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Comparative Analysis of Some Models of Motorcycle Aluminum Engine Blocks Using Weighted Property Method (WPM).

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ABSTRACT
In this study, compositions and different properties of five (5) models of motorcycle aluminum engine blocks were evaluated. This is fundamental to the development of a composite structure for the motorcycle engine block material. Elemental examination of these models were carried out using X-ray fluorescent (XRF).The study revealed that the dominant elements in these samples were Aluminum (Al) with 75.455 -84.955 wt. %, Silicon (Si) with 10.999 -20.103 wt. %, Copper (Cu) with 1.357- 1.577 wt. %, Magnesium (Mg) with 0.493 - 1.05 wt. %, Iron (Fe) with 0.623 -1.147 wt. %, and Zinc (Zn) with 0.532 -0.815 wt. % respectively. Other trace elements present that may have contributed to the enhancement of the mechanical properties included Calcium (Ca), Tin (Sn), Chromium (Cr), Nickel (Ni), Lead (Pb) and Barium (Ba).The material properties investigated included hardness, yield strength, modulus of elasticity, impact strength, thermal conductivity, mass density and corrosion rate. The result on the property tests showed that the hardness and elasticity values varied from 45.67 to 52.83 HRB and from 6771.67 to 8468.95 N/mm^2 respectively. The impact strength ranged from 1.25 to 2.0 J, the density values were within 2313.14 to 2746.41 kg/m^3 while the thermal conductivity values ranged from 88.35 to 292 W/m.°C approximately. A comparative analysis of the models was carried out using the weighted property method (wpm) of qualitative evaluation and a model with the highest performance index (PI) was obtained. The study established that the materials used in the production of these motorcycle aluminum engine block models are Al-Si alloys and fall within he hypo-eutectic, eutectic and hyper-eutectic categorizations. It therefore concludes that Al-Si alloys are suitable materials for use in motorcycle engine block manufacture subject to performance requirements and manufacturability issues.
Keywords: aluminum engine blocks, elemental composition, eutectic aluminum alloys, motorcycle engine, weighted property method (wpm)

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I. INTRODUCTION

A Motorcycle was defined by National Highway Traffic Safety Administration (NHTSA) of USA Federal Motor Vehicle Safety Standards [1] as a motor vehicle with motive power having a seat or saddle for the use of the rider and designed to travel on not more than three wheels in contact with the ground. An engine block is the main structure that houses almost all of the components required for effective performance

of the engine which provides this motive power. It is therefore a very important part of a motorcycle engine. Until now, cast iron and aluminum alloys have been the preferred materials used in internal combustion engine blocks manufacture Myagkov, *et al* [2] Labberton, *et al* [3] and Harwood [4]. In recent times however, the need for improved engine efficiency through weight reduction has called for alternative alloys that are effective and cost-saving. According to the findings of Mukesh [5] and Keay [6], the engine block alone accounts for 20-25% of the total weight of an engine and 3-4% of the total weight of the average vehicle by European Aluminum Association [7] findings. Thus, it must play a key role in all weight-reduction considerations. Therefore, in pursuit of increased efficiency of the engine through weight reduction, alternative alloy materials that are lighter than cast iron and aluminum alloys but capable of retaining the necessary strength to withstand the forces of an engine are being sought after. The use of aluminum alloy as the metal of choice for weight savings in the engine block manufacture is supported by

European Aluminium Association (EAA) [7] and Torres, *et al* [8]. The technical functions (performance) of engineering products or equipment depend largely on the capacity of their various components to withstand external influences such as load and environmental conditions. .From the reviewed works of Ghazaly [9] and Nguyen [10], the major requirements for an engine block material are high strength, modulus of elasticity, abrasion resistance, and corrosion resistance. The material should also have low density, thermal expansion (to resist expansion under high operating temperatures), and high thermal conductivity (to prevent failure under high temperatures) Good machinability and castability of the metal alloy are also important factors in selecting the proper materials. In addition to these mentioned properties, the material must possess good vibration damping properties to absorb the shuddering of the moving parts. .

