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Diagnosis and Repair of CNC Electromechanical Universal Testing Machine of a LR 5k Model

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ABSTRACT

The acute shortage and high cost of equipment and other machines in our research institution and environmental pollution have awakened the research efforts focused at diagnosing and repairing a faulty electromechanical universal testing machine. To ensure plant reliability and equipment availability the machine was tested, repair and diagnosed by condition-based monitoring maintenance procedure. The maintenance procedure is used to analyze the ensuing machinery faults, their causes and consequences. The results or data generate was used to carry out the repair action on the machine. The faults are enumerated and the general diagnosis procedure is explained. The results of the diagnosis were used to carry out repairs on the machine which makes the machine to be restored back to operation. The restored machine that was repaired is been used to perform pure tension test on metal rods. The machine provided information on strength properties of materials, being tested upon which Young Modulus were determined. Tension test was conducted, based on ASTM 143-63 standard, on Aluminium specimen with 9.5 mm diameter, Brass specimen with 3.5 mm and 3.71 mm diameter of Mild-Steel. The experimental Young Modulus from the test shown that Aluminium has 69.2 N/mm (0.12 % less than expected), while Mild-steel has 198.9 N/mm (0.1% less than expected) and Brass has 110 N/mm (0.27 % less than expected).
Keywords: Diagnosis, Repair, CNC Electromechanical, Universal Testing Machine, LR 5K Model, Diagnostic Process, Predictive maintenance (PdM) procedures, Aluminium

I. INTRODUCTION

Mechanical testing is that part of engineering design, development, and research that provides data about material properties. Maintenance, although requiring the expenditure of significant amounts of energy, is usually required in order to keep (or restore) equipment at an acceptable operational standard. For most equipment, maintenance practice is predominantly based on routine-scheduled prevention as well as previously unanticipated reactions to overcome faults. Predictive maintenance (PdM) procedures, such as that devised in this paper, are evolving and results in less wasted efforts. Condition monitoring (CM) an aspect of PdM is defined as the use of appropriate technology to determine the operational state of the considered machinery. For instance, it may involve current measurement, voltage, flow, temperature, capacitors, transistors and mechanical looseness etc. Testing is also required during manufacturing to ensure that a material or product meet some predefine specification. Diagnosis analysis is also requiring so that a defective element in a circuit can be identified with a view to repair, or to provide feedback data for improving the yield of machine process and as an aid to monitoring the performance of the machine process. In particular, universal testing machines measure the mechanical properties of materials in tension, compression, bending, or torsion. A tensile or compression test basically involves pulling a test specimen fixed into jaws at both ends until it breaks or compress and recording the load and the corresponding strain produced at varying instants using a Universal testing machine (or a tester machine). Testing machines are available in two classes, hydraulic and electromechanical. The principal difference is the way that the load is applied. Accurate mechanical testing requires not only familiarity with measurement systems, but also some understanding of the planning, execution, and evaluation of experiments. Much experimental equipment is often "homemade," especially in smaller companies where the high cost of specialized instruments cannot always be justified. If the designer of the "homemade" equipment does not carefully consider how the design functions under test conditions, then the stress vs. strain diagram may be in error.

In an electromechanical machine, a variable speed electric motor, gear reduction system, and one, two, or four screws move the crosshead up or down. This motion loads the specimen in tension or compression. A range of crosshead speeds can be achieved by changing the speed of the motor. A microprocessor- based closed-loop servo system can be implemented to accurately control the speed of the crosshead. In general, the electromechanical machine is capable of a wider range of test speeds and longer crosshead displacements, whereas the hydraulic machine is a more cost-effective solution for generating higher forces. Sensors are at the heart of all mechanical testing measurements. The test frame, power transmission, grips, and fixtures also affect the accuracy and repeatability of sensors. If sensors are mounted in the wrong position, are heated up, or are deformed by mounting bolts, they can introduce measurement errors. Because of the many component interdependencies in today's integrated systems, causes of failure are often difficult to distinguish. Thus, because of this increased complexity, more errors are made in the diagnosis and repair of electromechanical systems. This is a problem in *diagnosability*, the system characteristic defined as a measure of the ease of isolating faults in a system. There are two approaches to alleviating problems with fault isolation. The first is to make improvements to the diagnostic process for systems already designed and in-service. This approach includes developing maintenance and diagnostic procedures and processes and incorporating electronic diagnostics into system design. There has been much research and application in this area of diagnosis. Less work has been focused on a second approach to the problem, improving inherent system diagnosability. This approach involves looking at the problem during the repair stage and asking the questions: *How can this system be improved to make it easier to diagnose? What are ways of measuring this system's diagnosability during repair?* In this approach we assume that changes in the structure of the system will affect the efficiency of diagnosing the system's failures. In endeavoring to understand and develop methodologies for improving diagnosability in this sense, we must have a good understanding of the diagnostic process. Maintaining electromechanical systems is costly in both time and money, and diagnosability problems increase these costs. This fact is the primary motivation for exploring diagnosability improvement in systems ranging from airplanes to automobiles to high-tech manufacturing equipment. The ability to predict the diagnosability of a system early would enable the building of systems with more efficient fault isolation, leading to reduced life-cycle costs.

