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ASSESSMENT OF MECHANICAL PROPERTIES OF MILD STEEL DRAWN USING VEGETABLE FATTY-BASED OILS AS LUBRICANTS

A. M. JUMARE, S. Y. AKU, F. O. ANAFI AND R. B. O. SULEIMAN

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ABSTRACT

A comparative assessment of the Mechanical Properties (Yield Stress, Yield Strain, Ultimate Stress, Breaking Stress, Breaking Strain, Percentage Elongation and Percentage Reduction in Area) of Mild Steel wires drawn using standard (Sodium Stearate Solution) and three Vegetable fatty oils (Palm Oil, Cotton Seed Oil and Shear Butter) was carried out. The results show that the Vegetable fatty oils produced wires with higher strain-hardening than those of the standard lubricant but with the same ductility and malleability. It also shows that Palm Oil is the best lubricant among the three Vegetable fatty oils considered.

Significance

Mild steel is the most common metal used in any production process and lubrication is a very important aspect of any forming process. Fatty based oils are usually used as lubricants in this process. The work looks at the effects of vegetable fatty oils, as lubricants, on the mechanical properties of mild steel.

KEYWORDS: Mild Steel, Sodium Stearate Solution, Cotton Seed Oil, Shear Butter, Yield Stress.

1.0 INTRODUCTION

In a metal forming operation, lubricants provide lubricity, cooling and corrosion protection (Canter, 2008). The lubricant performs a very important role and many operations cannot be efficiently carried out without the correct type of lubricant (Wright et al, 2000). It is important that the type of lubricant and its composition be chosen to suit the metal being formed and the condition of the forming operation. It is also necessary that the point of application of the fluid be carefully chosen and the rate of flow is sufficient and uniform.

Popular among the essential lubricants in metal forming operations are fatty oils, which are long chained polar substances with one or more chemically active polar group at one end. Both the chemical and physical properties of these oils are determined by their fatty acid radicals which may contain some saturated (unreactive) and unsaturated (reactive) acids (Sharma et al, 1967; Morton, 1958).

The main interest of this investigation is to study the effect of lubricants on the mechanical properties of drawn wires and the suitability of various vegetable fatty-oils as lubricants in wire drawing. The material under investigation is mild steel and the vegetable fatty oils considered were palm oil, cotton seed oil and shear butter.

2.0 BACKGROUND

Previous studies by Mital and Dove (1977) and Ajala (1981) revealed that the saturated fatty acid contents of the vegetable oils are myristic, palmistic, stearic, capritic, lauric, arachidic, beharic and lignoceric acids. While the unsaturated fatty acids present in the oils are oleic and linoleci acids.

Fatty acids have outstanding effectiveness as boundary lubricants. This is due to the chemical reaction which takes place between the polar head of the acid molecules and the surface with which they come into contact. The reaction produces a soap film, which is chemically bound to the metal. This film of lubricant, which is sufficiently thick, is often maintained to separate the surfaces completely (Rowe, 1968). Bowden et al (1986) reported that the lubricating property of a fatty acid depends largely on the chemical reactivity of the metal to which it is applied. Lubrication during the wire drawing process is a vital and complex part of the operation. Non ferrous materials, apart from exotic metals are drawn with soap solution Jumare et al (2008).

The variables affecting lubricant selection are:

a. The type of metal on which the lubricant is to be used.
b. The reduction in area.
c. Machine design and performance.
d. Requirement of subsequent process.

The effectiveness of the fatty acids as boundary lubricants is outstanding. This is due to chemical reaction which takes place between the polar head of the acid molecules and the surface with which they came into contact. The reaction produces a soap film which is chemically bound to the metal. This film of lubricant which is sufficiently thick is often maintained to separate the surfaces completely (Rowe, 1968). According to Bowden el al (1986) the lubricating property of fatty acid depends on the chemical reactivity of the metal to which it is applied.

