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Gloss Evaluation of Autobody Paint Finishes by Some Enterprises in Kaduna Metropolis, Nigeria

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ABSTRACT: *Glossy surfaces are appealing to humans. Inability to meet product gloss appeals of customers can lead to complaints and rejection of products and low patronage of the product manufacturers or dealers by customers. Glosses of autobody paint finish by four top autobody painters in Kaduna metropolis, namely; Peugeot Automobile Nigeria (PAN) Limited, MA Motors, Alsarafa Body Painters, and IBK Motors was investigated by measurements and analysis to understand their values about acceptable engineering standards. A mild steel sheet was procured, ascertained, and used as an autobody material for the investigation. Four similarly produced samples from the steel sheet were taken one each to the enterprises where they were polished, surface-prepared, and painted according to the usual methods and standards used by the enterprises in paint-finishing autobodies. Glosses of the paint-finished surfaces were evaluated after proper curing using measurements made with the BYK Qualitest micro-TRI-gloss meter at refractive angles of 20º, 60º, and 85º by ASTM D523 standard procedure. Analysis of the measurements indicated comparable paint finishes of high gloss standard within the order of 60 to 90GU by the enterprises. The highest average gloss measurements by the angle from samples paint-finished at PAN, MA Motors, Alsarafa Body Painters, and IBK Motors were 87.29, 69.57, 92.42, and 60.73GU respectively*.

Keywords: *Aesthetic appeals, Engineering products, Gloss level, Needful information, Quality management*

I. INTRODUCTION

The physical appearance or outlook of any commodity or product is the chief motivating factor that influences the attitude of most people towards the commodity or product [1]. This is commonly observed in developing economies like Nigeria, which is predominantly consumption-driven. Many times, people tend to primarily value products based on the desired degree of surface finish and appearance of the products. This is one of the main reasons why manufacturers or entrepreneurs always strive to supply products to standards with the best aesthetic appeals for marketability as well as functional reasons [1, 2].

Gloss is the most important and commonly used term in describing the visual appearance of objects [2, 3]. It is an optical property that is used to quantify how well a surface reflects light in a specular or mirror-like direction. Apart from the most evident influence of gloss finish in the aesthetic value of products or items, its influence extends to other engineering areas such as noise and vibration control, corrosion and wear and tribological control, dimensional accuracy, bioengineering applications, and geomorphometric investigations [3].

The term glossy and matte are the opposite extremities on the gloss assessment scale. Glossy surfaces are shiny and capable of reflecting most light in the specular or mirror-like direction, while matte surfaces are least in terms of shininess level because; most incident light on the surfaces diffuse in different angles [1, 3]. Between the two extremes of glossy and matte, there are several achievable levels of intermediate gloss finishes for engineering products. Starting from the most shinny to the dullest, the achievable levels of gloss finishes include high gloss, semi-gloss, silk, satin, eggshell, and matte [2, 4, 5]. These terms are however not standard across the board, and not all manufacturers use the terms. Most manufacturers measure gloss in percentages at 60° angle of incidence and classify achievable levels as high gloss, 90-100% gloss; gloss, 70-89% gloss; semi-gloss, 41-69% gloss; eggshell, 26-40% gloss; low sheen, 10-25% gloss; and flat, 1-9% gloss [4. 5. 6].

Factors that affect the gloss of a product are the refractive index of the product material, the angle of incident light on the product, and its surface topography and color. High gloss surfaces are hard, brilliant, highly polished, and ultra-shiny with the ability to reflect images. High gloss surfaces are also more durable, and easier to clean than ordinary surfaces. High-gloss is a choice for applications to surface finishes in many areas of engineering such as kitchens, doors, window trims, bathrooms, automobiles, aircraft, street signs, decorative objects, clothes, etc. Gloss and surface roughness are inversely proportional to one another, hence, when the gloss is high, the surface roughness is low and vice versa. Gloss finish of products or items is therefore a critical quality factor to consider for commercial as well as functional reasons in engineering [5, 6. 7].