Wong [1994] developed methods for minimizing both the time and cost of diagnosis early in the design stage. Wong developed a *checking order index* for each system component, which was calculated by dividing the probability of failure by the average time to check the component. A ranking order of components to be checked could then be established for each possible failure indication. Wong then developed an *expected time to diagnose* for a given indication. Simpson and Sheppard [1994] devote a considerable portion of their book *System Test and Diagnosis* to diagnosability evaluation. They present a highly mathematical and theoretical analysis of diagnosis and testing adapted mainly for electrical and electronic applications. In evaluating diagnosability, they develop large matrices of test results and test conclusions to analyze and measure ambiguity and the ability to isolate faults. Kurki [1995] researched model-based fault diagnosis, exploring the use of structural and behavioral models in examining fault detection and fault localization processes. Ruff [1997] introduced the idea of mapping a system's *performance measurements* to system *parameters.* Performance measurements would be indications from lights, gauges, etc. Parameters were usually the system components being measured, such as valves, controllers, or actuators. The complexity of the interdependencies between measurements and parameters was directly related to the diagnosability of the system. Ruff also completed some initial work on evaluating competing designs based on life cycle costs associated with diagnosability. Clark [1996] extended Ruff's work by establishing some valuable metrics based on performance measurement parameter. Measurement parameter relationships. The most significant of these metrics, *Weighted Distinguishability (WD),* represents the complexities of interdependencies between components and indication. Murphy [1997] developed prediction methods for a system.s *Mean Time Between Unscheduled Removals (Unjustified)* (*MTBURunj*). The *MTBURunj* metric is a significant component attribute in doing diagnosability analysis. Finally, Fitzpatrick [1999] worked on developing methods for predicting *Mean Time between Failures (MTBF)* and *Mean Time Between Maintenance Actions (MTBMA)* in addition to *MTBURunj*.

The objectives of this research work are as follows:

i. To test the functionality and effectiveness of CNC Electromechanical universal testing machine
ii. To diagnose the components of a faulty CNC Electromechanical universal testing machine
iii. To repair its defective components
iv. To evaluate its performance

II. METHODOLOGY: TECHNICAL APPROACH

Diagnosis Analysis and Repair Procedures

The engine used in this study was LLORD K LR 5, Figure 1 shows the machine for our case study. Our main aim in this section is to: visit the faulty machine, get the anatomy of an electromechanical universal machine, use faulty finding technique, instrumentation, diagnosing and measurement of the electronic circuit, components specification, diagnosis and repair.

The faulty electromechanical universal testing machine (Fig. 1), are universal tester, which test materials in tension, compression, or bending. Their primary function is to create the stress-strain curve. Once the diagram is generated, a pencil and straight edge, or a computer algorithm, can calculate yield strength/young's modulus, tensile strength, or total elongation.

Engine Description and Operation

This electromechanical universal machine consists of a variable speed electric motor; a gear reduction system; and one, two, or four screws that move the crosshead up or down. This motion loads the specimen in tension or compression. It also has the following component: the test frame, power transmission, grips, and fixtures.

Instrumentation in undertaking investigation

In undertaking this investigation, the following instruments were used: magnifying mirrors, oscilloscope, signal generator, multimeter, line testers, transistor tester, transistors tester, transistor logic tester, RCL tester, tone tester and neon tester

Figure 1: The faulty electromechanical universal testing machine

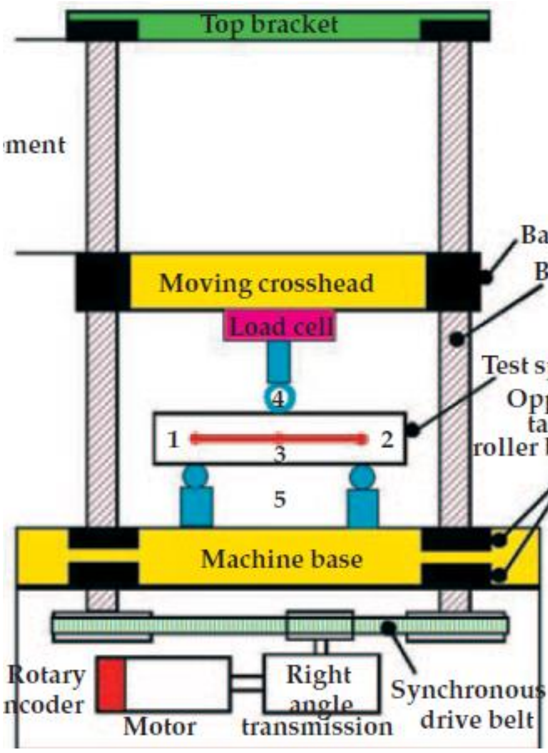

Figure 2: Anatomy of an electromechanical testing machine

Fault Finding Technique

The visual inspections used in this research include the following: (i) Checking the state of equipment (ii) Looking for obvious sign damage (iii) Further investigation as regard to the environmental situation and correctly Operation (iv) Measuring the voltage output (v) Checking Live signs in the equipment (vi) Confirming the complaint in relation to the symptoms. Confirmation of the complaints will then determine which sub-unit is faulty and whether it can be repaired or change out. Once a stage has been identify as the one that has faulty, then will move to the rest of the diagnostics techniques as listed on the chart above.

Components Specifications

This Electromechanical universal material testing machine uses electronic components, passive (R,C,L, capacitors and some diodes) and active (transistors, ICs e,t.c,), built up into assemblies to make complete operational units as well as mechanical assemblies. The technical specification of the machine is shown below:

Technical Specification:	LR 5K		
Maximum force	5KN (11001bf)		
Overall force using			
Interchangeable loads cell	0.1N-5KN (0.02-11001bf)		
Force measuring system	meets BS1610 1985 Grade 1, ASTE E4, DIN51221		
Crosshead speed range	0.2-1000mm/min (0.01-40in/min)		
Crosshead speed accuracy	+0.5% of set speed		
Maximum working width			
Between columns	400mm (16in)		
Maximum crosshead displacement			
excluding load cell and grips	1100mm (43in)		
Crosshead range setting	1-1000mm (0.05-40in)		
External extensometer connection	Analogue standard (0-10v)		
Analogue load/extension output	Standard		
Internal extensometer resolution	Better than 5 microns		
Frame stiffness without load cell	Greater than 25KN/min		
Supply voltage	230vac=10% 50-60Hz Fuse 10A (T) or 115vac=10% 50-60Hz. Fuse 10A (T)		
Power consumption	500 watts maximum		
Main frame dimensions	Height	1550mm (61in)	
		Depth	500mm (19.6in)
		Width	600mm (23.6in)
Console dimensions		Height	340mm (13.4in)
		Depth	70mm (2.8in)
		Width	310mm (12.2in)
Mass		105kg (231lb)	

Testing and Measurement of Electronic Circuits

Testing of individual compound in an electronic circuit of electromechanical testing machine is done under STATIC CONDITION of the equipment. This means that the equipment is switched off and component is tested by removing it completely from the circuit. The passive components, active components, faults and diagnosis in voltage source power, diagnosis by means of the standard protection system, power transistor open circuit fault diagnosis, diode rectifier open circuit faults diagnosis, diagnosis methods for capacitors and specification of tensile specimen are sought after.

Cases pins combination	Condition	Status
Base(p)/Emitter(N)	Normal reading	Ok NPN
Base(P)/collector(N)	" "	Identified
Emitter(P) Base(N)	No reading	
Emitter(P)/Collector(N)	" "	No identification
Collector (P) Base(N)	" "	" "
Collector(P) Emitter(N)	" "	" "

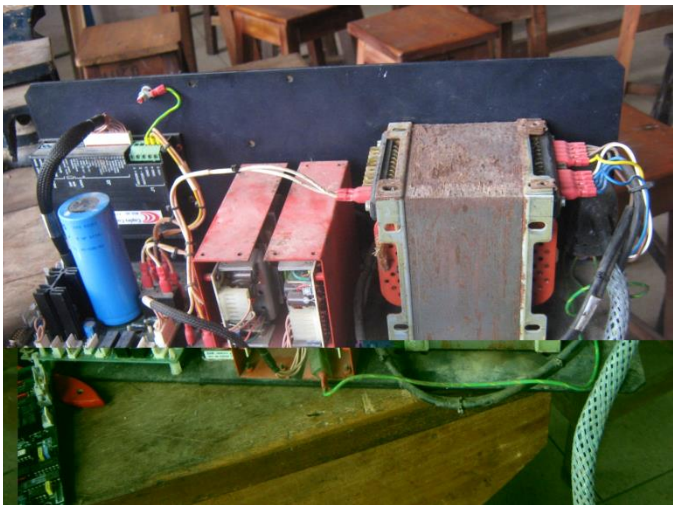

Figure 4: Diagnosing and measurement in progress

Figure 5 : Connecting wire lines under repair

Figure 6 : The restored machine after the repair has been carried out

III. RESULT AND DISCUSSION

A. Machine Testing Results and Evaluation

The following charts/table is the most suitable or general diagnostic test techniques that is chosen for this research work to diagnose and repair the CNC Electromechanical universal testing machine. The results of the diagnosed is presented in the table 4.1 - 4.3

Table 1

Complaints	Visual Inspection	Check power supply	Voltage check	Signal tracing	Wiring	Switch	Parts substitution
Dead	✓	*	*	*	*	*	
Weak	*	*	*	*	*	*	
Intermittent	*	*	*	*	*	*	
Distortion	*	*	*	*	*	*	
Oscillation	*	*	*	*	*	*	

Dead: means that the item does not work at all. There is no visible sign of life in the equipment.

Weak: Means that the equipment works but lacks of usually response. Usually when the output is low.

Distortion: Means that the equipment works but not quite clear.

Oscillation: Means the equipment is unstable.

Intermittent: Means the equipment works no and then unreliable, "works if it works", light flickers and occasional goes out.

Table 2: Average Current Space Vector for Transistor Open Circuit

Experimental Results			Derived Knowledge base	
Tran-sistor	$\lvert\vec{I}_{ac}\rvert / \vec{I}_{acN}$	$\Theta/°$	$\lvert\vec{I}_{ac}\rvert / \vec{I}_{acN}$	$\Theta/°$
T1	1,59	181,04	$>I_{lim}/I_{acN}$	150...210
T2	1,68	240,01	$>I_{lim}/I_{acN}$	210...270
T3	1,75	298,25	$>I_{lim}/I_{acN}$	270...330
T4	1,75	0,41	$>I_{lim}/I_{acN}$	330...30
T5	1,52	58,9	$>I_{lim}/I_{acN}$	30...90
T6	1,46	114,54	$>I_{lim}/I_{acN}$	90...150

These voltages were monitored and these irregularities may be detected, which gives a direct location of the faulty transistor position as has been derived.

Table 3: Voltage Error and Corresponding Defect Transistor for Open Circuit Fault

Δv_{1n}	Δv_{2n}	Δv_{3n}	Defect Transistor
2/3 Δv_{10}	-1/3 Δv_{10}	-1/3 Δv_{10}	T1
-1/3 Δv_{20}	2/3 Δv_{20}	-1/3 Δv_{20}	T2
-1/3 Δv_{30}	-1/3 Δv_{30}	2/3 Δv_{30}	T3
-2/3 Δv_{10}	1/3 Δv_{10}	1/3 Δv_{10}	T4
1/3 Δv_{20}	-2/3 Δv_{20}	1/3 Δv_{20}	T5
1/3 Δv_{30}	1/3 Δv_{30}	-2/3 Δv_{30}	T6

Detection times of one fourth of a period have been attained.