The vegetable fatty oils used for this work contain polar compounds in the form of saturated and unsaturated fatty acids. The saturated fatty acid contents of these oils are myristic, palmitic and stearic acids (Appendix

A. M. Jumare, Department of Mechanical Engineering, Ahmadu Bello University Zaria, Nigeria
S. Y. Aku, Department of Mechanical Engineering, Ahmadu Bello University Zaria, Nigeria
F. O. Anafi, Department of Mechanical Engineering, Ahmadu Bello University Zaria, Nigeria
R. B. O. Suleiman, Department of Mechanical Engineering, Ahmadu Bello University Zaria, Nigeria

II).These acids contain the polar carboxylic group at one end which favours their attachment to the surfaces of the interior of the die and the wire being drawn. By virtue of the polarity of the carboxylic end, the acids are preferentially absorbed on the drawing wire and the interior surfaces, forming a thin lubricating film, thus preventing metal-to-metal contact at the die interior-drawing wire interfaces, thus reducing friction and heat (Agwandas, 1997).

The lubricating efficiency of the oils increases with increasing chain lengths of the constituent compounds. Shaw (2004) observed a general decrease in coefficient of friction with increasing chain length. Thus, for example, stearic acid with 18 carbon atoms per molecule prevents metal-to-metal contact more than palmitic acid with 16 carbon atoms per molecule, which in turn is better than myristic acid having 14 carbon atoms per molecule etc.

3.0 EXPERIMENTAL PROCEDURE

The vegetable fatty oils (palm oil, cotton seed oil and shear butter) used were obtained from the local market in Zaria-Nigeria. The standard lubricant (sodium stearate solution) used was obtained from the National Institute for Chemical Technology (NARICT), Zaria-Nigeria.

Two different experiments were conducted using a total of 24 mild steel rods of length 250mm and 4.60mm diameter.

The experiments were conducted in the strength of materials laboratory of the Department of Mechanical Engineering, Ahmadu Bello University Zaria, Nigeria.

3.1 The Cold Wire Drawing Exercise

Six dies were designed and produced for the wire drawing process, having geometries shown in table 1.

Table 1: Die geometries.

Die No.	Die Reduction (%)	Die Angle (Degrees)
1.	16.64	20
2.	12.62	20
3.	8.51	20
4.	8.51	12
5.	4.30	16
6.	4.30	8

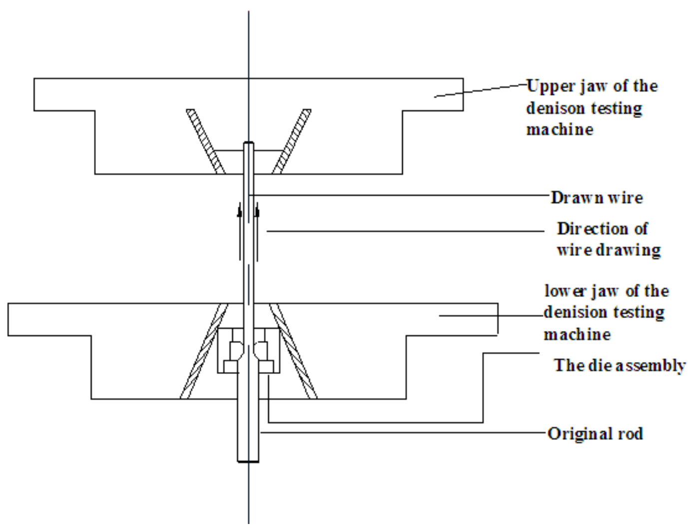

Figure 1: Wire Drawing Process

The wire drawing process was carried-out on the 500kN Universal testing machine. Tool steel was used for the production of the wire drawing dies with the following composition: 3.80%Ni, 0.35%C, 1.70%Cr and 0.3%Mo. The mechanical properties of the tool steel are: Ultimate Tensile Stress = 1850MN/m^2, Elastic Limit = 1400MN/m^2, Percentage Elongation (5d) = 8%, Brinell Hardness number =269.

