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Quality Characteristics of Basic Hand Tools Sold in Nigeria

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Abstract. Hand tools sold in Nigeria have become increasingly unreliable due to critical failures during use. The objective of this study is to test samples of these tools vis-à-vis manufacturer's claims. A total of fifteen (15) hand tools from six (6) different countries available on the Nigerian market were tested for their quality characteristics. The tested tools included spanners, hammers, screwdrivers, pliers and chisels. Three samples of each of the groups of hand tools were ranked in accordance to their impact energy which is a major property of percussion tools. The results showed that built-in mechanical properties of these hand tools were largely controlled by their alloying elements, manufacturing processes and heat-treatment. Five (5) of the fifteen (15) selected hand tools conformed to BS 876, 1981 and were adjudged safe and reliable.

Introduction

An auto mechanic was hospitalized because a chip from a cold chisel entered his body. A wheel spanner wiped off instead of turning the nuts to replace a punctured tyre. A flat spanner sheared during use. The catalogue continues to the extent that users are no longer sure of the kind of tools they are purchasing. It has been found that a well-designed product can be unreliable in service because of poor quality of production [1]. Control of production quality is thus critical in the reliability effort. The notion of inherent quality of products (and services) that are deemed to be superior as opposed to inferior has been a subject of discussion and debate for centuries [2]. Use of inferior and substandard tools has resulted in many avoidable accidents and near misses.

Quality is difficult to define; it is an abstract term [3]. Several definitions of quality have been given by reputable quality gurus, [4, 5, 6, 7,8]. Essentially, quality may be defined as the totality of features and characteristics of a product or service that bears on its ability to satisfy stated or implied needs. Quality Function Deployment (QFD) is a structured approach to defining customer needs or requirements which must be satisfied and translating them into specific plans to produce products that will meet those needs [9]. . In Six Sigma, QFD helps to prioritize actions to improve processes or products in meeting customers' expectations. QFD is used to translate customer requirements to engineering specifications. It is a link between the consumer, design engineer and manufacturing. The Taguchi methodology, [10], suggested that instead of an implied step function of acceptability, a more realistic function be used based on the square of the deviation from the ideal target, i.e. that customers/users get significantly more dissatisfied as performance varies from ideal.

This function, referred to as the quality loss function, is given by the expression:

$$L = k (x - a)^2$$

Where L = the loss to society of a unit of output of value x
a = the ideal state target value
k = a constant

Quality gap is characterized by the difference between the approved standards, criteria or expectations in any process or activity and the real results in such process or activity in accordance with the adopted national and or international standards by any country [3]. Each operation in the manufacturing process, which has an effect on the conformance of the end product to the customer's specifications, is assigned a quality target value. This value represents the maximum allowable discrepancy per 1,000 opportunities [11]. Quality management, in its own sense is a systematic set of activities that ensures that processes create products with maximum quality at minimum cost of quality. The activities include quality assurance, quality control, and quality improvement [12]. The properties and characteristics of materials figure prominently in almost every modern engineering design, providing problems as well as opportunities for new invention, and setting limits for many technological advances [13]. The cost-effective operation of laboratory testing processes depends on formulating quality control strategies that are appropriate for the quality requirements and performance characteristics of each testing process [14, 15].

Embarrassing failures have been observed lately in spanners, wheel spanners, cold chisels, hammers and screw drivers during workshop use. This has set the author thinking on the need to examine the claim of some manufacturers to high quality while such products were found to be of low quality. Hence, the objective of this study is to examine the mechanical properties of hand tools available in the Nigerian market with an aim of establishing their conformance or otherwise to performance standards in application.

Materials and Methods

Five types of hand tools which include hammer, chisel, screwdriver, spanner and pliers were selected from different markets and tools shops in Ibadan, South Western Nigeria. Selection was based on their country of manufacture and these include China, India, Germany, England, Switzerland and Nigeria. A total of 15 samples were selected by a sampling procedure, i.e., 5 types of hand tools with 3 of each type selected from different countries of origin. The test pieces were machined from the samples for metallography, impact, tensile and hardness test in the materials testing laboratory.