Painting is the most versatile, commonly, and widely used method of protecting engineering systems or components from corrosion and achieving the desired aesthetic values of the systems or components [8]. Over 90% of all autobodies worldwide are made of mild steel sheets and paint-finished [8]. The paint finish gloss level is a critical factor that

determines; the surface resistance to damage by corrosion and wear, surface durability, visibility of surface imperfections like scratches and dents, ease of surface cleaning, and aesthetics of autobodies and many other engineering products or systems [4, 9, 10]. Generally, a higher gloss finish is usually required for the durability and functionality of paintwork. The apparent color of the paintwork surface can also be easily affected by its gloss. It is therefore important that color and gloss are uniforms and of satisfactory appeal level for every critical product. This is commonly expected by customers from product manufacturers or dealers [6, 10, 11]. The gloss of paintwork is principally determined by the paint formulation or composition and method used in applying it. Although a consistent and homogeneous high gloss is required in paint finishes of many products, this cannot be ensured from even the same product type by different painters or dealers due to variations in skills or technologies and managerial strategies used by the painters or dealers in efforts to meet gloss needs of their customers [8,10, 11]. It is, therefore, needful to measure and characterize the gloss level of most engineering products from various sources as part of their quality evaluations. However, it cannot be assured due to lack of information that all or many autobody painters do meaningful gloss checking of their paint finishings as a necessary quality control strategy for greater profitability in the business [10, 11]. Frequent assessment and understanding of the gloss finish of a product or item can help in determining whether there is a need for adjusting the production technique or process variables for improvement. For a developing economy like Nigeria, this study can help the country's government have insight into the level of proficiency of her citizenry in the field of autobody paint finishes, and help her decide how best to assist in terms of grants, motivations, and training for those in the trade. This study can also give indications of how well the economy's products can compete with imported products in finished surface quality.

Because of the criticality of surface quality of finished products, several millions of dollars are spent in the United States alone by the aviation, automobile, and other industries on equipment acquirements and maintenances for high precision paintwork finishing [9, 12]. In Nigeria, millions of auto bodies are paint-finished every year by different entrepreneurs at artisanal, firm, and industrial levels but not much information has been documented on the assessment of their performance in the trade about meeting consistent gloss needs of their customers. Skills or technologies and equipment used by entrepreneurs in autobody paint-finishing can vary greatly at different work stations with corresponding variations in attained gloss levels [7, 13, 14]. This variation can result in substandard gloss appeal in a good number of cases with bad calls on economic and functional grounds.

This paper aims to present a study of autobody paint-finish glosses produced at PAN Limited (A) as a reputable auto industry and three popular firms, namely; MA Motors (B), Alsarafa Body Painters (C), and IBK Motors (D) in Kaduna metropolis in Nigeria to:

i. Have insight into gloss levels attained by the enterprises following engineering standards.
ii. Provide information for any positive rethinking by autobody painters in Kaduna metropolis and the Nigerian economy and relevant research interests.
iii. Provide information that may be needed by many customers for patronizing the autobody painters.

II. MATERIALS AND METHOD

A. Materials

A mild steel sheet of about 1600mm by 309mm by 2mm-thickness was procured from AREMCO Company in Kaduna metropolis for the study. The as-procured sheet is shown in Plate I.

Plate I: The as-procured mild steel sheet for the study

B. Method

a) Ascertainment of the procured mild steel sheet

The average nominal compositions of suitable test pieces sawn out at six different locations of the procured mild steel sheet were spectrometrically analyzed using the made-in-Japan Shimadzu PDA 7000 metal analyzer. The analysis confirmed that the sheet material was mild steel of average nominal chemical composition (ANCC) shown in Table 1.

Table 1: Nominal average chemical composition of the mild steel sheet used for the study

Chemical element	Fe	Al	C	Mg	Si	Ni	Cu	P
NACC (%)	99.175	0.162	0.093	0.184	0.205	0.121	0.017	0.034

b) Preparation of the paint-finished test samples

The confirmed mild steel material was used to produce four-sheet samples of 304.8mm by 304.8mm by 2mm-thickness by marking out the procured parent sheet with a scriber and mechanically sawing them out with a cutter. Plate I shows the procured steel sheet. After cutting out the samples from the parent sheet, they were taken one each to Peugeot Automobile Nigeria (PAN) Limited, M.A Motors, Alsarafa Body Painters, and I.B.K Motors; where the surfaces of the sheet samples were polished and painted according to the methods and standards used by each of the four enterprises in paint-finishing automobile bodies. Plates II, III, IV, and V show the surfaces of the paint-finished samples at PAN, M.A Motors, Alsarafa Body Painters, and I.B.K Motors as named by letters A, B, C, and, D respectively.