Before drawing, the rods were cleaned using emery cloth. Also one end of the mild steel rods was chamfered for effective clamping. The die assembly was clamped to the lower end jaws of the Denison testing machine and the upper jaws clamped to the chamfered rod. After clamping the lubricant was applied to the rod and the machine was turned on, then the load was applied to start the drawing process. At the end of the drawing process the machine was turned off and another rod was inserted and set for the next drawing. Four wires for each die were produced, using one of the four lubricants for each wire. The die assembly is as shown in figure 1.

3.2 Tensile Test to Destruction

A test piece of length of 26mm was cut from each wire and the ends of the test pieces were made square and smooth using a smooth file. Each test piece was mounted on the Hounsfield Tensometer using the two jaws of the machine. The autographic recording drum of the machine was covered with a graph sheet and inserted back to the machine. The scale of extension versus distance of the drum travel was recorded before mounting of the test piece.

The pointer was initially set at the origin of the graph sheet and the mercury level was set to zero. Then load was applied to the test piece using the handle. The load-extension diagram was traced out by following the mercury column with the sliding arm and depressing it to mark the graph sheet at regular intervals.

The gauges of percentage elongation and percentage reduction in area were set to zero before the test piece was mounted on the Hounsfield tensometer. After the tests to destruction the broken test pieces were removed from the jaws of the machine, placed in the set gauges and the percentages of elongation and reduction in area were read and recorded. The same procedure was carried out for all the test pieces.

The load versus extension curves were then corrected to stress-strain curves as indicated in Appendix I.

4.0 RESULTS

The stress – strain curves from the tests are presented in figures 2 to 7. The values for the yield stress, ultimate stress, breaking stress and corresponding strains were obtained respectively from these graphs and are presented in Tables 2 to 7.

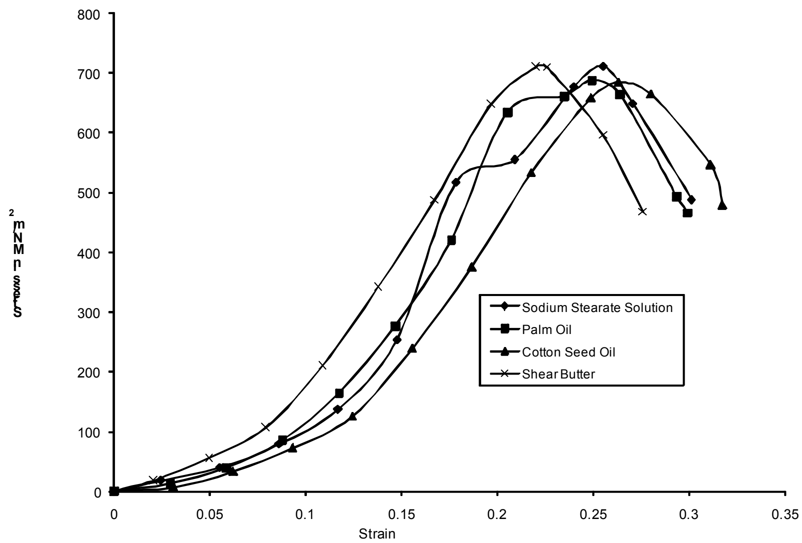

Fig. 2 : Stress - Strain graphs of Mild Steel wires produced using die of 16.64% reduction with 20° die angle.