In this study, performance consideration of the sample materials will be based on the following properties: hardness, yield strength, modulus of elasticity, impact strength, thermal conductivity, density and corrosion rate which are relevant to the design and production of the motorcycle aluminum engine block. Many methods exist in the selection of optimized materials for design among which are Fuzzy logic method, Multi-Criteria Decision Making method, Cost analysis, Limits Property Method and Weighted Property Method. Among these and other numerous material selection methods for evaluation of functional requirements of a product design, weighted properties method (WPM) is very useful when there are a lot of important criteria (properties) to compare and evaluate. This method involves more attributes or requirements /property and also takes each property into account in the selection process. The WPM has been employed by many notable scholars among whom are Farag, [11] in the quantitative methods of material selection, Manshadi, *et al*. [12] in the selection of materials for cryogenic storage tank design and Takur, *et al* [13] in the selection of materials for Vertical Axis Wind Turbine Rotor Blade. The WPM is also used in this study to comparatively evaluate the selected motorcycle engine blocks as fundamental step to the development of a composite structure for the engine block material.

II. EXPERIMENTAL PROCESS

2.1 Materials

The engine block samples used were procured from scrap automobile market (Panteka) in Kaduna, Nigeria. They included two (2) sets each of Piaggio (model VA46), Bajaj, (model W4),TVS (model Victor), Honda (model CG) and Jincheng (model AX100).

2.2 Methodology

A survey was conducted within Kaduna town metropolis in Nigeria where many motorcycle aluminum engine blocks were identified. Choice was made of the five (5) models of aluminum engine blocks of popular motorcycles in this study. Elemental composition of each sample was first examined at STEP-B Project Unit of Kaduna Polytechnic, Kaduna Nigeria. The samples were then re-melted in a crucible placed in a coal fired furnace at the National Metallurgical Development Centre (NMDC), Jos Nigeria. The process was carried out using Mohammed [14] procedure. The molten compound was then poured into already prepared sand moulds at the aluminum alloy optimum pouring temperature of 730^{o}C [14] and later, cast into different test specimen shapes. The temperature of the melt was monitored using a highly sensitive optical pyrometer. The casts were finally machined to standard specimen dimensions and tested under appropriate laboratory conditions. The chosen engine block models are shown in Table 1

Table 1: Motorcycle Engine Block Models

Sample	Symbol	Model	Make	Picture
1	S_1	VA46	Piaggio	
2	S_2	EW4	Bajaj	
3	S_3	Victor	TVS	
4	S_4	CG	Honda	
5	S_5	AX 100	Jincheng	

III. EXPERIMENTAL RESULT ANALYSIS

3.1 Chemical Composition

The elemental composition of the samples of motorcycle engine blocks was examined using Thermoscientific Niton XL3t X–Ray Fluorescence analyzer. The system setup is shown in Fig. 1. The tests were conducted in various magnifications of 5000x, 4000x, 3000x and 1000x.

Figure 1: Experimental Set-up for XRF Examination

3.2 Properties Test

The selected model samples were shaped by machining on the lathe into standard test specimen for the purpose of the following properties' examination.

3.2.1 Hardness Test

The hardness value of the samples were determined according to ASTM E18 – 79(2000) using Karl Frank Rockwell hardness tester (model 38506) with a 1.6mm steel ball indenter (Fig.2). Before the test, the mating surface of the indenter, plunger rod and test samples were thoroughly cleaned by removing dirt, scratches and oil. Finally, calibration of the testing machine was carried out using the standard block. The samples shown in Fig.3 were each placed on an anvil, which acted as a support for the test samples. A minor load of 10kg was applied to the sample in a controlled manner without inducing impact or vibration so as to establish the zero datum position. Thereafter, the major load of 100kg was then applied. The readings were taken when the larger pointer comes to rest or has slowed appreciably and stayed about 2 seconds. The load was then removed by returning the crank handle to the latched position and the hardness value read directly from the semi automatic digital scale.