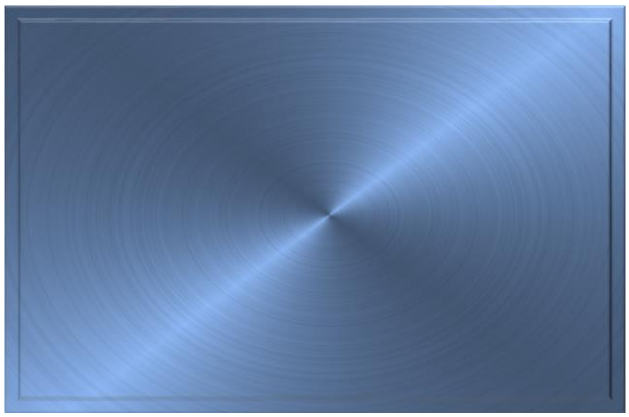

Plate II: Sample A

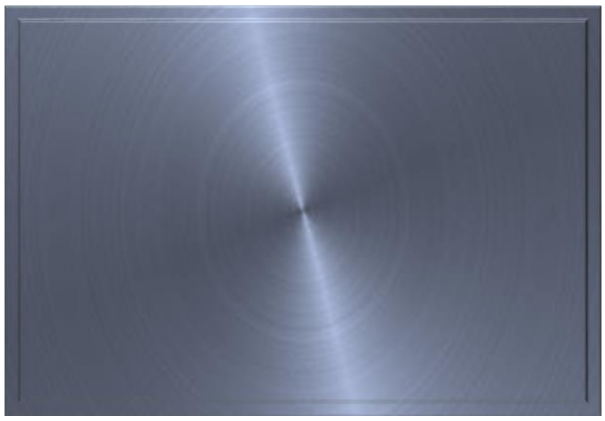

Plate IV: Sample C

Plate III: Sample B

Plate V: Sample D

c) Gloss evaluation of the paint-finished surfaces

Glosses of the paint-finished surfaces of samples A, B, C, and D shown in Plates II-V respectively, were determined using the battery-powered BYK 20/60/85-degree Qualitest micro-TRI-gloss meter of Serial No. 1056431 and type No. 4430. The gloss meter was supplied with a data transfer cable and user manual. Plates VI and VII show side views of the gloss meter case and unit. Ten measurements were made at different locations on the surface of each of samples A, B, C, and D, using the three standard illumination angles of; 20˚, 60˚, and 85˚ in accordance to the ASTM D-523 [15]. With the meter, all angles measure at the same location, and the results were automatically digitally displayed simultaneously.

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Plate VI: Complete test unit inside the carrying case

Plate VII: Calibration glass

Before carrying out the measurements, all the four samples were cleaned with a soft tissue paper to get rid of dust and dirt that might have been on the sample surfaces. The samples were thereto loaded one after another on the test table, under the lighting of the gloss meter. The instrument was turned on and placed on the black glass primary standard. The control knob was adjusted so that the meter indicated the value assigned to the primary standard. Next, the sensor was placed on the sample surface and the gloss value was read directly from the digital display. Thereafter, each sample was loaded back and readings were again taken simultaneously at 20^0, 60^0, and 85^0 at each point of measurement as shown in Fig. 1.

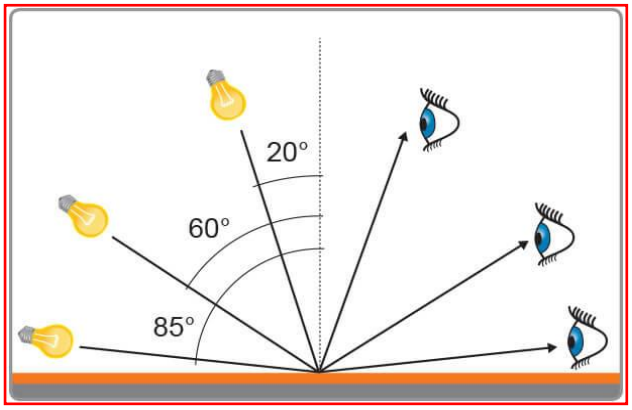

Fig. 1: Angles of the gloss measurements [6]

