KINETICS STUDY ON CORROSION INHIBITION EFFECTS OF CASTOR SEED OIL ON MILDSTEEL PIPE

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Abstract: In this research work, the kinetics of corrosion inhibition effects of castor seed oil on mildsteel pipe was studied. This was in the bid to appreciate the significance of kinetic energy in the corrosion process. Corrosion inhibition assessment of the mildsteel material by the Castor Seed Oil (CSO) sample was conducted for varying dosages (of 50, 60 and 70% Strokes) per unit time at different concentrations (of 10, 15 and 20g/L), temperatures (of 40, 50 and 60°C) within specified times (of 4, 8, 16, 24 and 32hours). Kinetics study was conducted to evaluate the values of the kinetic parameters. The first order kinetic rate constant (k_1) was found to have all positive values, indicating that there is a continuous need for kinetic energy during the corrosion process. Also, the half life ($t_{1/2}$) values generally increases down the table, in the direction of increase in dozing rate. This suggests that higher strokes, per unit time, entering the system generate greater kinetic energy through greater (persistent) intermolecular bombardment of the fluid molecules. The values of coefficient of determination (R^2) range from 0.7762-0.9854; this implies pa good data fit to the plots. However, the general trend in the values of the kinetic parameters (k and $t_{1/2}$) shows that corrosion rate increases with increase in the inhibitor concentration.

Keywords: Kinetics, Corrosion Inhibition Effect, Castor Seed Oil, Mildsteel Pipe.
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INTRODUCTION

Castor oil is a vegetable oil obtained by pressing the seeds of the castor oil plant. The oil is a colourless-to-very pale yellow liquid, with a distinct taste and odour once first digested. It is a triglyceride in which approximately 90 percent of fatty acid chains are ricinoleates. It is a monounsaturated, 18-carbon fatty acid. Among all the fatty acids, ricinoleic acid is unusual, in the sense that it has a hydroxyl functional group on the 12th carbon atom. This functional group causes ricinoleic acid (and castor oil) to be more polar than most fats. The chemical reactivity of the alcohol group also allows chemical derivations that are not possible with most other seed oils. Because of its ricinoleic acid content, castor oil is a valuable chemical in feedstock, commanding a higher price than other seed oils. Even half a century ago, castor oil was a stuff of *nightmares* for many children, and there were sufficient reasons for this: it was extensively used as a purgative, and most peculiarly, as a medicine for almost all ailments in both children and adults. The idea behind such a treatment was that malfunctions in the stomach were the root of all other diseases/problems. So, whenever such problem arises, there is need for a thorough cleansing of the digestive system. (Boel *et al*, 2009).

Castor seed oil has a number of benefits to humanity, but these benefits are significantly felt through its health and industrial usages. The benefits, as respectively documented by Wilson *et al* (1998) and Mohammed *et al* (2015), are seen in areas of medicine and pharmaceuticals, food preservation, precursor to industrial chemicals, lubrication, and more recently, in surface coatings.

As bio-based polyol in the polyurethane industry, the average functionality (number of hydroxyl groups per triglyceride molecule) of castor oil is 2.7; so it is widely used as rigid polyol and coating (Thomas, 2011). Also, castor oil is not a drying oil, meaning that it has a low reactivity towards air, compared to other oils (such as linseed and tung oils). Dehydration of castor oil gives linoleic acids, which have drying properties (Thomas, 2011; Mutlu and Meier, 2010).

MATERIALS AND METHOD

Corrosion Inhibition Assessment

Corrosion inhibition assessment of the mildsteel material by the Castor Seed Oil (CSO) sample was conducted at varying dosages (of *50, 60 and 70 Strokes*) per unit time, using weight loss analysis. Both ends of the mildsteel pipe, of initial weight, W_1, were connected to the corresponding points of a fitting hose, connected to a dozing pump. The hose is held firmly in position by means retort stand. Another hose connects the outlet of the dozing pump back to a plastic reservoir (recycle stream), from where 10g/L inhibitor (Castor Seed Oil, CSO) concentration is fed through the mildsteel pipe; the reservoir was firmly immersed in a thermostat water bath, containing a reasonable quantity of water and set at 40°C. After 4hours of continuous circulation of the CSO-in-acid medium (through the system), the steel pipe was removed, rinsed (with distilled water), dried in an oven and reweighed, to obtain a final weight, W_2. The same procedure was used for the blank. The procedure was repeated at various times of *8, 16, 24 and 32hours* for the varying dosages per unit time, and the weight loss were consequently evaluated and recorded as presented in *Appendix 1*.