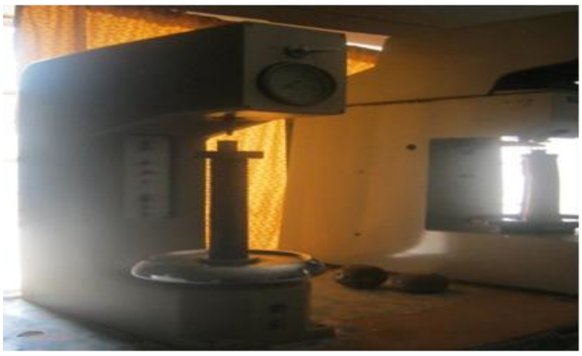

Figure 2: Karl Frank Rockwell hardness tester

Figure 3: Specimen Samples for Hardness Tests

3.2.2 Tensile Tests

The tensile properties were determined according to ASTM D2000 standard by using the Testometric tensile testing machine, Model FS300AT shown in Fig.4. The cast test pieces were machined to the standard dimensions and shape (Fig. 5) with original gauge length (GO) as 60 mm, the diameter of the grip (D) as 20mm, the length of the grip section (B) as 70mm, the radius of fillet (R) as 10mm, the Length of the reduced section (L) as 80mm and the overall length (A) as 240mm.The specimen was locked securely in the grips of the upper and lower jaws of the testing machine. A small load of 5N was initially applied to seat the sample in the jaws and then the load was increased until failure occurred. The values of the load and the extension were recorded and used in obtaining the stress – strain graph.

Figure 4: Experimental Set-up of Tensile Tests

Figure 5: Samples of Tensile Test Specimen.

3.2.3 **Impact Strength Test**

The impact test of the motorcycle engine block samples were conducted using a fully instrumented Avery Denison Notch Bar impact testing machine (Fig.6). A standard circular impact test sample specimen measuring 75 x 11.4mm Φ with a notch depth of 2 mm and a notch tip radius of 0.02mm at angle of 45^0 were used according to ASTM D, 2000 standard.

Figure 6: Experimental Set-up for Notch Impact Measurement

3.2.4 **Thermal Conductivity Test**:

The test was carried out in accordance with the Lee's Disc Method as recommended by [15]. Solid circular material specimens of 114±0.5 mm diameter with a varying thickness dimensions (10 ±2 mm) were used (Fig.7).

Figure 7: Samples of Machined Thermal Conductivity Test Specimen

In the experiment, the specimen was placed between two metal discs (of the brass material) of same diameter in a steam chamber (Fig.8). A thermometer was inserted into the holes provided on the brass base and the brass disc respectively. Steam from the hot flask was passed through the cylindrical vessel until a steady state was reached. At the steady state, heat conducted through the specimen was equal to heat radiated from the Lee's discs The upper disc temperature T_2 and the lower disc temperature T_1 were recorded.

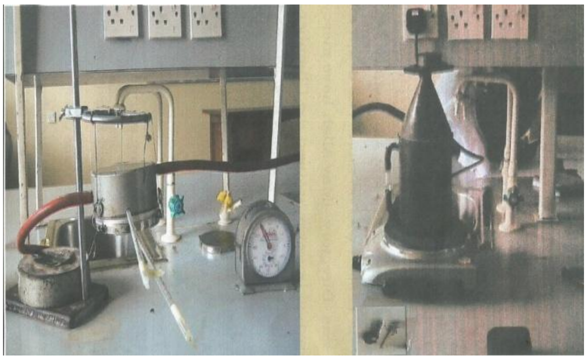

Figure 8: Experimental Set-up for Thermal Conductivity Test

The specimen was removed and the lower metal disc was allowed to heat up to the upper disc temperature T_2. Finally, the steam chamber and upper disc were removed and replaced by a disc made of a sample materialr. The metal disc was then allowed to cool through $T_1 < T_2$ and toward room temperature T_0. The temperature of the metal disc was recorded as it cools so that a cooling curve can be plotted. Then the slope 'R' of the cooling curve was obtained from the plot. Temperature in the laboratory during the experiment was 25^0C and did not vary for more than ± 2° C From this test, and using the expression of Eq.1, thermal conductivity values were evaluated