d) Reflectance and haze determination

Other factors that were considered in the gloss measurement were the percentage reflectance and the haze. The percentage reflectance dealt with comparing the amount of light energy that was transmitted and received by the gloss meter. It expressed the light energy value as a percentage of the angle of the incident's full measurement range. It was determined from the fact that Gloss Unit (GU) scale is a linear scale, however, each angle of incidence has a different measurement range as follows: 0-2000GU (20°), 0-1000GU (60°), and 0-160GU (85°). Since the measurement range for a 20° gloss meter is 0-2000GU, it can be shown for example that a measured value of say 1200GU at 20° would be expressed as 60%20, and a value of 800GU at 20°would be expressed as 40%20. Similarly, a value of 800GU at 60° can be expressed in % reflectance as 80%60 as the measurement range for the 60° is 0-1000GU [4, 5, 6, 15]. The shinier a surface is, the closer its %reflectance value will be to 100% [4, 5, 6]. It is therefore a common practice to express gloss measurement values in percentage reflectance. Another term that was associated with gloss measurement is called 'haze'. Haze causes a drop in reflected contrast and causes 'halos' to appear around the reflected light sources, dramatically reducing the visual quality. Following ASTM D4039 Haze, is defined as the numeric difference between the specular reflectance at 60° and 20° [6, 15]. This is expressed in Haze Units (HU) [6, 15].

III. RESULTS AND DISCUSSION

A. Results

Results of the measured Gloss Units at angles 20^0, 60^0, and 85^0 at 10 different points on the flat surfaces of the paint-finished samples are shown in Figs. 2, 3, 4, and 5 for samples A, B, C, and D respectively. On the other hand, results of the comparative Gloss Units of the four sample surfaces at 20^0, 60^0, and 85^0 are presented in Figs. 6. 7. and 8 respectively. Results of the evaluated average values of gloss (GU), percentage reflectance, and haze (HU) for measurements obtained at angles 20^o, 60^o, and 85^o with samples A, B, C, and D are presented in Table 1.

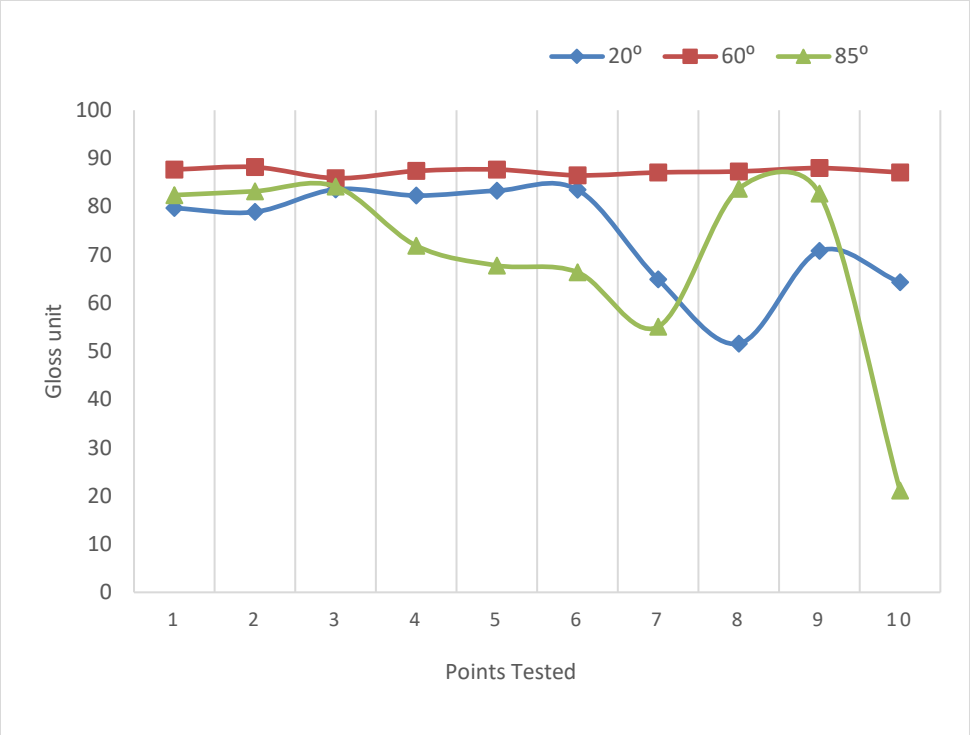

Fig. 2: Gloss of the paint finish by PAN (Sample A)