Kinetics Study

The kinetics study of the corrosion inhibition reaction was performed, in order to understand the impact of kinetic energy on the fluid activities. In this case, the relationship between negative logarithm of the *Weight Loss* and *Time* of *equation 1*, as specified by Eddy *et al* (2009), was applied.

$$-\log W = \frac{k_1 t}{2.303} \quad (1)$$

The negative logarithm of the weight loss, '*-log W*' was plotted against Time, '*t*' at various dosages per unit time. The slope of each of the graphs is equivalent to the factor: '$k_1/2.303$', as contained in *equation 1*, from which the first-order kinetic rate constant, k_1 was evaluated. Also, the first order kinetic rate constant, as reported by Eddy *et al* (2009) is related with the half life (the time taken for the loaded inhibitor sample to be adsorbed by the material by half) as stated in *equation 2*.

$$t_{1/2} = \frac{0.693}{k_1} \quad (2)$$

Thus, *equation 2* was adopted to evaluate the half life values for the cases under study, haven known the value of k_1; the values of k_1 and the corresponding values of $t_{1/2}$ (for study sample) are presented in *Table 1*.

DISCUSSION

The kinetic plots at 10g/L concentration (40°C) for the various study conditions, with and without inhibitor, are presented in *Figures 1* and *2* respectively; the plots at 15g/L concentration, with and without inhibitor, are respectively presented in *Figures 3* and *4*, while those at 20g/L concentration are presented in Figures 5 and 6 respectively. Also, the consequent kinetic parameters evaluated at various concentrations of *10*, *15* and *20g/L* are presented in *Tables 1*, *2* and *3* respectively.