Metallographic Test

In the course of the examination, the substrate metals were etched in turn and viewed on the metallurgical microscope. All the various test specimens were in turn etched first with NITAL and thereafter with the PICRAL before being examined on the metallurgical microscope.

Impact Test

A notched specimen was prepared and struck in turn and the total energy absorbed in breaking the test pieces recorded. Low values of impact energy indicated high notch sensitivity.

Hardness Test

A load of 1,000N using 10mm diameter steel balls was applied to 15 test specimens and examined after 30seconds each. The corresponding diameters of impression were recorded.

Tensile Test

The test was conducted by placing in sequence, each of the 15 test specimens in the extensometer. The force required to produce a given elongation for each test specimen was recorded and used to analyze the tensile strengths possessed by the selected hand tools.

Results and Discussion

Metallographic Results

On carrying out the metallographic test, the following microstructures were observed from the micrographs of the test pieces of the hand tools and labelled from Plate 1 to Plate 15 below:

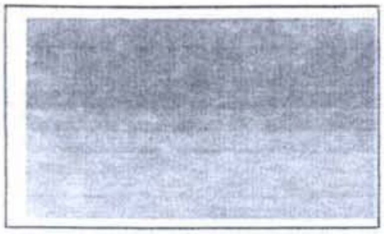
Plate 1: Hammer (China)

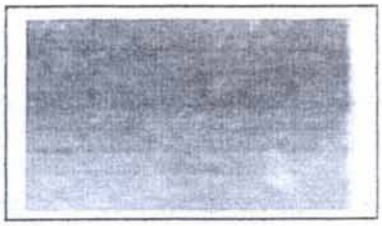
Plate 2: Hammer (India)

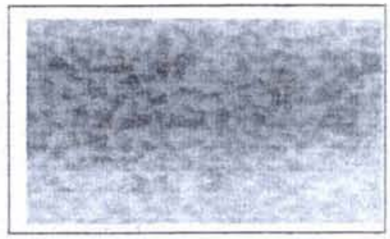
Plate 3: Pliers (Germany)

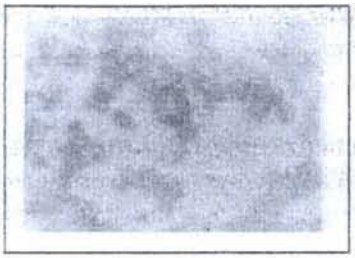
Plate 4: Pliers (India)

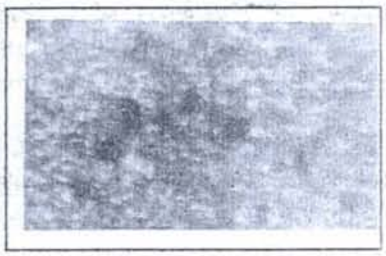
Plate 5: Chisel (China)

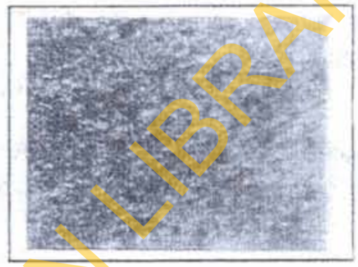
Plate 6: Screwdriver (India)

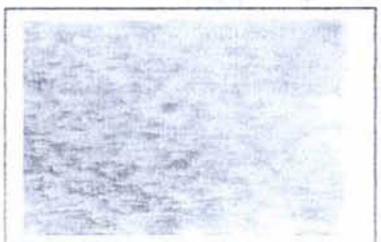
Plate 7: Drop-forged spanner (China)


Plate 8: Chisel (Nigeria)