B. Mathematical Equations Applied

Test results were determined using the following classical tension expression:

Force load F=mg (1)

Cross sectional Area, S=πd/4 (2)

Engineering stress = Force / Original Specimen Area = F / S_o (3)

Engineering strain = extension/ Original Specimen Length = $\Delta L / L_o$

Engineering strain=$\Delta\ell/\ell_\circ$ (4)

Young Modulus E = Tensile stress/Tensile strain (5)

The true stress and the true strain differ from the real value continuously as the strain increases.

The true stress = Force / Actual Specimen minimum area Area = F / S

True strain = logarithmic strain = Sum of incremental elongations /current length

$$\text{True Strain} \quad \varepsilon = \int_{Lo}^{L} \frac{dL}{L} \qquad (6)$$

Table 4: Test Results of 9.5mm Diameter of Aluminum

L(KG)	EXT(in)	EXT(mm)	F(KN)	δ=F/S	ΔL	ϵ=ΔL/L◦
0.1	0.064	0.16256	1	0.014041	0.010308	0.000203
0.2	0.128	0.32512	2	0.028082	0.020615	0.000406
0.3	0.192	0.48768	3	0.042123	0.030923	0.000609
0.4	0.256	0.65024	4	0.056164	0.04123	0.000812
0.5	0.32	0.8128	5	0.070205	0.051538	0.001015
0.6	0.332	0.84328	6	0.084246	0.061846	0.001217
0.7	0.344	0.87376	7	0.098287	0.072153	0.00142
0.8	0.356	0.90424	8	0.112328	0.082461	0.001623
0.9	0.368	0.93472	9	0.126369	0.092768	0.001826
1	0.38	0.9652	10	0.14041	0.103076	0.002029
1.1	0.4	1.016	11	0.154451	0.113384	0.002232
1.2	0.42	1.0668	12	0.168492	0.123691	0.002435
1.3	0.44	1.1176	13	0.182533	0.133999	0.002638
1.4	0.46	1.1684	14	0.196574	0.144306	0.002841
1.5	0.8	2.032	15	0.210615	0.154614	0.003044
1.6	0.5	1.27	16	0.224656	0.164922	0.003246
1.7	0.52	1.3208	17	0.238697	0.175229	0.003449
1.8	0.54	1.3716	18	0.252738	0.185537	0.003652
1.9	0.56	1.4224	19	0.266779	0.195844	0.003855
2	0.585	1.4859	20	0.28082	0.206152	0.004058
2.1	0.61	1.5494	21	0.294861	0.21646	0.004261
2.2	0.62	1.5748	22	0.308902	0.226767	0.004464
L(KG)	EXT(in)	EXT(mm)	F(KN)	δ=F/A	ΔL	ϵ=ΔL/L◦
0.1	0.064	0.16256	1	0.014041	0.010308	0.000203
0.2	0.128	0.32512	2	0.028082	0.020615	0.000406
0.3	0.192	0.48768	3	0.042123	0.030923	0.000609
0.4	0.256	0.65024	4	0.056164	0.04123	0.000812
0.5	0.32	0.8128	5	0.070205	0.051538	0.001015

Gage Length = 50.8 mm

Table 5: Test Results of 3.5 Mm Diameter Brass

L(KN)	ELON(MM)	F=Mg	δ=F/S	ΔL	ϵ=ΔL/L◦	E=STRESS/STRAIN
0.5	0.135	5	0.519953	0.047268	0.004727	110
1	0.27	10	1.039906	0.094537	0.009454	
1.5	0.42	15	1.55986	0.141805	0.014181	
2	0.57	20	2.079813	0.189074	0.018907	
2.5	0.74	25	2.599766	0.236342	0.023634	
3	0.91	30	3.119719	0.283611	0.028361	
3.5	1.07	35	3.639672	0.330879	0.033088	
4	1.22	40	4.159626	0.378148	0.037815	
4.5	1.42	45	4.679579	0.425416	0.042542	
5	1.62	50	5.199532	0.472685	0.047268	
5.5	1.82	55	5.719485	0.519953	0.051995	
6	2	60	6.239438	0.567222	0.056722	
6.5	2.24	65	6.759392	0.61449	0.061449	
7	2.4	70	7.279345	0.661759	0.066176	
7.5	2.7	75	7.799298	0.709027	0.070903	
8	2.9	80	8.319251	0.756296	0.07563	
8.5	3.12	85	8.839204	0.803564	0.080356	
9	3.25	90	9.359158	0.850833	0.085083	
9.5	3.44	95	9.879111	0.898101	0.08981	
10	3.6	100	10.39906	0.945369	0.094537	
L(KN)	ELON(MM)	F=Mg	δ=F/S	ΔL	ϵ=ΔL/L◦	E=STRESS/STRAIN

Initial Diameter 3.5 Mm
Final Diameter 3.3 Mm
Initial Length 10mm
Final Length 11mm