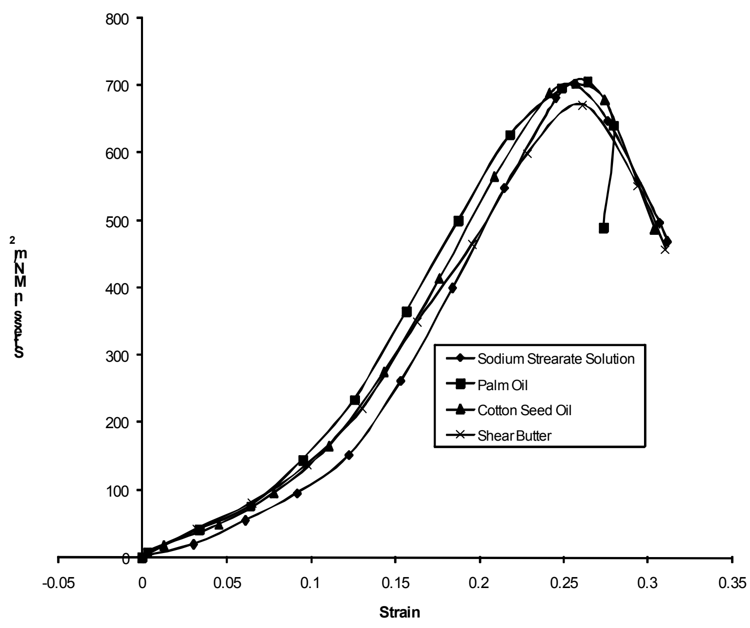

Fig. 3 : Stress - Strain graphs of Mild Steel wires produced using die of 12.62% reduction with 20° die angle.

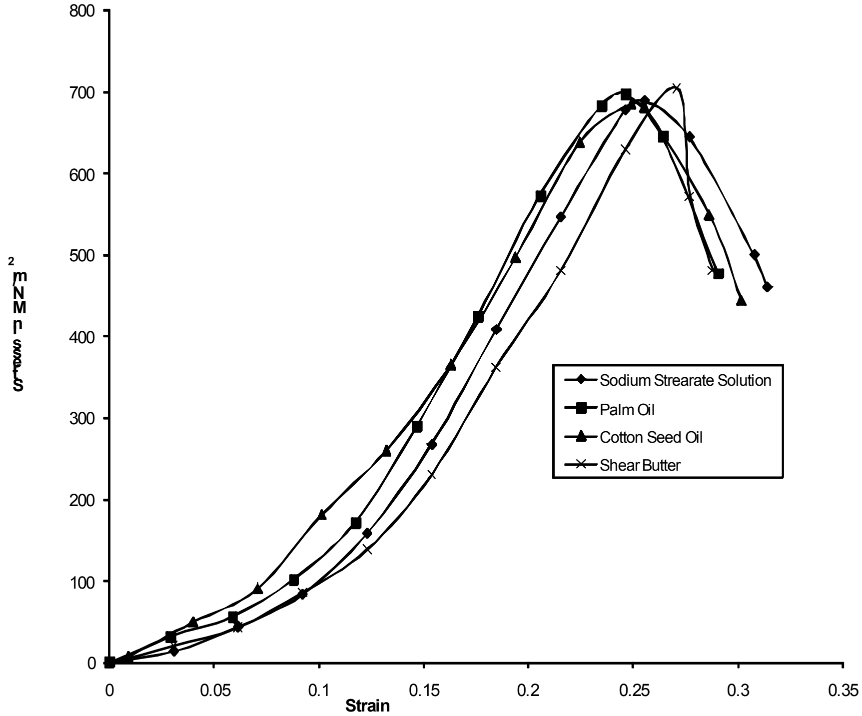

Fig. 5 : Stress - Strain graphs of Mild Steel wires produced using die of 8.51% reduction with 8° die angle.