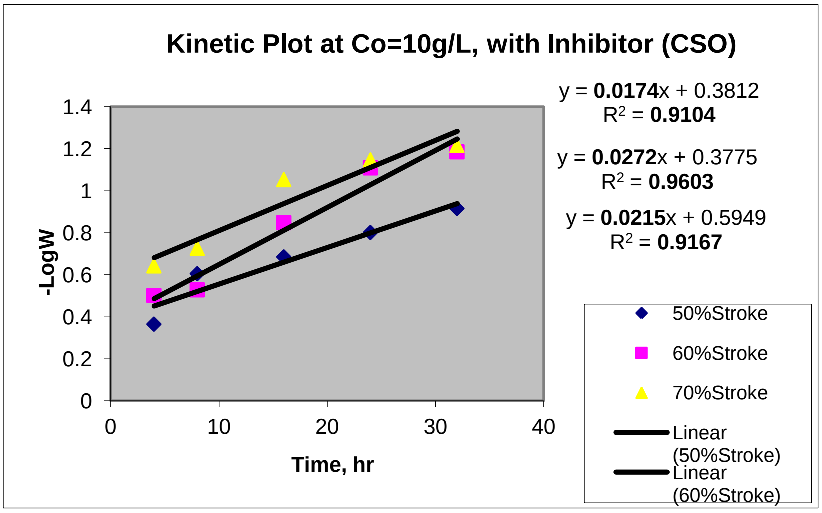

Fig.1: Kinetic Plot at C_o = 10g/L (40°C), with Inhibitor- CSO

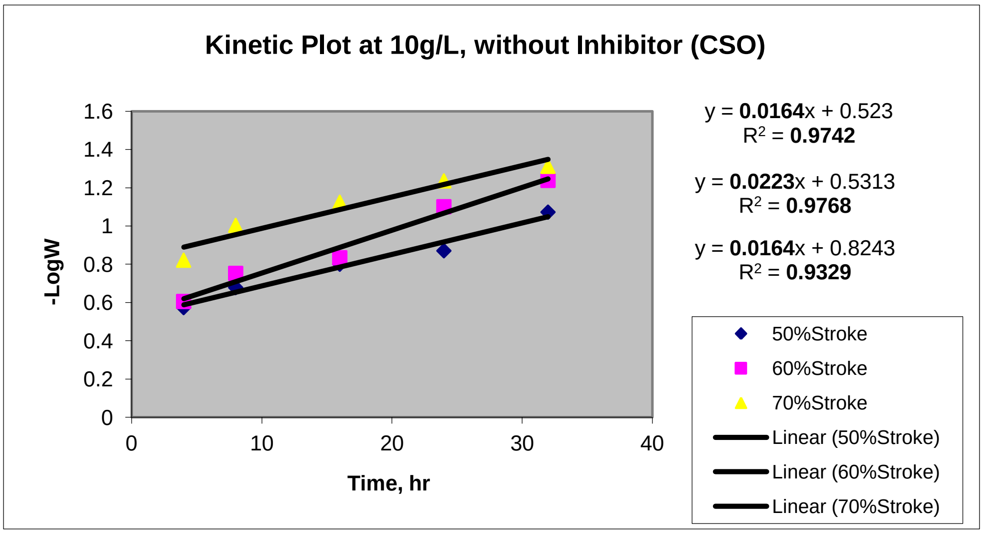

Fig.2: Kinetic Plot at C_o = 10g/L (40°C), without Inhibitor- CSO

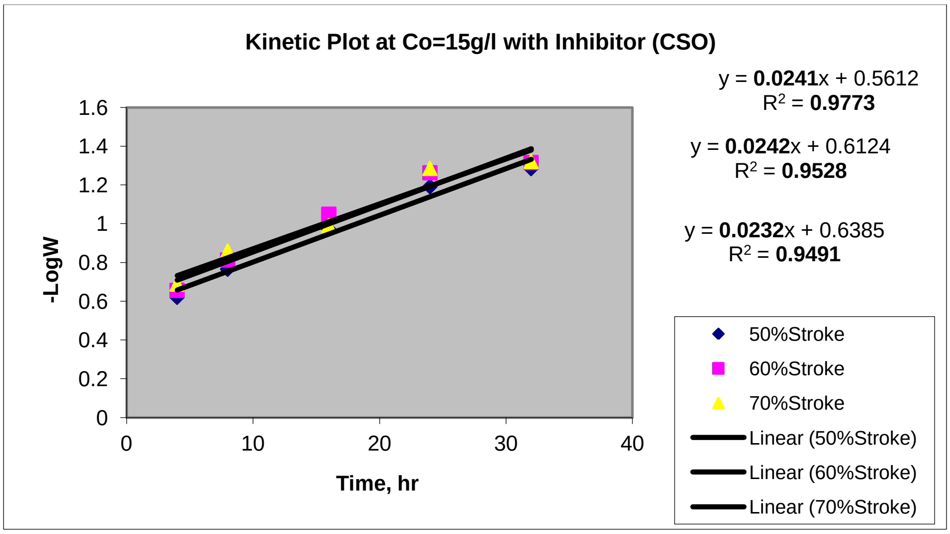

Fig.3: Kinetic Plot at C_o = 15g/L (50°C), with Inhibitor- CSO

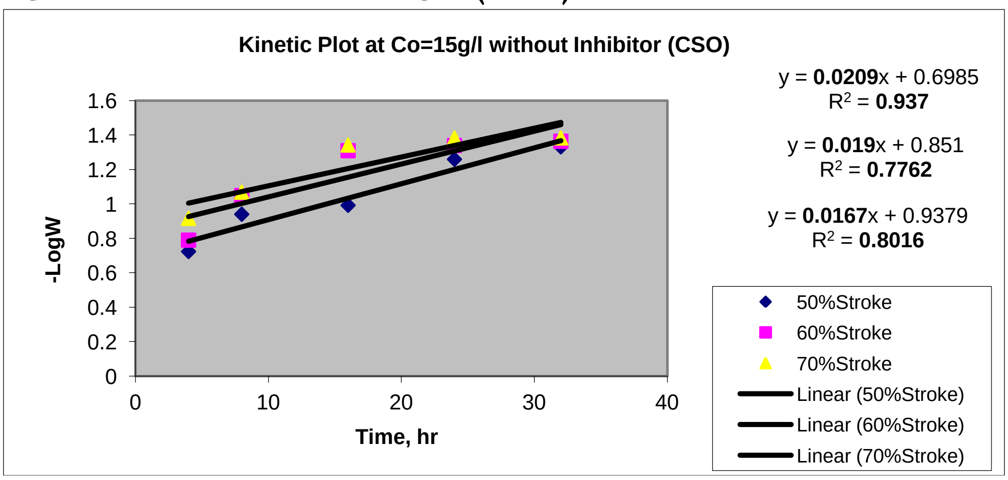

Fig.4: Kinetic Plot at C_o = 15g/L (50°C), without Inhibitor- CSO

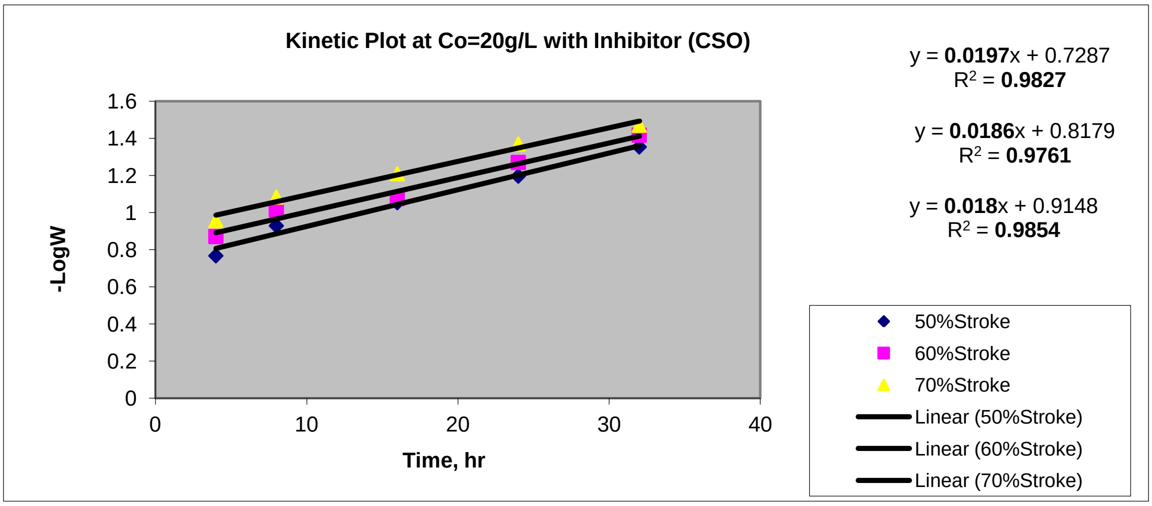

Fig.5: Kinetic Plot at C_o = 20g/L (60°C), with Inhibitor- CSO

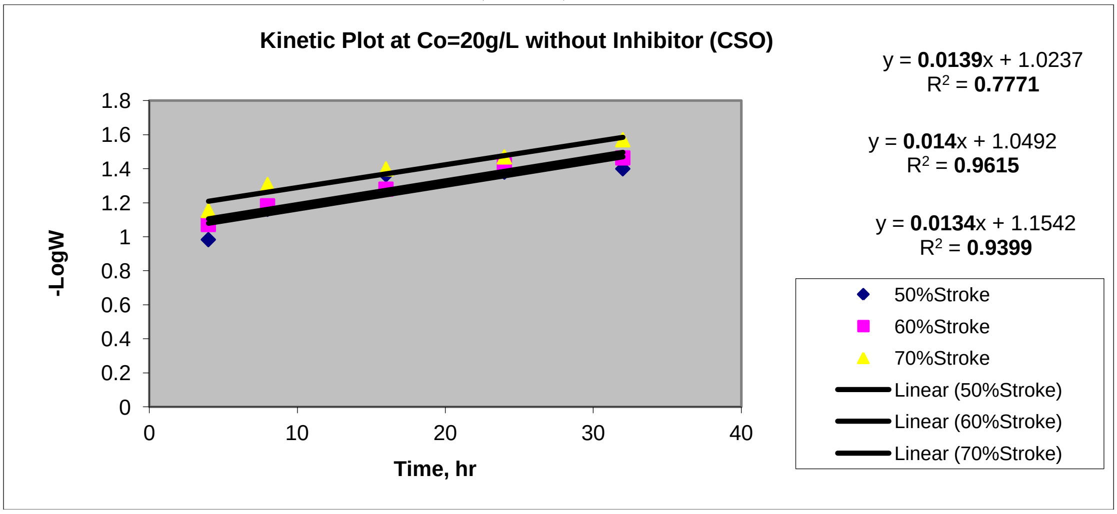

Fig.6: Kinetic Plot at C_o = 20g/L (60°C), without Inhibitor- CSO

Table 1: Kinetic Parameters for CSO at 10g/L (40°C)

Percent Stroke	With Inhibitor			Without Inhibitor		
	K_1	$t_{1/2}$	R^2	K_1	$t_{1/2}$	R^2
50	0.040	17.325	0.9104	0.038	18.237	0.9740
60	0.063	11.000	0.9603	0.051	13.588	0.9768
70	0.050	13.860	0.9167	0.038	18.236	0.9329

Table 2: Kinetic Parameters for CSO at 15g/L (50°C)

Percent Stroke	With Inhibitor			Without Inhibitor		
	K_1	$t_{1/2}$	R^2	K_1	$t_{1/2}$	R^2