Table 6: Test Results of 3.71 mm Diameter Mild Steel

L(KN)	F=Mg	ELON(MM)	δ=F/S	ΔL	ϵ=ΔL/L◦	Y=STRESS/STRAIN
0.5	5	0.11	0.462535	0.023127	0.002313	198.9
1	10	0.22	0.925069	0.046253	0.004625	198.9
1.5	15	0.37	1.387604	0.06938	0.006938	198.9
2	20	0.51	1.850139	0.092507	0.009251	198.9
2.5	25	0.68	2.312673	0.115634	0.011563	198.9
3	30	0.85	2.775208	0.13876	0.013876	198.9
3.5	35	0.97	3.237743	0.161887	0.016189	198.9
4	40	1.09	3.700278	0.185014	0.018501	198.9
4.5	45	1.22	4.162812	0.208141	0.020814	198.9
5	50	1.34	4.625347	0.231267	0.023127	198.9
5.5	55	1.505	5.087882	0.254394	0.025439	198.9
6	60	1.67	5.550416	0.277521	0.027752	198.9
6.5	65	1.79	6.012951	0.300648	0.030065	198.9
6.5	65	1.79	6.012951	0.300648	0.030065	198.9
7	70	1.9	6.475486	0.323774	0.032377	198.9
7.5	75	2.05	6.93802	0.346901	0.03469	198.9
8	80	2.2	7.400555	0.370028	0.037003	198.9
8.5	85	2.31	7.86309	0.393154	0.039315	198.9
9	90	2.45	8.325624	0.416281	0.041628	198.9
9.5	95	2.53	8.788159	0.439408	0.043941	198.9
10	100	2.6	9.250694	0.462535	0.046253	198.9
10.5	105	2.7	9.713228	0.485661	0.048566	198.9
11	110	2.8	10.17576	0.508788	0.050879	198.9
11.5	115	2.93	10.6383	0.531915	0.053191	198.9
12	120	3.1	11.10083	0.555042	0.055504	198.9
12.5	125	3.23	11.56337	0.578168	0.057817	198.9
13	130	3.4	12.0259	0.601295	0.06013	198.9
13.5	135	3.51	12.48844	0.624422	0.062442	198.9
14	140	3.65	12.95097	0.647549	0.064755	198.9
14.5	145	3.76	13.41351	0.670675	0.067068	198.9
15	150	3.82	13.87604	0.693802	0.06938	198.9

INITIAL DIAMETER = 3.71mm
FINAL DIAMETER = 3.5 mm
INITIAL LENGTH = 10 mm
FINAL LENGTH = 18 mm

C. Evaluation

The tension test was conducted on the three materials; namely Aluminium, Brass, and Mild steel. The experimental results were given by Tables 4 to 6 and using MS-Excel software (2007 Version), the experimental slopes (i.e. Young Modulus, E) of the three metals were determined in the elastic range.

Aluminium specimen has a Young Modulus of 69.199 N/mm, Brass has 110 N/mm, and Mild-steel has 198.9 N/mm respectively. Data from literature show that experimental value, E, of Mild-steel is much correct, as it as the least percentage error of 0.01 (Table 4). The percentage deviations of Brass and Aluminium are 0.027 and 0.012 respectively

Table 7: Comparison of Experimental Young Modulus with Standard Values

MATERIA L	YOUNG MODULUS FROM THE EXPERIME NT (N/mm	STANDA RD YOUNG MODULU S(	EXPERIMENT AL DEVIATIONS FROM STANDAD(1- PERFORMAN

	²)	N/mm ²)	CE)
MILD STEEL	198.9	200	0.01
ALUMINIUM	69.2	72	0.012
BRASS	110.0	113	0.027

Source: TERCO (2004)

The various curves showing the relationship involving tensile stress versus tensile strain; tension versus value of elongation of the three materials were shown in Figure 1 to 11. The curves of Mild-steel and Aluminium specimen show some better linearity thus exhibit good ductility properties.

The physical examination of the three deformed specimen shows that, after loading is applied up to a certain stress, the strain is directly proportional to stress (obeys Hooke's law).

After plotting strain on horizontal axis and stress on vertical axis, the prominent features of a stress-strain curve are: *Proportional Limit, Elastic Limit. Resilience, Yield point, Ultimate Tensile strength,* and *Fracture Strengths were made use of for the research.*

IV. CONCLUSION

An CNC Electromechanical Universal Testing machine of 5KN load capacity was diagnosed and repaired. Approach to this study uses the development of a maintenance procedure which restores the CNC Electromechanical universal machine back to life. The electromechanical universal testing machine, are universal tester, which test materials in tension, compression, or bending.

After the diagnosed and the repaired, the test based on ASTM 143-63 Standards, was conducted with a sample each of Mild-steel, Aluminium and brass specimens. The diameter (mm), gauge length (mm) and total length (mm) of the three specimens were Ø3.7 x 10 x 18, Ø8.5 x 50.8 x 55, Ǿ3.5 x 10 x 11 respectively. The experimental Young modulus obtained from the test shown that Mild-steel has 198.9 N/mm (0.1% less than expected), Aluminium has 69.2 N/mm, (0.12 % less than expected) and Brass 110 N/mm (0.27 % less than expected).

V. RECOMMENDATIONS

(i) The software should be incorporated to create/generate the stress-strain curve. Once the diagram is generated, a pencil and straight edge, or a computer algorithm, can calculate yield strength/young's modulus, tensile strength, or total elongation.

(ii) It is recommended as teaching aid in tertiary institution to facilitate ease learning.

