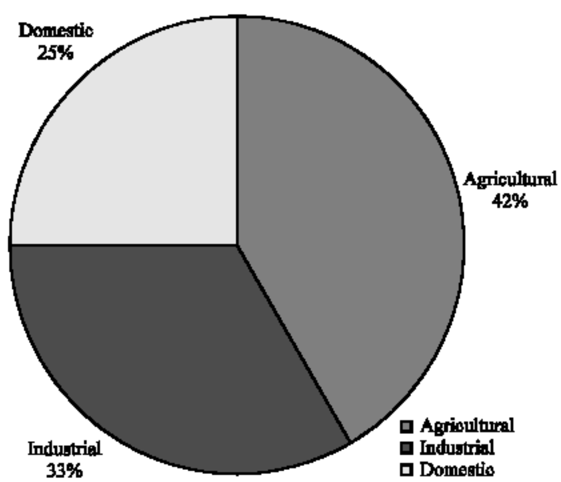


Fig. 4: Category of smith products in Nigeria

and thereby improving the economy of the country. This implies that existence and development of blacksmith shop is very important for the development and widening of industrial base of Nigerian economy.

All blacksmiths interviewed, made it known that they do not have problem in the sales of their products but they are unable to meet up with the demand of the customers, in term of quality and quantity. Unfortunately, the mode of manufacturing processes, workshop layout and the source of raw materials are the same for the entire visited blacksmith shops in the South- west of Nigeria, which, is sub standard and inappropriate compared to standard smith operation. These production facilities include; open furnace without any temperature-measuring instruments to help in reaching appropriate forging or heat treatment temperature, Inappropriate quenching bath and forging with the aid of hammer and anvil which absolutely stressful even below forging temperature.

Lack of money and credit facilities to buy quality raw materials to produce these products is one of the major problems militating against productions of quality and quantity products.

However, base on the mentality of people and government that blacksmithing is not profit oriented business which is contrary to information gathered from the blacksmiths, the shop is not receiving any financial assistance from cooperate bodies or government.

Analysis of experimental results: Figure 2a-f Micrographs of smith products showing the microstructure and the arrangement of the grain of imported, redesigned equipment and locally made smith products. The white circular features are ferrite while the darker features are pealite. The arrangement of the grain structures in imported smith product from the micrograph in 2a and d shown that, they have well arranged fine grains. Also the grain structure of the product from redesigned equipment in Fig. 2b and e have fine grains arrangement but not as fine as imported product while that of locally made one in Fig. 2c and f have not well arranged coarse structure. Figure 2a (original hammer head) had well arranged fine pearlitic (dark) matrix structure with moderate ferrite (whitish) matrix formed within the pearlite.

The same applicable to Fig. 2b (hammer head from redesigned equipment) but with few coarse structure while Fig. 2c (locally made hammer head) has coarse and not well-arranged structure. The same thing is applicable to other plates of imported smith products, redesigned equipment products and locally made blacksmith products.

The results from Table 2 shows that the average percentage elongation of locally made blacksmith products is lower than redesigned equipment products one, despite the fact that the products have higher hardness as shown in Table 1which is as a result of better manufacturing processes.

The imported product is a little bit better than redesigned equipment products in terms of percentage elongation and hardness. Adequate percentage of allowing elements in the imported products as shown in Table 3 makes the imported product to be able to blend high hardness with high ductility property. It also very clear from the results shown in Table 2 that the ultimate and fracture stress of redesigned equipment products is higher than the locally made ones. Therefore, the ability to withstand wear and tear in redesigned equipment products is more than local blacksmith products. The moderate hardness in redesigned equipment products is as a result of well arranged pearlite with ferrite formed within the pealite and lower hardness of the locally made is as a result of soft sport formed within the grain thereby reduces the hardness. The low value of harness and strength observed in local blacksmith products with inconsistent in the properties due to poor forging below forging temperature, inappropriate heating and heat treatment process in local blacksmith shop.

CONCLUSION AND RECOMMENDATIONS

Inhomogeniuty in the property and the recurrent failure of local blacksmith products in Nigeria is as a result of poor and sub- standard manufacturing process using inappropriate production facilities. The combine effects of all developed blacksmith facilities, which include close furnace, forging machine and heat treatment bath, has tremendously improve in the quality and the quantity of local blacksmith products in term of uniform mechanical property with less distortion and internal stress as indicated in Table 1-3. The new developed facilities make it easy for the blacksmiths to return back the products into the furnace without hesitation for proper heating any time the products temperature fall bellow forging temperature, which would have cause inhomogeneous deformation of the product.

Therefore, mechanization of local blacksmith shop through improvement of substandard production facilities is extremely necessary for a reasonable improvement in the quantity and quality of the by-product of the shop in Nigeria. Despite all the improvement in quality and quantity of the products produced, the quality is not as good as the imported products, which serve as a control. It can be concluded, that the source of material which is from abandon vehicle is the source of the remaining problem since there is tremendous improvement in quality as indicated in Table 1 and 2 and Fig. 2a-f but looking through Table 3, alloy element are not in the same proportion with imported product. It is clear that sourcing for appropriate material with required consequence elements will make the product to meet up the international standard. Improving our abandoned steel industries and making provision for appropriate addition of alloying elements will also be important in resolving this problem.

Government should establish a research center to work with abandon local blacksmith shops and steel company so that blacksmith raw material will be made available with appropriate consistent elements. The results from the center should be made available to the shops for improvement of their products instead of discouraging people from local blacksmith products. Use of scrap form abandoned vehicle should be discouraged since the durability, strength, hardness and ductility properties of the products from the scarp cannot be guaranty because of uncertainty of the material composition of the products.

Impact of blacksmith products on all endeavor of life of Nigeria people as shown in Fig. 1 make it clear that development of this engineering sub system will bring about a realist industrial base and sustainable development. Development of blacksmith shop in rural and sub-urban area will end up creating wealth and reduce poverty in Nigeria. Moreover, it will bring an end to excessive import dependence of automobile and industrial machine spare; consequently enhance industrial and economic self reliance.

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