50	0.056	12.375	0.9773	0.048	14.438	0.9370
60	0.056	12.375	0.9528	0.044	15.750	0.7762
70	0.053	13.075	0.9491	0.038	18.237	0.8016

Table 3: Kinetic Parameters for CSO at 20g/L (60°C)

Percent Stroke	With Inhibitor			Without Inhibitor		
	K_1	$t_{1/2}$	R^2	K_1	$t_{1/2}$	R^2
50	0.045	15.400	0.9827	0.032	21.656	0.7771
60	0.043	16.116	0.9761	0.032	21.656	0.9615
70	0.041	16.902	0.9854	0.031	22.355	0.9399

The plots of the kinetic study, in *Figures 1-6*, all have positive slopes, indicating a direct proportionality between the rate of corrosion of the material and the time taken for the corrosion reaction to occur. In other words, weight loss (due to corrosion) increases with time in a given corrosion environment (Amadi, 2006). The values of first order kinetic rate constant (k_1) were all positive, indicating that there is a continuous need for kinetic energy during the corrosion reaction. Also, the $t_{1/2}$ values generally increase down the table, in the direction of increase in dozing rate. This suggests that higher pressure strokes, per unit time, entering the system generate greater kinetic energy through greater (persistent) intermolecular bombardment of the fluid molecules. The values of

coefficient of determination (R^2), as presented in *Tables 1-4*, range from *0.7762-0.9854*; these indicate a good data fit to the plot. However, the general trend in the values of the kinetic parameters (k and $t_{1/2}$) shows that corrosion rate increases with increase in the inhibitor concentration.

CONCLUSION

Kinetic study involves the study of the effect of kinetic energy on the molecular activities of a fluid within a given time interval. The corrosion kinetics studied show that the rate of corrosion increases with time, and there is continuous (steady) demand of kinetic energy to overcome the process requirements. The half life increases with increase in dosage per unit time, and the values of coefficient of determination indicate that the plots fitted well with their corresponding data.

Generally, the findings from this study show that the rate of corrosion of a corrodible material increases with increase in inhibitor concentration.