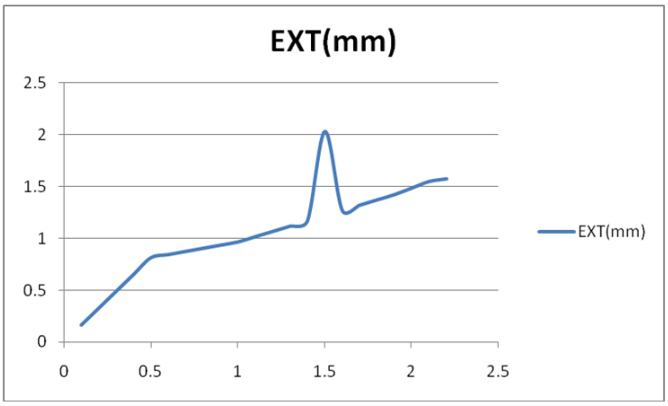

Figure 7: Curve of load against extension of Aluminium

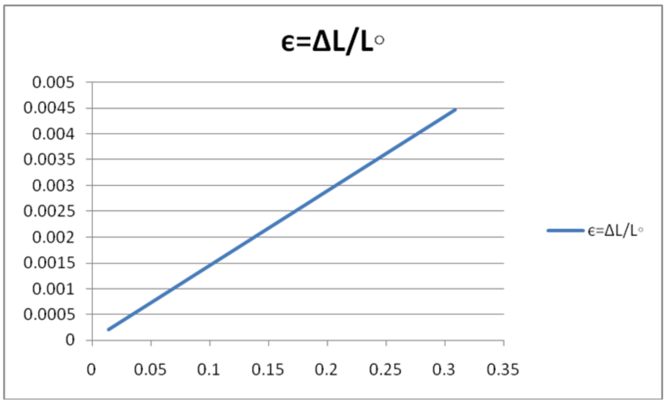

Figure 8: Curve of Tensile Stress against Tensile Strain of Aluminium

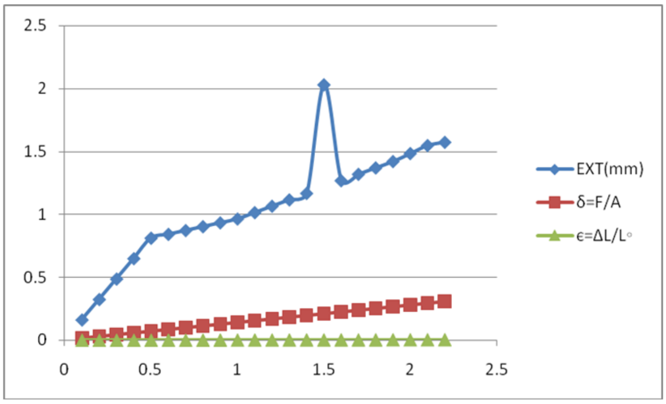

Figure 9: Curve of Tensile Strain against Load of Aluminium

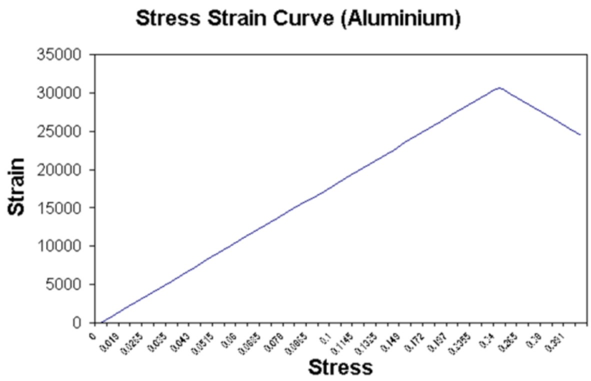

Figure 10: Stress strain curve (Alumnium)