$$k = \frac{mcRx}{A(T_2 - T_1)} \quad \text{……………………………………………-…..(1)}$$

where ***k*** is the Coefficient of thermal conductivity of the sample, ***A*** is the area of the sample in contact with the metallic disc, **x** is the thickness of the sample, $\boldsymbol{T_2 - T_1}$ is the temperature difference across the sample thickness, ***m*** is the mass of the brass disc, ***c*** is the heat capacity of the brass disc and ***dT/dt*** is the rate of cooling (***R***) of the brass disc at $T_{2..}$

3.2.5 **Density**

The density value of each sample was obtained from a solid circular specimen machined from cast samples. Each specimen was machined to the dimensions of 114 ±0.5 mm diameter by 10 ±2 mm thickness and weighed on the digital weighing balance. The volume of the respective specimen was calculated. The basic method of determining the density of a specimen by measuring the mass and volume of the specimen was used. The density of the specimen was then estimated from the relationship given by the usual formula for density i.e Density = mass/volume (g/cm^3)

3.2.6 **Corrosion Test**

The standard immersion corrosion test was used to investigate the weight loss and corrosion rates of the motorcycle engine block samples in stimulated sea water solution containing 3.5gm of NaCl in 100 mls of distilled water. Each cast sample was cut and machined to the dimensions of 10mm diameter by 15mm long corrosion coupons. The samples were polished using several grades of emery paper ranging from 240 to 600grit, rinsed in water and methanol, dried and then weighed using digital weighing balance. A total of twenty (20) coupons were produced, four (4) for each sample. The coupons were suspended in the simulated seawater by means of thread as shown in Fig. 9 The weight loss was determined by finding the difference between the initial weight of the coupon and the final weight after twenty (20) days from the relationship ;$\boldsymbol{W = W_0 - W_f}$ where $\boldsymbol{W}$ is the weight loss after 20 days, $\boldsymbol{W_0}$ is the initial weight and $\boldsymbol{W_f}$ is the final weight after 20 days. The standard expression for measurement of corrosion rate in Mils per Year (MPY) was used and which is given as $MPY = 534W/DAT$. Where W is the weight loss in (mg), D is the density of the material in (g/cm^3), $\boldsymbol{T}$ is the time of exposure in hours and $\boldsymbol{A}$ is the area in (in^2).

Figure 9: Experimental Set-up for Corrosion Measurement

IV. RESULTS AND ANALYSIS

4.1 Chemical Composition

The result of the elemental examination of the samples of motorcycle engine blocks is represented in Table 2. The XRF investigation revealed that Aluminum (AL), Silicon (Si), Copper (Cu) and Magnesium (Mg) were the dominant elements.

Table 2: Composition of Engine Block Samples

Samples	Mg	Al	Si	S	Cu	Mn	Fe	Cu	Zn	Others	Total	Si/Mg
S_1	0.866	75.455	20.103	0.278	0.129	0.143	0.623	1.577	0.613	0.211	99.998	23.21
S_2	0.493	78.094	16.515	0.912	0.081	0.141	1.147	1.565	0.815	0.235	99.998	33.50
S_3	1.050	82.211	13.331	0.111	0.032	0.282	0.875	1.401	0.609	0.097	99.999	12.70
S_4	0.599	84.955	10.999	0.174	0.016	0.154	0.903	1.357	0.654	0.188	99.999	18.36
S_5	0.664	84.019	11.522	0.162	0.073	0.221	1.107	1.520	0.532	0.360	99.997	17.35

4.2 Property Test Results

The results of the standard tests on samples specimen are presented here as Fig.10 for hardness, yield strength, modulus of elasticity, thermal conductivity, impact strength, density and corrosion rate .

