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# Development of Quality Acceptance Sampling Plan for Imported Hot Rolled Steel Sheet in Nigeria

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***ABSTRACT:*** *This paper presents the development of quality acceptance sampling plan for imported hot steel sheet in Nigeria. Acceptance sampling technique is one of the most efficient and cost effective sampling method of determining the quality assurance of lot of production product and material. Double sampling plan used in this presentation lead to rejection of a lot of hot rolled steel sheet imported in to the Country. Though not conclusive because of low data collected, but the analysis indicate the possibility of large volume of imported Hot rolled steel sheet into the Country* ***have quality much lower than the internationally accepted Quality standard.***

***KEY WORDS: Acceptance sampling****, Hot rolled steel, yield strength, ultimate yield strength.*

## I. INTRODUCTION

Several metric tons of hot rolled steel sheets are imported through the Nigerian ports annually with little or no quality checks at all entry point by the standard organization of Nigeria to ascertain the quality standard of these most widely used product by Nigerian industries both large, medium and small scale. Similarly within most of these industries no quality process is established to control the production processes of variety of products made out of Hot Rolled Steel Sheets and similar products. The need therefore becomes necessary to develop an acceptance sampling and or quality control process with a view to checking and controlling the influx of substandard material into the country thereby guarantying high quality products made of these sheets that will stand the test of time. A typical steel sheet may be tested on the following properties: thickness, tensile strength and resistance to corrosion etc. At international level this sheet are produce in the range of size available from 1.2mm to 25.4mm thickness, 600mm to 2180mm width, similarly depending on the area of application, the tensile strength varies in the range of 459.879 KN/mm$^2$ while the yield strength goes from 533.6529 KN/mm$^2$ and 655.00 KN/mm$^2$. Hence standardizing and checking these two variables alone can greatly enhance the quality of products made from this materials and also safe guide the industries and the end users of these products from substandard materials and products. In this study however, we shall restrict the test to tensile strength and ultimate yield strength. Acceptance sampling is a widely used technique for economically assessing the quality of a ‘‘lot’’ of items. A single-sampling attributes plan of the form (n, c) specifies that n items will be sampled and the lot will be accepted if no more than c defective items are discovered. The values of n and c are chosen based on the operating characteristic (OC) curve they imply. The OC curve is the probability of accepting a lot as a function of the lot quality, where quality is usually stated in terms of the probability of a defective item [1].

**Hot Rolled Steel Sheet:** A rolling process at temperatures over 1,000 degrees Fahrenheit is use to create hot rolled steel. Steel products that have been processed in this manner will have a blue-gray finish that feels rough to touch. Hot rolled steel actually reconfigures itself during the cooling process, giving the finished product closer tolerances than the original material and when compared to cold rolled steel products. Hot rolled steel is more malleable, allowing it to be forced into a variety of different shapes. This makes hot rolled steel a good choice for the manufacturing of structural components, such as I beams or simple cross sections, such as rail tracks. It is also used to produce sheet steels which are generally less than 6mm thick; they are provided on manufacturing facilities as flat pieces or strips in coils for further processing into various products. They are used for automobile and aircraft bodies, appliances, food and beverage containers, and kitchen and office equipments. [2]

**Yield Strength:** The yield strength is a measure of the pressure at which the material will permanently deform and lose its shape. Steel has a limited elasticity and when stretch and compress under minor strength without permanently losing its shape. This is one of the properties that make hot rolled steel so useful. However, there is a point at which the material permanently deforms and will not “snap back” into its original shape. The strength of hot rolled steel sheets is approximately 459.879 KN/mm$^2$. Under this load, hot rolled steel sheet will permanently deform.

**Ultimate Tensile Strength:** Tensile strength is a measure of the pressure at which a single piece of the material will suffer a break and shear or snap into multiple pieces. This tensile yield strength is important to engineering when designing applications which undergo dynamic stresses, such as the plating on an oceangoing ship. As the ship cuts its way through the water, the ship's plating will encounter different amounts of strength depending on the weather conditions, the speed of the ship and the weight of the ship's cargo. The ultimate tensile strength of hot rolled steel sheets is 533.6529 KN/mm$^2$ and 655.00 KN/mm$^2$. This properties of Hot rolled steel sheet are important for an engineering design most importantly in selecting suitable steels for various jobs.