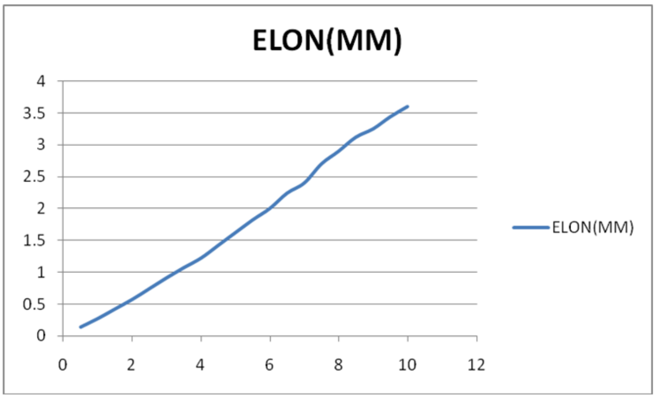

Figure 11: Curve of Load againt Elongation of 3.5mm Diameter Brass

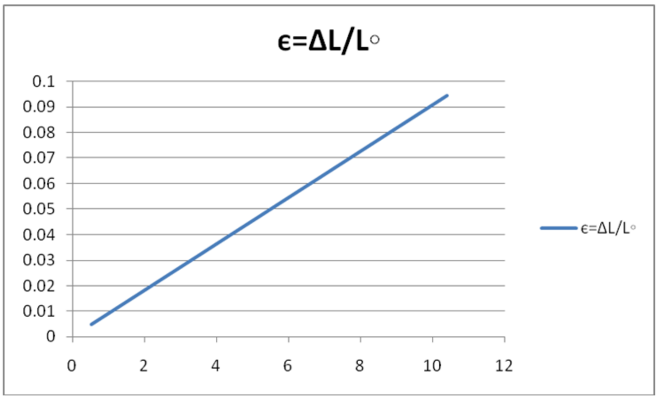

Figure 12: Curve of Tensile Stress against Tensile Strain of Brass

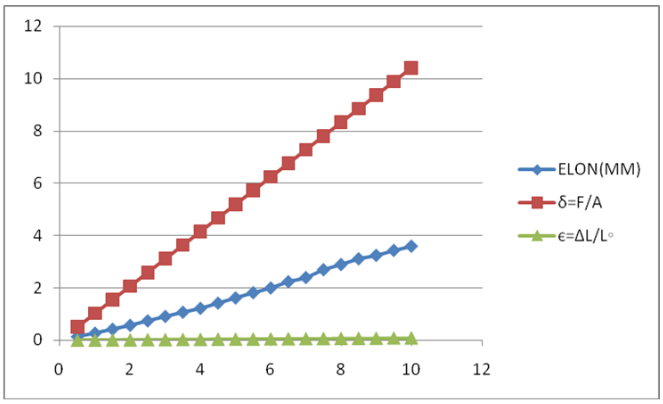

Figure 13: Curve of Tensile Strain against Load of Brass

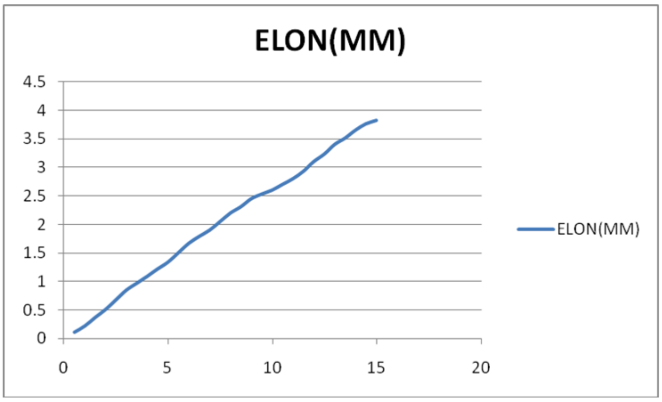

Figure 14: Curve of Load against Extension of Mild Steel

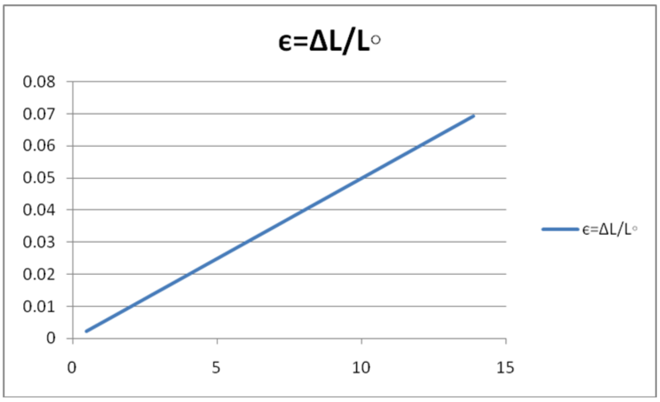

Figure 15: Curve of Tensile Stress against Tensile Strain of Mild Steel

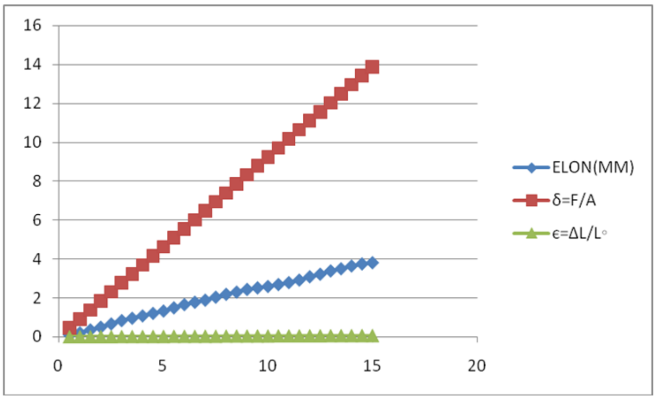

Figure 16: Curve of Tensile Strain against Load of Mild Steel

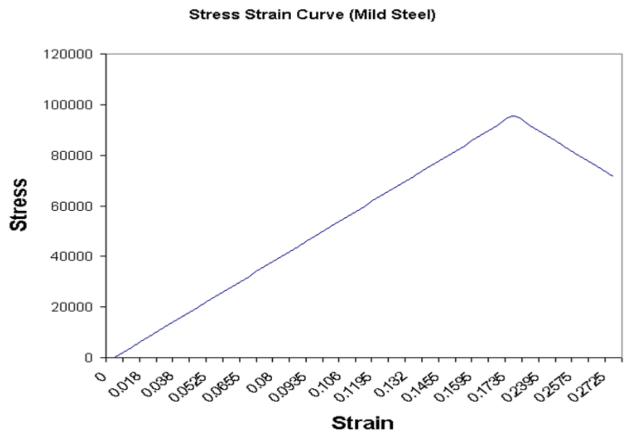

Figure 17: Stress strain curve (Mild steel)

VI. REFERENCES

[1] Nandi, S., Toliyat, H. A.: Condition monitoring and fault diagnosis of electrical machines - a review; 35th IEEE-IAS Annual Meeting, 1999, vol. 1, pp. 197-204.

[2] Kastha, D.; Bose, B. K.: Investigation of Fault Modes of Voltage-Fed Inverter Systems for Induction Motor Drives; IEEE Transactions on Industry Applications, Vol. 30, No. 4, 1994, pp. 1028-1038.

[3] Peuget, Raphael; Courtine, Stéphane; Rognon, Jean- Pierre: Fault Detection and Isolation on a PWM Inverter by Knowledge-Based Model; IEEE Transactions on Industry Applications, Vol. 34, No. 6, 1998, pp. 1318 – 1325.

[4] Zhang, L.; Aris, I. B.; Hulley, L. N.: A Knowledge- Based System for On-Line Fault Diagnosis of Power Inverter Circuits for AC Machines; European Power Electronics Conference, Sevilla, 1995, pp. 3.334-3.339.

[5] Debebe, K.; Rajagopalan, V.; Sankar, T. S.: Expert Systems for Fault Diagnosis of VSI Fed Drives; IEEE Conference on Industry Applications, 1991, pp. 368- 373.

[6] Chrzan, P. J.; Szczesny, R.: Fault Diagnosis of Voltage- Fed Inverter for Induction Motor Drive; IEEE International Symposium on Industrial Electronics ISIE, 1996, pp. 1011-1016.

[7] Peuget, R.; Courtine, S.; Rognon, J. P.: Fault Diagnosis in DC/DC Converters Using Fault Tree Analysis; IEEE Int. Symp. Diagnostics for Electrical Machines, Power Electronics and Drives, 1997, Carry-le Rouet, France, 1997, pp. 132-139.