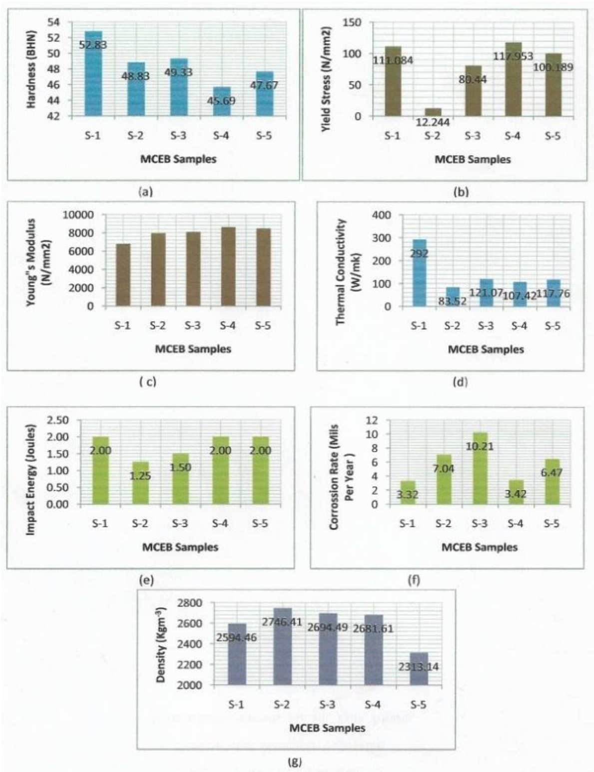

Figure 10:Test results for (a) Hardness (b) Yield Strength (c) Modulus of Elasticity (d)Thermal Conductivity (e) Impact Strength (f) Corrosion Rate and (g) Density

4.3 Evaluation of Engine Block Samples

List of properties required in this valuation process are hardness (H) in HRB, yield strength (YS) and modulus of elasticity (ME) in N/mm^2, thermal conductivity (TC) in W/m.^{o}C, impact energy (IE) in Joules, density (D) in Kg/m^3 and

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corrosion rates (CR) in MPY. The quantitative values of these parameters are presented in Table 3 while the scaled values obtained using the Weighted Property Method (WPM) with Modified Digital Logic (MDL) approaches are presented in Table 4.

Table **3**: Quantitative Data for Engine Block Samples

MCEB Samples	Response (Properties)						
	H	YS	ME	TC	IE	D	CR
S_1	52.83	111.084	6771.672	292.00	2.00	2594.46	-3.32
S_2	48.83	12.044	7933.235	90.34	1.25	2746.41	-7.04
S_3	49.33	80.440	8075.532	126.40	1.50	2694.49	-10.21
S_4	45.67	117.953	8418.105	88.35	2.00	2681.61	-3.42
S_5	47.67	100.189	8468.952	119.72	2.00	2313.14	6.47

Table 4: Scaled Property of Motorcycle Engine Block Samples

MCEB Samples	Scaled Properties (β)						
	H	YS	ME	TC	IE	D	CR
S_1	100.00	94.18	79.96	100.00	100.00	89.16	100.00
S_2	92.43	10.21	93.67	30.94	62.50	84.22	47.16
S_3	93.38	68.20	95.36	45.29	75.00	85.85	32.52
S_4	86.45	100.00	99.40	30.25	100.00	86.26	97.08
S_5	90.23	84.94	100.00	41.00	100.00	100.00	51.31

The decision yield for the sampled motorcycle engine blocks is shown as Table 5 and the weighing factors were calculated by dividing the number of positive decisions given to each property by the total number of decisions. The resulting weighting factors and performance index evaluation are given in Table 6 and 7 respectively. Shown in Fig.11 are plots of the performance ratings of the sample motorcycle engine block models.