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APPENDIX 1

10g/L at 40°C (50% Stroke)

S/N	Time, *hr*	WITH INHIBITOR		WITHOUT INHIBITOR	
		Weight Loss, *g*	-LogW	Weight Loss, *g*	-LogW
1	4	2.3246	0.3645	3.7453	0.5735
2	8	4.0219	0.6044	4.7664	0.6782
3	16	4.8346	0.6844	6.3128	0.8002
4	24	6.3172	0.8005	7.4217	0.8705
5	32	8.2214	0.9149	11.8161	1.0725

10g/L at 40°C (60% Stroke)

S/N	Time, *hr*	WITH INHIBITOR		WITHOUT INHIBITOR	
		Weight Loss, *g*	-LogW	Weight Loss, *g*	-LogW
1	4	3.1681	0.5008	4.0317	0.6055
2	8	3.3716	0.5278	5.6551	0.7524
3	16	7.0348	0.8473	6.8224	0.8339
4	24	12.8365	1.1082	12.6103	1.1007
5	32	15.3012	1.1847	17.3168	1.2385

10g/L at 40°C (70% Stroke)

S/N	Time, *hr*	WITH INHIBITOR		WITHOUT INHIBITOR	
		Weight Loss, *g*	-LogW	Weight Loss, *g*	-LogW
1	4	4.3813	0.6416	6.6281	0.8214
2	8	5.3106	0.7251	10.0816	1.0035
3	16	11.2753	1.0521	13.3188	1.1245
4	24	13.9926	1.1459	17.2140	1.2359
5	32	16.3827	1.2144	20.5111	1.3120

15g/L at 50°C (50% Stroke)

S/N	Time, *hr*	WITH INHIBITOR		WITHOUT INHIBITOR	
		Weight Loss, *g*	-LogW	Weight Loss, *g*	-LogW
1	4	4.1671	0.6198	5.2993	0.7242
2	8	5.8174	0.7647	8.7232	0.9407
3	16	9.3566	0.9711	9.8341	0.9927
4	24	15.5027	1.1904	18.2005	1.2601
5	32	19.2218	1.2838	21.4840	1.3321

15g/L at 50°C (60% Stroke)

S/N	Time, *hr*	WITH INHIBITOR		WITHOUT INHIBITOR	
		Weight Loss, *g*	-LogW	Weight Loss, *g*	-LogW
1	4	4.5263	0.6557	6.1715	0.7904
2	8	6.4907	0.8123	11.2010	1.0493
3	16	11.1778	1.0484	20.4134	1.3099
4	24	18.2817	1.2620	21.8703	1.3399
5	32	20.6418	1.3147	23.1465	1.3645

15g/L at 50°C (70% Stroke)

S/N	Time, *hr*	WITH INHIBITOR		WITHOUT INHIBITOR	
		Weight Loss, *g*	-LogW	Weight Loss, *g*	-LogW
1	4	4.8694	0.6875	8.2592	0.9169
2	8	7.2153	0.8583	11.7149	1.0687
3	16	9.7629	0.9896	22.0146	1.3427
4	24	19.2471	1.2844	24.1755	1.3834
5	32	20.8918	1.3200	24.2222	1.3842

20g/L at 60°C (at 50% Stroke)

S/N	Time, *hr*	WITH INHIBITOR		WITHOUT INHIBITOR	
		Weight Loss, *g*	-LogW	Weight Loss, *g*	-LogW
1	4	5.8514	0.7673	9.6221	0.9833
2	8	8.4915	0.9290	14.5052	1.1615
3	16	11.3118	1.0535	23.1624	1.3648
4	24	15.7144	1.1963	24.0043	1.3803
5	32	22.5619	1.3534	25.1057	1.3998

20g/L at 60°C (60% Stroke)

S/N	Time, *hr*	WITH INHIBITOR		WITHOUT INHIBITOR	
		Weight Loss, *g*	-LogW	Weight Loss, *g*	-LogW
1	4	7.4317	0.8711	11.8126	1.0723
2	8	10.3484	1.0149	15.2115	1.1822
3	16	11.8996	1.0755	19.0473	1.2798
4	24	18.6218	1.2700	26.4816	1.4229
5	32	26.1153	1.4169	29.0887	1.4637

20g/L at 60°C (70% Stroke)

S/N	Time, *hr*	WITH INHIBITOR		WITHOUT INHIBITOR	
		Weight Loss, *g*	-LogW	Weight Loss, *g*	-LogW
1	4	9.0422	0.9563	14.2647	1.1543
2	8	12.1285	1.0838	20.2776	1.3070
3	16	16.1819	1.2090	25.0618	1.3990
4	24	23.4251	1.3697	29.4751	1.4695
5	32	29.5454	1.4705	37.1825	1.5703

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