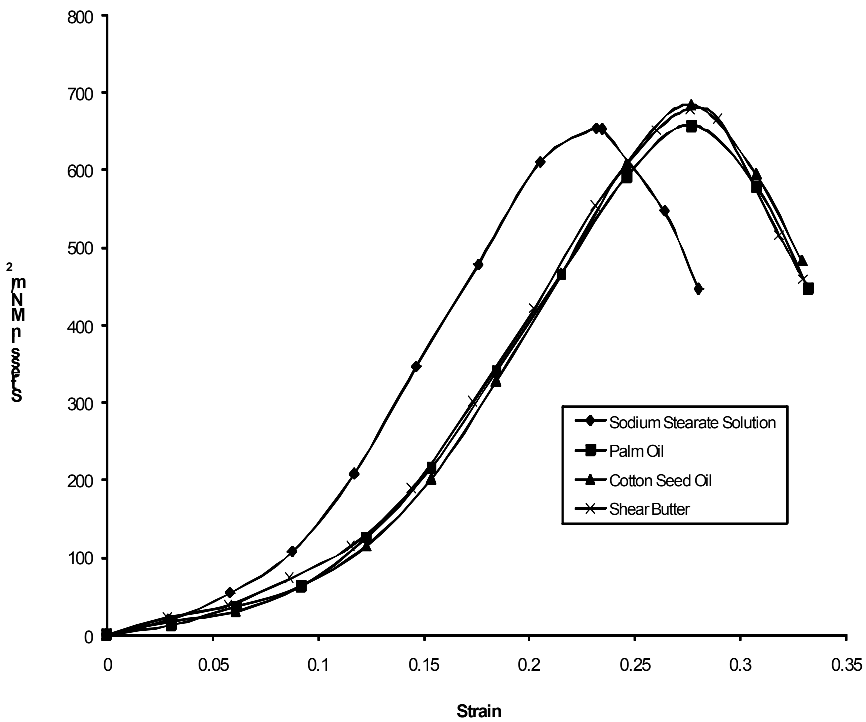

Fig. 6 : Stress - Strain graphs of Mild Steel wires produced using die of 4.3% reduction with 16° die angle.

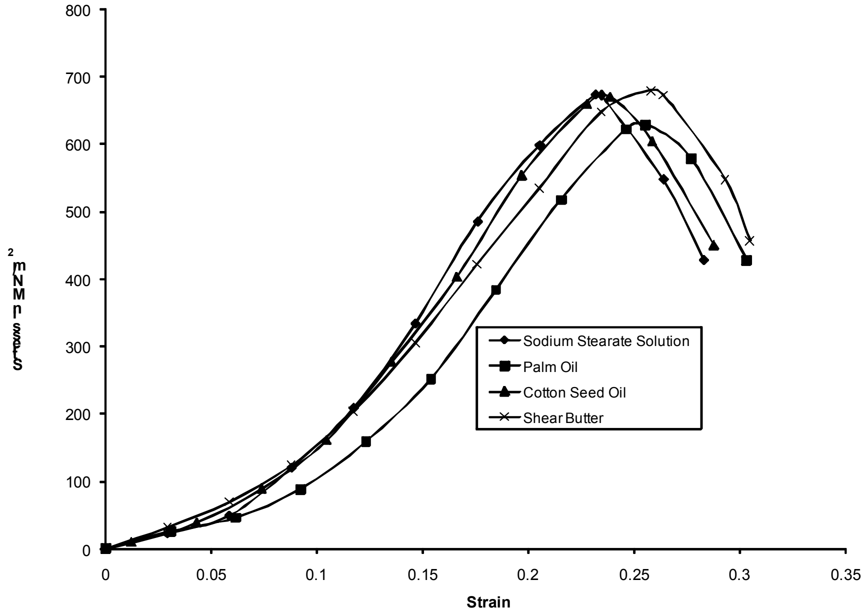

Fig. 7 : Stress - Strain graphs of Mild Steel wires produced using die of 4.3 % reduction with 8° die angle.

Table 2 Mild steel wires of 16.64% Reduction with 20° Die Angle.

Lubricant	Yield		Ultimate	Breaking	
	Stress (MN/m^2)	Strain	Stress (MN/m^2)	Stress (MN/m^2)	Strain
Sodium Stearate Soln.	524	0.1950	736	1106.7	0.2911
Palm Oil	588	0.2000	736	1071.1	0.2831
Cotton Seed Oil	480	0.2000	750	1077.9	0.3077
Shear Butter	632	0.2400	716	980.0	0.3142

Table 3 Mild Steel wires of 12.62% Reduction with 20° Die Angle.