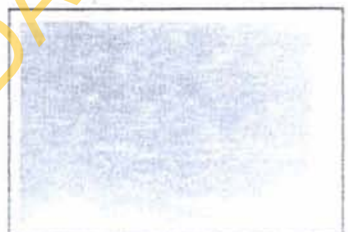
Plate 9: Pliers (China)

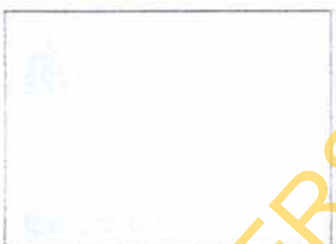
Plate 10: Spanner (England)


Plate 11: Screwdriver (England)

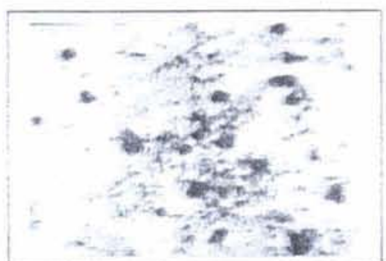
Plate 12: Screwdriver (Switzerland)

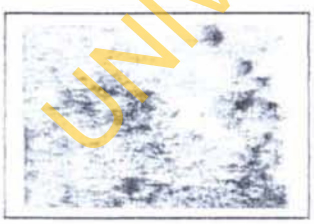
Plate 13: Diamond Spanner (China)

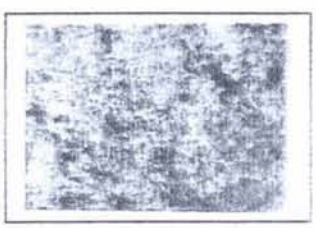
Plate 14: Hammer (England)

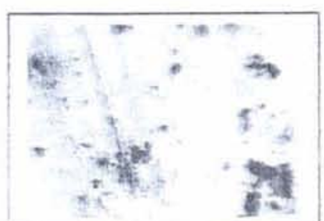
Plate 15: Chisel (Germany)

On carrying out these mechanical tests (impact, hardness and tensile tests), the results were obtained and tabulated as shown below, rounded up to 2 places of decimal.

Table 1: Impact test

Hand tool	Country	Impact Strength			
		Value/Ft Ib	Joules	Psi	Newtons
Hand hammer	China	17.40	23.66	24,742.80	77.40
Hand hammer	India	16.80	22.85	23,889.60	74.73
Hand hammer	England	18.60.	25.30	26,449.20	82.73
Pliers	India	11.80	16.05	16,779.60	52.49
Pliers	Germany	14.20	19.31	20,192.40	63.16
Pliers	China	13.60	18.50	19,339.20	60.49
Chisel	China	15.60	21.22	22,183.20	69.39
Chisel	Nigeria	16.20	22.03	23,036.40	2.10
Chisel	Germany	18.30	24.89	26,022.60	81.40
Flat-Spanner (Drop-forged)	China	25.20	34.20	35,834.40	112.10
Flat-Spanner (Diamond-type)	China	20.00	27.20	28,440.00	88.96
Flat-Spanner (Premium)	England	30.00	40.80	42,660.00	133.44
Flat-Screwdriver	Switzerland	35.00	47.60	49,770.00	155.68
Flat-Screwdriver	England	27.00	36.72	38,394.00	120.01
Flat-Screwdriver	India	22.70	30.87	32,279.40	101.00

Table 2: Hardness test (Brinell hardness)

Hand tool	Country	Hardness HBn
Hand hammer	China	210.00
Hand hammer	India	206.00
Hand hammer	England	229.00
Pliers	India	210.00
Pliers	Germany	225.00
Pliers	China	217.00
Chisel	China	203.50
Chisel	Nigeria	198.00
Chisel	Germany	215.00
Flat-Spanner (Drop-forged)	China	278.00
Flat-Spanner (Diamond-type)	China	288.00
Flat-Spanner (Premium)	England	354.00
Flat-Screwdriver	Switzerland	378.00
Flat-Screwdriver	England	341.00
Flat-Screwdriver	India	263.00