**Elongation at Break:** The property of “elongation at break” refers to the point at which the hot rolled steel sheets will suffer a permanent break. Steel is elastic and will snap back into shape under minor loads. However, if the steel is subjected to increasing amounts of force, in the next phase steel will elongate and deform, but not break. If the strength increases from this point, the steel will eventually break. Hot rolled steel sheets will elongate by 15 percent to 19 percent of the original length and then break into multiple pieces. [3]

**Linear Elasticity and Hooke’s Law**

The linear relationship between strength and strain for a bar in simple tension or compression can be expressed by the equation $\alpha = E\varepsilon$. E is a constant of proportionality known as the modulus of elasticity for the material. The modulus of elasticity is the slope of the strength-strain diagram in the linear elasticity region, and its value depends upon the particular material being used. The unit of E is the same as the unit of strength; in as much as strain is dimensionless, typical units of E are Pascal’s (or multiples thereof) in SI units. The equation $\alpha = E\varepsilon$ is commonly known as Hooke's law named for the famous English scientist Robert Hooke (1635-1703). Hooke was the first person to investigate the elastic properties of materials and he tested such diverse materials as steel, wood, stone, bones and sinews. He measured the stretching of long wires supporting weights and observed that the elongations "always bear the same proportions one to the other that the weights do that makes them". Thus Hooke established the linear relationship between the applied load and the resulting elongation. The modulus of elasticity is often called Young's modulus, after another English scientist, Thomas Young (1773-1829). In connection with an investigation of tension and compression of prismatic bar, Young introduced the idea of a "modulus of the elasticity" [4].

## II. MATERIALS AND METHODS

**Materials:** The materials were hot rolled steel sheets obtained from Tower Galvanized Products, Kaduna. In order that test result will be comparable, the dimensions of test specimens and the methods of applying loads have been standardized. The test was carried out on specimens having uniform cross section throughout the gauge length as shown in appendix A. The length used for the test was 300mm and the width was 60mm, the length and width were chosen so as to fit in between the jaws. The gauge length for all the test specimens was 90mm.

**The Tensile Test:** Maekawa Universal testing machine was used for conducting this test. First of all, one end of the specimen was gripped in the jaws provided in the adjustable crosshead to the appropriate height (depending upon the length of the specimen) the other end of the specimen was fixed in jaws in the top crosshead. The tensile load was now applied hydraulically to the specimen by turning the hand wheel (towards right) provided in the control unit. The load measuring gauge incorporated in the control unit shows the magnitude of the applied load. The load was gradually increased until the specimen breaks and the corresponding extensions were recorded. The yield strength and tensile strength were obtained from the graphs which have been plotted by the machine in the course of the test. This procedure was followed until all the specimens of the samples under study were subjected to the test.

**ACCEPTANCE SAMPLING MODEL:** OC curves for standard acceptance-sampling plans are derived under the assumption that the quality of items can be modeled as independent and identically distributed (i.i.d.) Bernoulli random variables. Although this model is often plausible, the quality of items produced by some processes exhibit statistical dependence. The goal of this simulation experiment is to estimate the OC curve for sampling plan (10, 1) when item quality is dependent. Let $X_1$, $X_2$,...,$X_n$ represent a sample of n items, where $X_i$ is 1 if the $i^{th}$ item is defective and $X_i$ is 0 if the $i^{th}$ item is acceptable. The probability that an item is defective is p, and the quality of any item may be dependent on the other items. Specifically, the items are assumed to have a joint Po´lya distribution with pairwise correlation of 0.08. Standard tables of sampling plans are not appropriate for this situation. Let Y be the number of defective items in the sample. The performance parameter of n $X_i$ is 1 i interest is (p) Pr{Y, c,p}, the probability that there are c or fewer defective items (i.e., that the lot is accepted) as a function of p. This simulation experiment is called a static simulation because there is no explicit modeling of the passage of time ($X_1$, $X_2$,...,$X_n$ need not even be arranged by order of selection). Although static simulations are conceptually the easiest to design and analyze, they nevertheless present important design and analysis problems. In addition, this example illustrates estimating a probability, (p) [1].