Lubricant	Yield		Ultimate	Breaking	
	Stress in (MN/m^2)	Strain	Stress (MN/m^2)	Stress (MN/m^2)	Strain
Sodium Stearate Soln.	580	0.2200	702	1202.2	0.3015
Palm Oil	554	0.2000	706	1086.7	0.2992
Cotton Seed Oil	568	0.2100	702	1076.5	0.3174
Shear Butter	598	0.2275	671	936.0	0.2758

Table 4 Mild Steel wires of 8.51% Reduction with 20° Die Angle.

Lubricant	Yield		Ultimate	Breaking	
	Stress (MN/m^2)	Strain	Stress (MN/m^2)	Stress (MN/m^2)	Strain
Sodium Stearate Soln.	548	0.2150	688	1022.2	0.3139
Palm Oil	548	0.2075	696	1006.3	0.2904
Cotton Seed Oil	600	0.2175	685	986.7	0.3015
Shear Butter	628	0.2450	703	1066.7	0.2877

Table 5 Mild Steel wires of 8.51% Reduction with 12° Die Angle.

Lubricant	Yield		Ultimate	Breaking	
	Stress (MN/m^2)	Strain	Stress (MN/m^2)	Stress (MN/m^2)	Strain
Sodium Stearate Soln.	518	0.1750	710	1023.2	0.3015
Palm Oil	472	0.1850	690	1083.7	0.2992
Cotton Seed Oil	540	0.2200	684	956.0	0.3174
Shear Butter	646	0.1975	710	932.0	0.2758

Table 6 Mild Steel wires of 4.3% Reduction with 16° Die Angle.

Lubricant	Yield		Ultimate	Breaking	
	Stress (MN/m^2)	Strain	Stress (MN/m^2)	Stress (MN/m^2)	Strain
Sodium Stearate Soln.	580	0.2000	654.0	1027.9	0.2802
Palm Oil	544	0.2300	658.0	1049.4	0.3323
Cotton Seed Oil	528	0.2200	684.0	1071.1	0.3292
Shear Butter	554	0.2320	657.5	1017.8	0.3302

Table 7 Mild Steel wires of 4.3% Reduction with 8° Die Angle.

Lubricant	Yield		Ultimate	Breaking	
	Stress (MN/m^2)	Strain	Stress (MN/m^2)	Stress (MN/m^2)	Strain
Sodium Stearate Soln.	556	0.1925	673	1065.0	0.2831
Palm Oil	517	0.2150	629	844.0	0.3031
Cotton Seed Oil	560	0.2000	670	1000.0	0.2877
Shear Butter	648	0.2300	678	1562.5	0.3051

5.0 DISCUSSION OF RESULTS

Since sodium stearate solution is the standard lubricant for wire drawing, a comparison should be made between it and the vegetable fatty oils lubricants used in this work.

The results from the tables 2 to 7 above show that the yield, ultimate and breaking stresses from the vegetable fatty oils (palm oil and cotton seed oil) are lower than those of the standard lubricant (sodium stearate solution). But the percentage elongations and percentage reductions in area (Tables 8 to 13) for the standard lubricant were almost the same with those of the drawn wires for all the dies used. This means that they produced wires of the same ductility and malleability.

Palm oil produced wires with the lowest yield, ultimate and breaking stresses (Tables 2 to12) among the three vegetable fatty oils investigated for most of the six dies used, followed by cotton seed oil and lastly shear butter.

Table 8 Mild Steel Wires of 16.64 Percent Reduction with 20 Degrees Die Angle.

Lubricant	Percentage	
	Elongation	Reduction in Area
Sodium Stearate Soln.	13	55
Palm Oil	10	55
Cotton Seed Oil	9	52.5
Shear Butter	9	50

Table 9 Mild Steel Wires of 12.62 Percent Reduction with 20 Degrees Die Angle.