Table 3: Tensile test

Hand tool	Country	Tensile Force(Newton)	Tensile Strength (N/mm^2)	Psi
Hand hammer	China	715.15	74.495	105,931.89
Hand hammer	India	687.68	71.63	101,857.86
Hand hammer	England	826.98	86.144	122,496.77
Pliers	India	491.48	51.20	72,806.40
Pliers	Germany	760.28	79.20	112,622.40
Pliers	China	676.89	70.51	100,265.22
Chisel	China	691.61	72.042	102,443.72
Chisel	Nigeria	673.00	70.101	99,685.62
Chisel	Germany	725.94	75.62	107,531.64
Flat-Spanner (Drop-forged)	China	946.67	98.61	140,223.42
Flat-Spanner (Diamond-type)	China	979.04	101.9	145,015.56
Flat-Spanner (Premium)	England	1,203.69	125.38	178,290.36
Flat-Screwdriver	Switzerland	1,285.11	133.87	190,363.14
Flat-Screwdriver	England	1,159.54	120.78	171,749.16
Flat-Screwdriver	India	893.69	93.093	132,378.25

Impact energy was the one mechanical property of interest since most of these hand tools being percussion tools normally experience 'impact shock' in service. We observe that there are no standards presently set by Standards Organisation of Nigeria (S.O.N.). As a result we decided to compare the mechanical properties observed in these hand tools with international standards. In most cases toughness was found to be more important as a criterion for suitability of a hand tool in operation. The higher the hardness of a material the lower its corresponding toughness and vice-versa. (Barrett et. al., 1973; Ashby & Jones, 1994). This means the hammer sample from England should have the least toughness value, followed by that from China before the Indian sample. However, results as obtained in this study indicated that this may not be true in all instances for the sample from England exhibited highest impact energy and tensile strength, due to combination of martensite and bainite in its microstructure.

Likewise, the sample of pliers from Germany should have the least impact energy, followed by that from China and finally, the sample from India. But again, the pliers from Germany still absorbed the highest amount of energy on impact testing, meaning that it possessed the highest toughness of the 3 samples of pliers. It also displayed the highest tensile strength. The results obtained for the Chinese made pliers also followed this same trend. Presence of nodules of pearlite in the microstructure of the German pliers accounted for its outstanding strength and toughness.

For the 2 chisel samples from China and Nigeria, it actually holds for them that increase in hardness means increase in tensile strength but with corresponding decrease in toughness (impact energy) because the one from China exhibited a higher hardness value as well as tensile strength than its counterpart from Nigeria but the resulting impact energy on measurement (toughness) of the chisel from Nigeria is higher. The German chisel was able to combine highest impact energy with highest hardness value and tensile strength. The mixed microstructure of martensite and pearlite in the specimen of the German chisel explains why it was able to outwit its counterparts when tested mechanically.

By comparing the 2 samples of spanners from China, it would be noted that as the hardness increased the impact energy decreased and vice-versa. However, the spanner from England exhibited the highest impact energy despite its highest hardness value compared to the other three spanner samples selected because bainite, which is the phase between pearlite and martensite was contained in its microstructure.

Lastly, comparing the three screwdriver samples from Switzerland, England and India, results showed that the sample from Switzerland displayed highest mechanical properties measured in this study. The Swiss-made specimen revealed a mixed microstructure of martensite and pearlite which would normally indicate a combination of high toughness and tensile strength. This probably explains why it exhibited the best results among others when mechanically tested.