**Some Specific Points on the OC Curve:** Because sampling doesn't allow the ideal OC curve, we need to consider certain risks. The first risk is that the consumer will reject a lot that satisfies the established conditions, i.e., the process quality is acceptable, but, by the luck of the draw, there are too many nonconforming items in the sample. This is called the producer's risk, and is denoted by the Greek letter α. The second risk is that the consumer will accept a lot that doesn't meet the conditions, i.e., by the luck of the draw there are not many nonconforming items in the sample, so the lot is accepted. This is the consumer's risk and is denoted by the Greek letter β. The literature contains a variety of typical values for α and β, but common values are 5% and 10%. When we locate these values on the OC curve, expressed in terms of probability of acceptance, we actually locate 1 – α.

**Single and Double Sample Plans:** The material above discusses sampling plans in which we draw one sample from the lot. This is called a single sample plan. We describe the plan by a set of parameters: n is the sample size c is the maximum number of nonconforming items allowed for acceptance, and r is the minimum number of nonconforming items allowed for rejection. In a single sample plan r and c differ by 1. In contrast, there are double sampling plans in which we take the first sample and make one of the three decisions: accept, reject, or take a second sample. If we take the second sample, we then make an accept/reject decision. As described above the set of parameters used to describe a double sample plan are: $n_i$ is the $i^{th}$ sample size, $c_i$ is the maximum number of nonconforming items allowed for acceptance on the $i^{th}$ sample, and $r_i$ is the minimum number of nonconforming items allowed for rejection on the $i^{th}$ sample. [8]

## III. RESULTS AND DISCUSSIONS

The tables 1 and 3 below shows the results of first and second samples conducted on the various specimens. In each case five (5) samples were taken each of different thickness range from 1.0mm to 3.0mm. While tables 2 and 4 present the calculated values of area before and after the test, it also presents the percentage reduction in area. Table 6 present the average value of the test on the two samples. For cost consideration the sampling plan (n, c) were n is 5 and c is 1 was assumed, that is if only one sample failed the lot or batch is accepted but if two or more samples failed a second sample is taken. A failure of one in the second sample will lead to rejection of the entire lot or batch.

**Table 1: Tensile Test Results for First Sample**

| Thickness before test T (mm). | Thickness After Test t (mm) | Width Before Test W (mm) | Width After Test w (mm) | Gauge length L (mm) | Extension $L_1$ (mm) | Yield Load Py (KN) | Maximum Load $P_{max}$ (KN) |
|---|---|---|---|---|---|---|---|
| **HOT ROLLED STEEL SHEET** | | | | | | | |
| 1.0 | 0.85 | 60 | 56.35 | 90 | 35 | 27 | 29 |
| 1.2 | 0.98 | 60 | 56.90 | 90 | 30 | 30 | 31 |
| 1.5 | 1.13 | 60 | 57.87 | 90 | 28 | 33 | 34 |
| 2.0 | 1.56 | 60 | 56.90 | 90 | 32 | 44 | 47.5 |
| 3.0 | 2.31 | 60 | 53.30 | 90 | 33 | 71 | 72 |

**Table 2: Tensile Test Results Calculated Values for the First Sample**

| Thickness before test T (mm) | Area Before Test A ($mm^2$) | Area After Test Al ($mm^2$) | Yield Strength $\sigma_y$ (KN/$mm^2$) | Ultimate Tensile Strength $\sigma_y$ (KN/$mm^2$) | Percentage Elongation (%) | Percentage Reduction in Area (%) |
|---|---|---|---|---|---|---|
| HOT ROLLED STEEL SHEET | | | | | | |
| 1.0 | 30 | 47.90 | 450.00 | 483.33 | 38.89 | 20.17 |
| 1.2 | 72 | 55.76 | 416.67 | 430.56 | 33.33 | 22.56 |
| 1.5 | 90 | 65.39 | 366.67 | 377.78 | 31.11 | 27.34 |
| 2.0 | 120 | 88.76 | 366.67 | 395.83 | 35.56 | 26.03 |
| 3.0 | 180 | 123.12 | 394.44 | 400.00 | 36.67 | 31.6 |