Lubricant	Percentage	
	Elongation	Reduction in Area
Sodium Stearate Soln.	10	55
Palm Oil	10	55
Cotton Seed Oil	9	57.5
Shear Butter	9	50

Table 10 Mild Steel Wires of 8.51 Percent Reduction with 20 Degrees Die Angle.

Lubricant	Percentage	
	Elongation	Reduction in Area
Sodium Stearate Soln.	10	55
Palm Oil	11	52.5
Cotton Seed Oil	10	55
Shear Butter	10	55

Table 11 Mild Steel Wires of 8.51Percent Reduction with 12 Degrees Die Angle.

Lubricant	Percentage	
	Elongation	Reduction in Area
Sodium Stearate Soln.	10	52.5
Palm Oil	11	57
Cotton Seed Oil	10.5	50
Shear Butter	11	50

Table 12 Mild Steel Wires of 4.3 Percent Reduction with 16 Degrees Die Angle.

Lubricant	Percentage	
	Elongation	Reduction in Area
Sodium Stearate Soln.	11	57
Palm Oil	10	57.5
Cotton Seed Oil	15	55
Shear Butter	13	55

Table 13 Mild Steel Wires of 4.3 Percent Reduction with 8 Degrees Die Angle.

Lubricant	Percentage	
	Elongation	Reduction in Area
Sodium Stearate Soln.	11	60
Palm Oil	10	50
Cotton Seed Oil	10	55
Shear Butter	11	57.5

6.0 CONCLUSION

For the investigations carried out, the vegetable fatty oils perform better than sodium stearate solution (standard lubricant) while the ductility and malleability of the wires produced using local fatty oils, as lubricant and sodium stearate solution (standard lubricant) remain the same.

In drawing mild steel the lubricant performance (in order of the best first) is palm oil followed by cotton seed oil and then shear butter.

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APPENDIX I

A sample of how the correction of load Vs extension curve is made.

The extension indicated on the autographic diagram includes many other movements besides the extension of the gauge length of the specimen (e.g. movement of the beam and that due to flexibility of the frame). The additional movements may be represented by recording a trace for a rigid member. Thus a corrected diagram of load versus extension may be obtained, as shown in figure 8 below, by subtracting movements recorded for the rigid member from those recorded for the specimen.

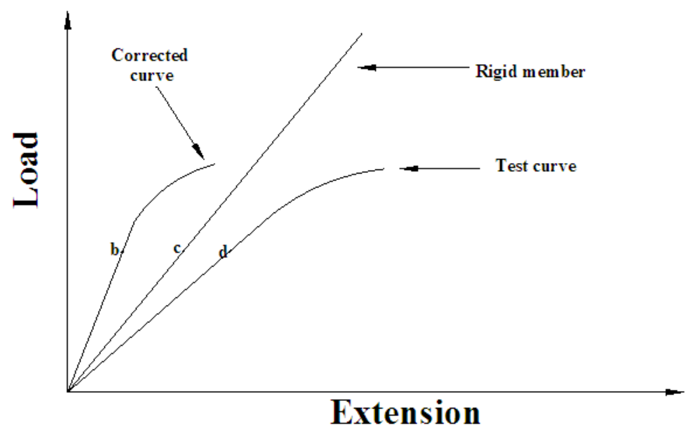

Figure 8: Load Vs Extension curve

Appendix II

Chemical composition of Some Vegetable Fatty Oils

Fatty Acids	Percentages of Fatty Acids in the Various Oils			
	Chain Length	Cotton Seed Oil	Palm Oil	Shear Butter
Myristic	14.0	1.0	1.0	---
Palmistic	16.0	21.5	48.0	8.0
Stearic	18.0	2.0	4.0	35.0
Oleic	18.0	24	38.0	49.0
Linoleic	18.0	46	9.0	4.0

(Source Ajala, 1981).

Appendix III

Iodine Value of the Vegetable Fatty Oils.

Lubricant	Iodine valve
Palm Oil	64.5
Cotton Seed Oil	111.15
Shear Butter	68.2 - 687

(Source: Ajala, 1981)