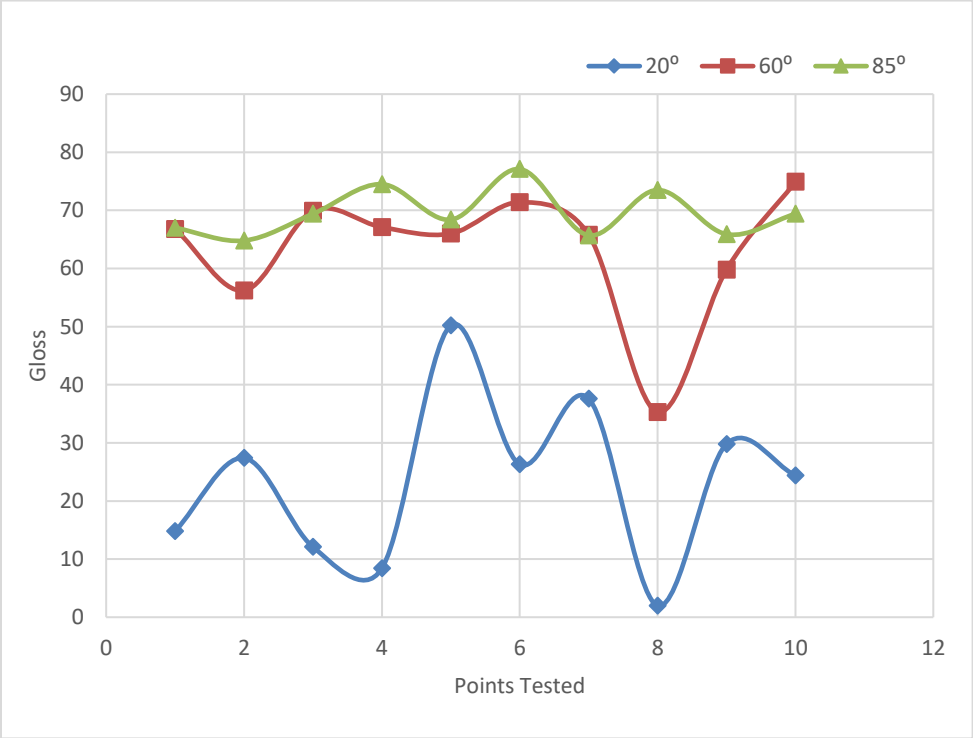

Fig. 3: Gloss of the paint finish by M.A Motors (Sample B)

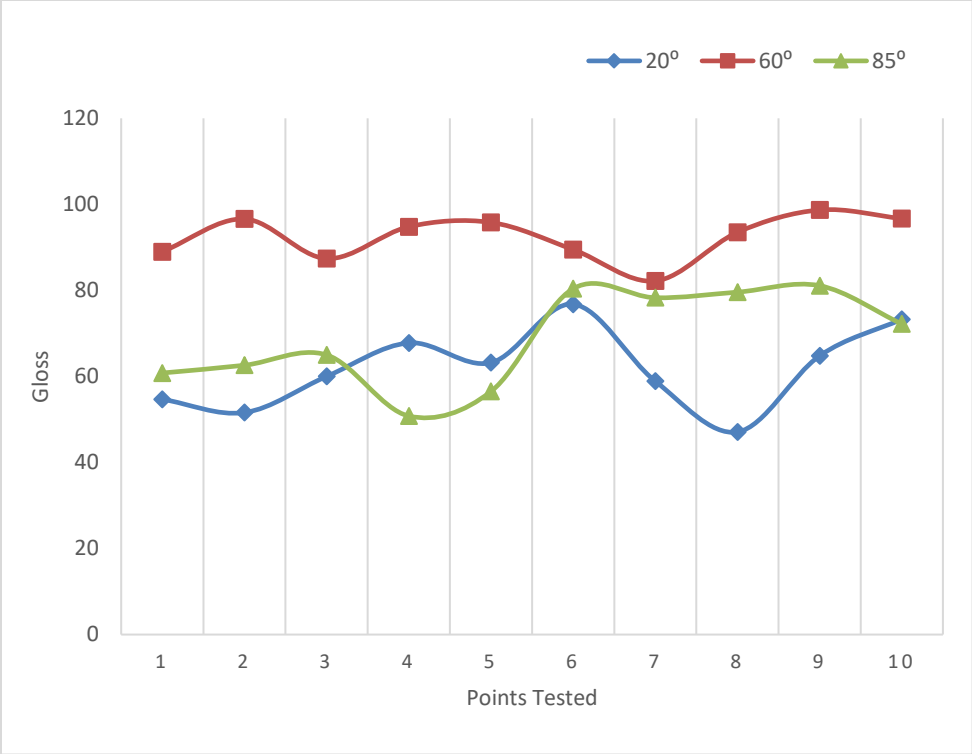

Fig. 4: Gloss of the paint finish by Alsarafa Body Painters (Sample C)