[8] Lahyani, A.; Venet, P.; Grellet, G.,; Viverge, P.-J-: Failure Prediction of Electrolytic Capacitors During Operation of Switchmode Power Supply; IEEE Trans. Power Electronics, Vol. 13, No. 6, 1998, pp. 1199-1206.

[9] Thorsen, O.V.; Dalva, M.: A Survey of the Reliability with an Analysis of Faults on Variable Frequency Drives in the Industry; European Conference on Power Electronics and Applications, Sevilla, 1995, pp. 1.033- 1.038.

[10] Kral, C.; Kafka, K.: Power Electronics Monitoring for a Controlled Voltage Source Inverter Drive with Induction Machines; Proceedings IEEE Power Electronics Specialists Conference, 2000.

[11] Mendes, A. M. S.; Marques Cardoso A. J.: Fault Diagnosis in a Rectifier-Inverter System Used in Variable Speed AC Drives, by the Average Current Park´s Vector Approach; European Power Electronics Confrence, Lausanne, 1999, pp. 1-9.

[12] Ribeiro, R. L. A.; Jacobina, C. B.; da Silva, E. R. C.; Lima, A. M. N.: Fault Detection in Voltage-Fed PWM Motor Drive Systems, IEEE IAS Annual Meeting, 2000.

[13] Szczesny, R.; Piquet, H.; Kurzynski, P.: Fault Detection and Diagnosis in the Electric Drives; European Conference on Power Electronics and Applications, Trondheim, 1997, pp. 2.995-2.1000.

[14] Raison, Bertand; Rostaing, Gilles; Rognon, Jean-Pierre: Towards a Global Monitoring Scheme for Induction Motor Drives; International Power Electronics Conference, Tokio, 2000, pp. 1183-1188.

[15] Marques Cardoso, A. J.; Mendes, A. M. S.: On-Line Diagnostics of Three-Phase Diode Rectifiers,

by Park´s Vector Approach; International Conference on Electrical Machines, 1996, pp. 433-438.

[16] Mendes, A. M. S.; Marques Cardoso A. J.: Fault Diagnosis in a Rectifier-Inverter System Used in Variable Speed AC Drives, by the Average Current Park´s Vector Approach; European Conference on Power Electronics and Applications, Lausanne, 1999, pp. 1-9.

[17] Strobl, Bernhard: A Diagnostic System for Asymmetries in Bridge Converters; Power Electronics and Motion Conference, Kosice, 2000, 2.160-2.164.

[18] Filippetti, F.; Franceschini, G.; Tassoni, C.: Integrated Diagnostic System for Failure Identification in Power Converters; European Conference on Power Electronics and Applications, Sevilla, 1995, pp. 3.270-3.274.

[19] Kastha, Debaprasad; Majumandar, Asim Kumar: An Improved Starting Strategy for Voltage-Source Inverter Fed Three Phase Induction Motor Drives Under Inverter Fault conditions; IEEE Trans. Power Electronics Vol. 15, No. 4, July 2000, pp. 726-732.

[20] Khasta, Debaprasad; Bose, Bimal K.: Fault Mode Single- Phase Operation of a Variable Frequency Induction Motor Drive and Improvement of Pulsating Torque Characteristics; IEEE Trans. Ind. Electronics, Vol. 41, No. 4, Aug. 1994, pp. 426-433.

[21] Venet, P.; Kahyani, A.; Grellt, G.; Ah-Jaco, A.: Influence of Aging on Electrolytic Capacitors Function in Static Converters: Fault Prediction Method; The European Physics, Journal of Applied Physics, Vol. 5, 1999, pp. 71-83.

[22] Lahyani, A.; Venet, P.; Grellet, G.: Desgn of Processing System for State Diagnosis of Electrolytic Capacitors; EPE Journal Vol. 11, No. 1, February 2001, pp. 19-24.

[23] L.R. Higgins, "Maintenance Engineering Handbook," McGraw-Hill Book company, New York,USA,pp.22-35,1995

[24] J. M. Moubray," Maintenance management: A New Paradigm, Strategic Technologies," Inc., Aladon Ltd,UK,pp.7-11,2006

[25] E. A. Ogbonnaya, "Modelling Vibration-Basic Faults in Rotor Shaft of a Gas Turbine ," PhD Thesis, Department of Marine Engineering, Rivers state University of Science and Technology, Port - Harcout, Nigeria, p.251,2004

[26] W.P.P. Ralph,"Maintenance Management and Control," in Handbook of Industrial Engineering: Technology and Operation Management, 3rd Ed., Inc. New York, USA, pp. 1611-1615, 2001

[27] C. I. Ugechi,"Condition-Based Diagnostic Approach for Predicting the Maintenance Requirement of Machinery Engineering Journal 1, pp 177-187,2009

[28] Olagoke S.A (1999), Properties of materials, first edition Ibadan, S.A.O Multi ventures

[29] L.R. Higgins (1983), Engineering Metallurgy; Part 1: Applied Physical Metallurgy, Fifth Edition, London, Edward ARNOLD

[30] Ashby et al (1984), Engineering Materials, An Introduction to their Properties and Application, First Edition Oxford, Pergamon Press

[31] Callister(Jr) (1987), Materials Science and Engineering; An Introduction; Forth Edition, New York, John Wiley and Sons

[32] Beer and Johnson (1987), Mechanisms of Materials, S.I Metric Edition, Singapore McGraw-Hill Book co.

[33] Hajral Chondhury (1977), Material Science and Processes; Dehili, Indian book Distribution co.

[34] Dillamre,I.L (1972).Material Properties for Sheet Formability. Corporate Laboratory Report MG/16/72.British Steel Corporation, London