Table 5: Application of Digital Logic (DL) in the Evaluation of MCEB Samples

PROPERTY		POSSIBLE NUMBER OF DECISION																				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
P_1	Hardness	1	1	1	1	1	1															
P_2	Yield strength	0						1	0	0	1	1										
P_3	Modulus of Elasticity		0-					0					0	1	0	1						
P_4	Thermal Conductivity			0					1				1				1	1	1			
P_5	Impact Energy				0					1				0			0			1	1	
P_6	Density					0					0				1			0		0		0
P_7	Corrosion Rate						0					0				0			0		0	1

Table 6: Weighting factors for Properties

Property	Positive decisions	Weighting factor (α)
Hardness	6	0.28
Yield strength	3	0.14
Modulus of Elasticity	2	0.10
Thermal Conductivity	5	0.24
Impact Energy	3	0.14
Density	1	0.05
Corrosion Rate	1	0.05
Total	**21**	**1.00**

Table 7: Evaluation of Performance Index

MCEB Samples	Performance Index (PI) of Properties							PI (γ)	Rank
	H	YS	ME	TC	IE	D	CR	$\Sigma(\alpha\beta)$	
S_1	28.00	13.19	8.00	24.00	14.00	44.58	50.00	181.77	1
S_2	25.88	1.43	9.37	7.43	8.75	44.11	23.58	119.89	5
S_3	26.15	9.55	9.54	10.87	10.50	42.93	16.26	124.31	4
S_4	24.21	14.00	9.94	7.8	14.00	43.13	48.54	161.25	2
S_5	25.26	11.89	10.00	9.84	14.00	50.00	25.66	146.65	3

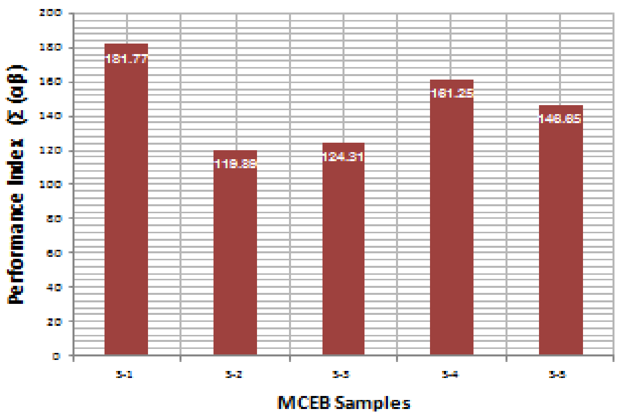

Figure 11: Performance Rating of the MCEB Models

V. DISCUSSION:

The result of XRF investigation into the motorcycle aluminum engine block samples revealed that Aluminum (AL), Silicon (Si), Copper (Cu) Iron (Fe), Zinc (Zn) and Magnesium (Mg) were the dominant elements. Therefore, consistent with the works of [7], these alloys can be classified as Al-Si alloys. The compositions also revealed that these samples, similar to the 6xxx series aluminum alloys are characterized by their main alloying elements, Si and Mg. The alloys vary not only in their Si/Mg ratio but also differ in their transition element additions such as Cu, Mn, Fe and V Ramona,*et al*.[16] The samples studied are so composed and exhibit different Si/Mg ratios of 23.21, 33.50, 12.70, 18.36 and 17.35 respectively and also different Si values similar to the series. The presence of Mg is associated with enhancing the tensile properties of Al-Si alloys at elevated temperature (up to 200 ºC). Mg also enhances creep resistance and decreases the rate of strength loss at high temperature in the alloys Zamani, [17] and Stadler, *et al* [18]. Another important feature of the compositions is the level of copper, iron and manganese contents. Some reviewed works [17, 18] showed that Cu addition was found to increase the strength at elevated temperatures (up to 200 ºC) and to improve creep resistance of Al-Si alloys. Iron is one of the most common tramp elements contained in aluminum processed from bauxite, and commercial Al alloys produced through iron-based tools and equipment. Recycling also increases the iron levels in these alloys through accumulation. Zhang *et al* [19]. Its presence therefore endangers the possible formation of inter-metallic compounds like Fe_3SiAl_{12} and $Fe_2Si_2Al_9$. Therefore, the adequate presence of manganese (Mn) as the commonly used alloying addition to neutralize the effect of Fe is most welcome.