Table 3: Tensile Test Result for Second Sample

| Thickness before test T (mm). | Thickness After Test t (mm) | Width Before Test W (mm) | Width After Test w (mm) | Gauge length L (mm) | Extension $L_1$ (mm) | Yield Load Py (KN) | Maximum Load $P_{max}$ (KN) |
|---|---|---|---|---|---|---|---|
| HOT ROLLED STEEL SHEET | | | | | | | |
| 1.0 | 0.85 | 60 | 56.40 | 90 | 31 | 21.0 | 21.2 |
| 1.2 | 0.98 | 60 | 56.90 | 90 | 31.5 | 24.0 | 24.5 |
| 1.5 | 1.13 | 60 | 57.50 | 90 | 29.0 | 33.0 | 34.2 |
| 2.0 | 1.56 | 60 | 59.40 | 90 | 42.0 | 39.5 | 41.5 |
| 3.0 | 2.31 | 60 | 53.50 | 90 | 48.0 | 67.0 | 68.0 |

**Table 4: Tensile Test Results Calculated values for Second Sample**

| Thickness before test T(mm) | Area Before Test A ($mm^2$) | Area After Test Al ($mm^2$) | Yield Strength $\sigma_y$ (KN/$mm^2$) | Ultimate Tensile Strength $\sigma_u$ (KN/$mm^2$) | Percentage Elongation (%) | Percentage Reduction in Area (%) |
|---|---|---|---|---|---|---|
| HOT ROLLED STEEL SHEET | | | | | | |
| 1.0 | 60 | 47.09 | 350.00 | 353.33 | 34.4 | 21.52 |
| 1.2 | 72 | 55.76 | 333.33 | 340.33 | 35.00 | 22.56 |
| 1.5 | 90 | 69.00 | 366.67 | 380.00 | 32.22 | 23.33 |
| 2.0 | 120 | 95.04 | 329 17 | ·345.83 | 46.67 | 20.8 |
| 3.0 | 180 | 128.4 | 372.22 | 377.78 | 53.33 | |

We now take the mean tensile strength as 459.879 KN/$mm^2$ and the mean ultimate yield strength as 533.6529 KN/$mm^2$ these are the internationally accepted value. From table 2, only the first sample with 1.0mm thickness falls with the standard limit i.e. c=4. Ideally we should reject the lot with c=4, but to justify our claim, we took another sample of 5 and the result of the calculated variables is shown on table 4. Here also all the five samples failed leading to a total and absolute rejection of the entire batch.
Looking at his analysis from attribute control chart, the upper control limit is given by:

For tensile strength UCL= $459.879 + 3*\sqrt{459.879} = 461.914$ KN/$mm^2$

And the LCL = $459.879 - 3*\sqrt{459.879} = 457.845$ KN/$mm^2$

Similarly for the ultimate yield strength: UCL=535.844 KN/$mm^2$ and the LCL = 533.653 KN/$mm^2$.

With the UCL and LCL calculated, it is now clear that the entire sample calculated tensile and yield strength will fall outside the control limits.

## IV. CONCLUSIONS

An attempt is hereby made to develop an acceptance sample plan for evaluating the quality standard of imported hot rolled steel sheet into Nigeria base on sample data collected from Tower Galvanized Products, Kaduna a Double sample plan of n=5 and c=1. Both the first and the second sample failed. Even though only two samples were collected which may be small but however, it lead the expected conclusion that majority of the hot rolled steel sheets imported into the Country are likely to be substandard thereby justifying the high rate of sheet steel products produced in the Country failing to meet the much desired international quality standard.

## V. RECOMMENDATIONS

Additional samples need to be collected and analysed both using the acceptance sampling technique and attribute control chart to further justify the claim of substandard quality hot rolled steel sheet been imported into the country. The need also for standard organisation of Nigeria to develop and implement an acceptance sampling plan together with a quality inspection procedure both at the premises of the manufacturer, our respective ports and manufacturing plants within the Country to ensure and protect manufacturer and end user from substandard material and products that is if none exist**.**

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