Table 4.: **Ranking of the Mechanical Properties of the Hand tools.**

Tool type	Country	Hardness	Impact Energy (Joules)	Tensile Strength (p.s.i)	Microstructure	Position	Remarks
Hand hammer	China	210	23.66	105,931.89	Tempered martensite	2nd	Not satisfactory.
Hand hammer	India	206	22.85	101,857.86	Tempered martensite	3rd	Not satisfactory.
Hand hammer	England	229	25.30	122,496.77	Martensite+ lower bainite	1st	Reasonable combination of properties.
Pliers	India	210	16.05	72,806.40	Pearlite + Pry.ferrite	3rd	Not satisfactory.
Pliers	Germany	225	19.31	112,622.40	Fine nodules of pearlite	1st	Inadequate combination of properties.
Pliers	China	217	18.50	100,265.22	Fine pearlite + Pry.ferrite	2nd	Not satisfactory.
Chisel	China	203.50	21.22	102,443.72	Martensite + bainite	3rd	Fairly satisfactory.
Chisel	Nigeria	198	22.03	99,683.62	Pearlite + Pry cementite	2nd	Fairly satisfactory.
Chisel	Germany	215	24.89	107,531.64	Martensite + Pearlite	1st	Excellent combination of properties.
Flat Spanner (Drop Forged)	China	278	34.20	140,223.42	Pearlite + Martensite with traces of bainite	2nd	Not satisfactory.
Flat Spanner (Diamond)	China	288	27.20	145,015.56	Pearlite + Pry. Ferrite	3rd	Not satisfactory.
Flat Spanner (By Premium)	England	354	40.80	178,290.36	Upper bainite	1st	Excellent combination of mechanical properties.
Flat Screwdriver	Switzerland	378	47.60	190,363.14	Martensite + Pearlite	1st	Excellent combination of mechanical properties.
Flat Screwdriver	England	341	36.72	171,749.16	Lower bainite	2nd	Fairly satisfactory.
Flat Screwdriver	Indian	263	30.87	132,378.25	Tempered martensite	3rd	Not satisfactory.

As shown below, the scope of the standards available could not adequately indicate the standard impact strength (toughness) required in almost all the tool alloys. According to Carpenter Technology Corporation (2006), the determination of accurate, meaningful mechanical properties on high strength, notch sensitive materials is extremely difficult.

Table 5: ASTM based Carpenter Technology Standards for the various selected tools.

Tool	Tensile strength/p.s.i	Rockwell Hardness (c)	Conversion (HBn)
Chisel	100,000	16	202
Hammer	120,000	24	248
Pliers	120,000	24	248
Screwdriver	180,000	40	375
Spanner	150,000	32	302

On comparing the results obtained with the standards derived online from the Carpenter Technology Corporation (2006), which itself is registered with ISO 9001: 2000 and AS 9100 Rev. A Standards. Of the hammer samples tested, only the English made hammer conformed to the available standard of stentor alloy AISI Type 02 /ASTM standards (UNS T31502). Amongst the tested pliers samples, having compared them with the corresponding No 883 tool alloy of AISI Type H13 (UNS T20813) standard, only the German pliers was within this standard. Looking at the available alloy standard for the tested chisel samples, which is a tool alloy No 883 of AISI H13 Type (UNS T20813), the German chisel conformed to standards. Both the Chinese and the Nigerian samples conformed to some extent. Of the spanner samples, comparison with the corresponding stentor standard alloy of AISI Type 02 / ASTM standards (UNS T31502) revealed that only the English spanner was in conformity to the available standards. Lastly, by comparing the screwdriver samples with the available standard of tool alloy No 883 of AISI Type H13 (UNS T20813), the 'Swiss made' conformed very well to standard while the 'English made' only conformed to some extent.

Conclusion

A combination of hardness, tensile strength and toughness of the hand tools has been assessed. Some of the selected hand tools conformed to standards while others did not. The English hammer, the German pliers, the German chisel, the English spanner, and the Swiss screwdriver, possessed excellent properties and all conformed to AISI/ASTM (2006) standards in terms of reliability and good performance. In all, about sixty percent of the tools examined were below standard in at least one or more characteristics. Some of the tools marked "drop forged" were found not to have been drop forged.

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