From Table 7, it can be observed that the ranking of the performance index (PI) gave the motorcycle engine block Sample-1 (representing Piaggio, VA46 engine block model) the most desirable attributes and showed a well-weighted property profile for use as a motorcycle engine block. This model exhibited excellent hardness, good thermal conductivity, high impact strength, the lowest density and corrosion rate values. The improvement in the investigated properties of this sample relative to other samples can be traced to its elemental composition and hyper-eutectic (20 wt.% Si) nature of the alloy. Silicon is generally known as the next hardest material after diamond. In hypereutectic alloy with silicon above 12% concentration, silicon will not dissolve but rather precipitate out in crystal form. Therefore, the additional silicon concentration gives the hypereutectic Al-Si alloy adequate hardness for use as a cylinder block material. Lenny (Jnr.)[20]. This sample also has relatively, the highest presence of Cu at 1.577wt. %. Sample-2 has relatively high level of Fe (1.147 wt.%) in its composition and subsequently, the worst Mn/Fe ratio of approximately 1:8 which impacted negatively on the corrosion rate and density values. The sample also had a very high and unacceptable magnesium-silicon ratio of 33.5:1 which denied it the required yield and impact strengths.

Sample-3 had a hyper-eutectic composition of 13.33 wt. % of Si. It had the lowest Si/Mg and Mn/Fe ratios of approximately 12.7 and 3 respectively. The good corrosion resistance of this sample in comparison with others can be related to their low Si/Mg ratio, which goes hand in hand with a low amount of Si in excess.

Samples-4 had a hypo-eutectic alloy composition with a relatively lower hardness and thermal conductivity values. However, it had excellent yield strength, elasticity and impact energy values. These factor combinations made it an outstanding material for engine block fabrication.

Samples-5 was another hypo-eutectic alloy material. It had the Si/Mg and Mn/Fe ratios of approximately 17.35 and 5 respectively. Even with a relative lower hardness and thermal conductivity values it displayed outstanding yield strength, elasticity and impact energy values. For the capacity category, it was an excellent light weight material for engine block manufacture. It can be observed that samples 4 and 5 also belonged to the A356 group of hypoeutectic Al-Si alloys that had a wide field of applications in the automotive and avionics industries. Castings made of A356 exhibit many benefits such as wear and corrosion resistance, hot tearing resistance, good weldability and high strength to weight ratio [19].The results also revealed that all samples had a net weight gain with outstanding corrosion resistance. This made them suitable for marine and salty- water environment applications

VI. CONCLUSIONS AND RECOMMENDATIONS

The study established that the materials used in the production of these motorcycle aluminum engine block models were Al-Si alloys that fell within the hypo-eutectic, eutectic and hyper-eutectic categorizations. It therefore concludes that Al-Si alloys are suitable materials for use in motorcycle engine block manufacture subject to performance requirements and manufacturability issues.

Tests results obtained here were conducted on un-tempered sample specimen. Usually, manufactured parts used in automotive industry are subjected to solution and temper heat treatment depending on the functional requirements. A typical heat treatment applied to sand and gravity die-cast Al-Si alloys is the T6 heat treatment–age-hardening. It is therefore expected that the mechanical properties of these alloys would be further enhanced if heat treated.

REFERENCES

[1]. National Highway Traffic Safety Administration (NHTSA).,Federal Motor Vehicle Safety Standards by Department of Transportation, Sub-part A, Section 571.3 definitions 1970,. https://www.law.cornell.edu/cfr/text/49/571.3

[2]. Myagkov, L., Mahkamov, K., Chainov, N. D., 2014, Alternative Fuels and Advanced Vehicle Technologies for Improved Environmental Performance Advanced and Conventional Internal Combustion Engine Materials 11 pp 370-392

[3]. Labberton, M.G., 2014, Aluminium Packaging Recycling: The Contribution from Romania Towards A More Resource Efficient Europe. Proceeding of European Recycling Society Annual Conference, 2nd edition, Bucharest

[4]. Harwood, G., 2008, Aluminium. The Rest of Now, Manifesta7, Bolzano, Italy.

[5]. Mukesh, A., Design and Analysis of Four Cylinder Engine Block by Using F.E.A. Published by International Journal & Magazine of Engineering, Technology, Management and Research (IJMETMR), 2016, vol.3, page 443.