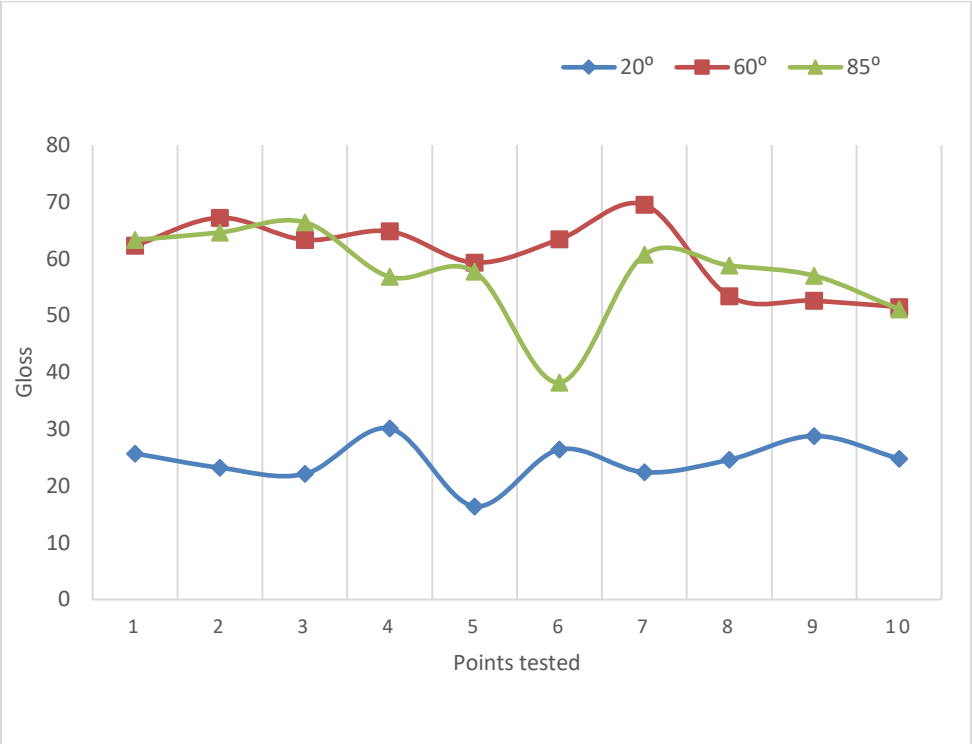

Fig. 5: Gloss of the paint finish by I.B.K Motors (Sample D)

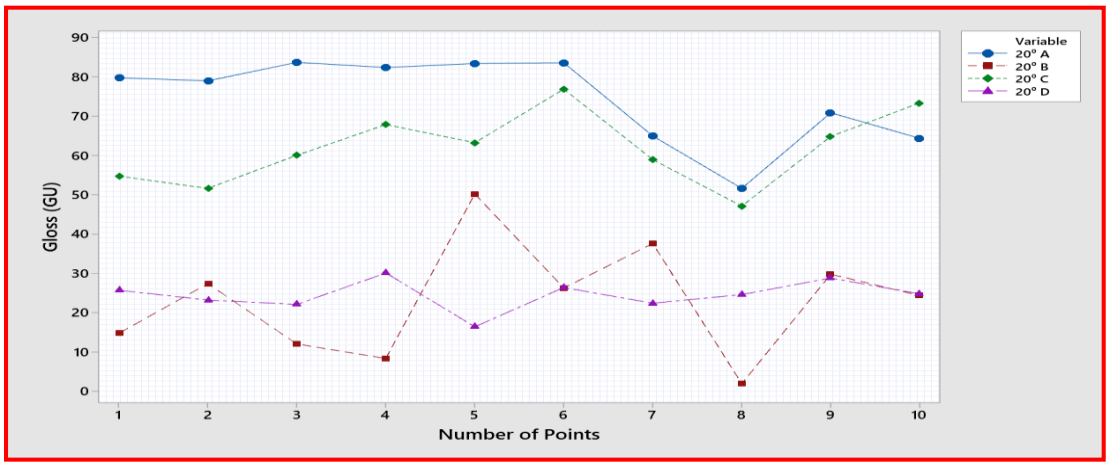

Fig. 6: Gloss Finishes of A, B, C, and D at 20°

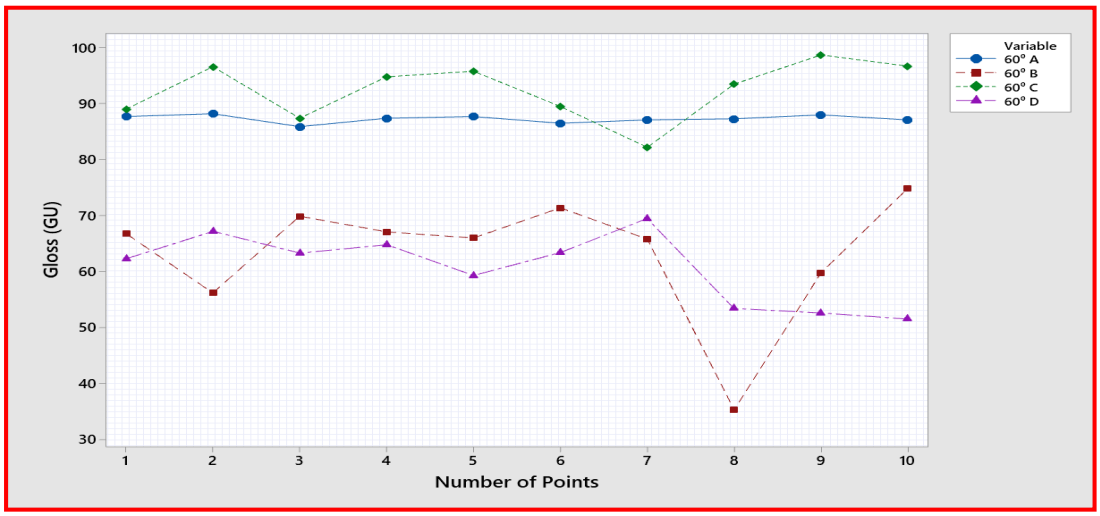

Fig. 7: Gloss Finishes of A, B, C, and D at 60°

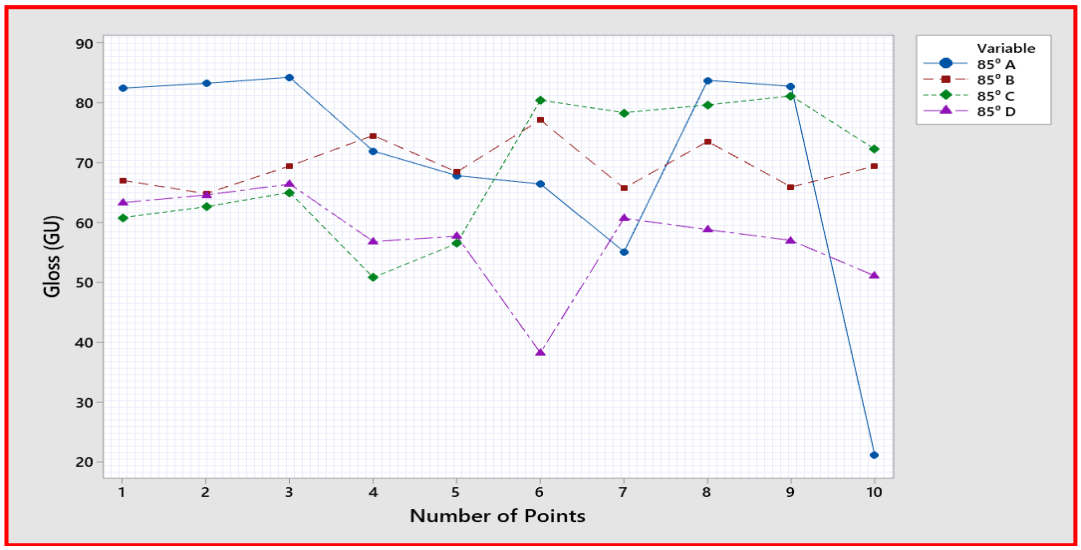

Fig. 8 Gloss Finishes of A, B, C, and D at 85°

Table 1:Evaluated average values of gloss (GU), percentage reflectance, and haze (HU) of samples A, B, C, and D for measured values at angles 20º, 60º, and 85º.

Sample	A			B		
Angle	20º	60º	85º	20º	60º	85º
Average gloss (GU)	74.29	87.29	69.85	23.3	63.32	69.57
Reflectance (%)	3.71%20	8.73%60	43.66%85	1.17%20	6.33%60	43.48%85
Haze	13.0			40.02		

Sample	C			D		
Angle of measurement	20º	60º	85º	20º	60º	85º
Average gloss (GU)	61.82	92.42	68.73	24.45	60.73	57.46
Reflectance (%)	3.09%20	9.24%60	42.97%85	1.22%20	6.07%60	35.91%85
Haze (HU)	30.6			36.28		

B. Discussion

Figs. 2-4 shows gloss measurements at 20º-angle for high gloss, 60º-angle for semi-gloss, and 85º-angle for matte. Automobiles are among the many products that require their gloss finish in the high band.