[6]. Keay, S., 2002, "Diet of Australian Metal Lightens Cars and Pollution"Mediarelease http://www.ijmetmr.com.

[7]. European Aluminium Association (EAA)., 2011, Aluminum Automotive Manual, The Aluminum Inc. 900 19th Street, N.W,Washington DC 20006 www.aluminium.org.

[8]. Torres, R.., Esparza, J.,Velasco, E., García-Luna, S. and Colás, R., 2006,'Characterisation of An Aluminium Engine Block', Int. J. Microstructure and Materials Properties, Vol. 1, No 2, pp.129–138. 130

[9]. Ghazaly, M. Nouby, Engine Block, Automotive and Tractor Engineering Department, College of Engineering, Minia University, 61111, India, https://www.scribd.com/doc/98724458/case-study-engineblock,email.auto@gmail.com 2011.

[10]. Nguyen, H., Manufacturing Processes and Engineering Materials Used in Automotive Engine Blocks , Materials Science and Engrg (EGR250) Term Paper submitted to School of Engineering of Grand Valley State University, USA, 2005.

[11]. Farag, M. Mahmoud, Materials and Process Selection for Engineering Design, published by CRC Press , 37-41 Mortimer Street, London, England, 3rd Edition, Pages 89-95 B/W ISBN 9781466564091, 2013.

[12]. Manshadi, B.D., Mahmudi, H., Abedian, A. and Mahmudi, R., A Novel Method for Materials Selection in Mechanical Design: Combination of Nonlinear Normalization and A Modified Digital Logic Method, published by Materials and Design, 2007,volume 28, pages 8–15.

[13]. Takur, S., Kiran Kumar, P. and Madhusudhan,T, Selection of Material by Weighted Property Method for Savonius Vertical Axis Wind Turbine Rotor Blade, published by Int. Research Journal of Engineering and Technology.(IRJET). e-ISSN: 2395-0056, ., 2015, Vol: 02 Issue: 01

[14]. Mohammad, B. N. and Akpan, P. P, Behavior of Aluminum Alloy Castings under Different Pouring Temperatures and Speeds, http://lejpt.academicdirect.org/A, ., 2006.

[15]. vlab.amrita.edu, 2011, Lee's Disc Apparatus from lab.amrita.edu/?sub=1&brch=194&sim Copyright @ 2017 under the NME ICT initiative of NHRD.

[16]. Ramona, P., Gunther, R., Josef, B., Helmut, A., Peter, J. U and Stefan, P., Property Criteria for Automotive Al-Mg-Si Sheet Alloys, published online by. Multidisciplinary Digital Publishing Institute (MDPI), 10.3390/ma7075047, 2014.

[17]. Zamani, M., Al-Si Cast Alloys - Microstructure and Mechanical Properties at ambient and Elevated Temperature**,** published by School of Engineering, Jönköping University, Department of Materials and Manufacturing SE-551 11 Jönköping, Sweden, 2015,

[18]. Stadler,F, Antrekowitsch, H. Fragner, W Kaufmann, H. Uggowitzer P., Int lab.amrita.edu/?sub=1&brch=194&sim=353 &cnt=1 Copyright @ 2017 under the NME ICT initiative of NHRD ernational Journal of Cast Metals Research, 2012, vol. 25 pg 215-224.

[19]. Zhang, L.Y., Jiang, Y.H., Ma, Z., Shan, S.F., Jia, Y.Z., Fan C.Z. and Wang, W.K., Effect of Cooling Rate on Solidified Microstructure and Mechanical Properties of Aluminium-A356 Alloy. J. Mater. Process. Technology. 207, 2008,: 107-111.

[20]. Lenny (Jr), J., Replacing the Cast Iron Liners for Aluminum Engine Cylinder Blocks: A Comparative Assessment of Potential Candidates An Engineering Project Submitted to the Graduate Faculty of Rensselaer Polytechnic Institute Hartford, Connecticut 2011,.