From Fig. 2 and Fig. 7, sample A produced a high and almost consistent gloss level at the 60º-angle. An average gloss value of 87.29GU was obtained for the 60^0-angle measurements for sample A as can be seen from Table 1. This value is higher than the value of 74.29GU obtained at 20º-angle for the sample as can also be seen from Table 1. This is expected as any semi-gloss surface or matte surface can qualify for the high-gloss and vice versa. At all three angles, all the surface views of sample A depicted high or nearly high gloss levels as can be observed from Fig, 2 and Table 1.

From Fig 3, it can be observed that the gloss level of sample B is highest at the 85º-angle of view by measurements that range from about 66 to 76GU, and the average value of 69.57GU. This indicates that for sample B, the 85º-angle is the high gloss, and the 60º and the 20º-angles semi-gloss as can be observed from Fig.3 and Table 1.

From the results presented in Fig. 4, it is evident that sample C had a very high average gloss level of 92GU at 60º-angle. Therefore 60º-angle was a high gloss surface, and the 85º-angle and 20º-angle produced semi-gloss of the surface as can be observed from Fig.4 and Table 1.

From the results presented in Fig. 5, it can be similarly observed that the paint-finish of sample D did not produce high gloss at any angle but produced semi-gloss with an average gloss level of 60.73 at 60º-angle, and a more or less average semi goss value of 57.46GU at the 85º-angle measurements and average matte gloss value of 24.45GU at the 20º-angle, as can be observed from Fig 5 and seen in Table 1.

From the result obtained at the first reading on 60º, only sample A and C qualify to be in the high gloss band, as their initial gloss values at 60º are all greater than 70GU as can be seen in Fig 7. Hence by comparison of samples A and C, sample A from PAN is a clear edge over B in surface gloss values. Another point that shows that sample A was indeed a good high gloss finish is the *haze*. Generally, haze and gloss can be said to be inversely proportional; that is. the higher the gloss, the lower haze, and vice versa [6, 15]. Sample A has the lowest haze of 13HU among all the four samples as can be seen from Table 1.

By careful look at the samples in plates II, III, IV, and V, it is evident that sample C produced the least reflectance, yet it ranked second best in the high gloss band. This is attributed to the color of the paint used for the sample. This goes to show that color is a prime factor in deciding how much light is reflected off a painted surface. Bright colors reflect more light than dark colors.

Samples B and D on the other hand qualify for the semi-gloss

characterization as can be evidentially seen from plates III and V. The reflections on the surfaces are a little fuzzy. From Table 1, the haze values of 40.02 and 36.28 HU for samples B and D respectively are setbacks to their not being as reflective as sample A or C as can be observed from Plates II, III, IV, and V.

Fig. 6 shows the measured glosses of all samples at 20°. Comparing the high gloss measurements (20°), it is observed that enterprise A has the highest high-gloss measurement followed by C, B, and D.

From Fig. 7 it is evident that among the glosses of all samples measured at 60°-angle, enterprise C produced the highest semi-gloss paint-finish followed by A while results for B and C are more or less similar. However, enterprise A produced a more uniformly distributed gloss finish than C because it has an almost straight line of gloss values as can be observed from Fig. 7...

Fig. 8 shows surface locational variations of gloss values of all the samples as measured at 85° which corresponds to low gloss. From Fig. 8, it is observable that at this angle of gloss measurements; enterprise A produced the highest low-gloss at some point locations on its paint-finished surface but ended up being the least at some points as can be observed in Fig. 8. The other three enterprises-B, C, and D produced comparable locational gloss variation on their painted surfaces as can be seen from Fig. 8.

IV. CONCLUSION

Glosses of autobody paint finish by four top autobody painters in Kaduna metropolis, namely; Peugeot Automobile Nigeria (PAN) Limited, MA Motors, Alsarafa Body Painters, and IBK Motors has been investigated by measurements to understand their values concerning acceptable engineering standards. Analysis of the measurements indicated comparable paint finishes of high gloss standard within the order of 60 to 90GU by the entrepreneurs. The highest average gloss measurement by angle values from samples paint-finished at PAN, MA Motors, Alsarafa Body Painters, and IBK Motors was 87.29, 69.57, 92.42, and 60.73GU respectively.

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