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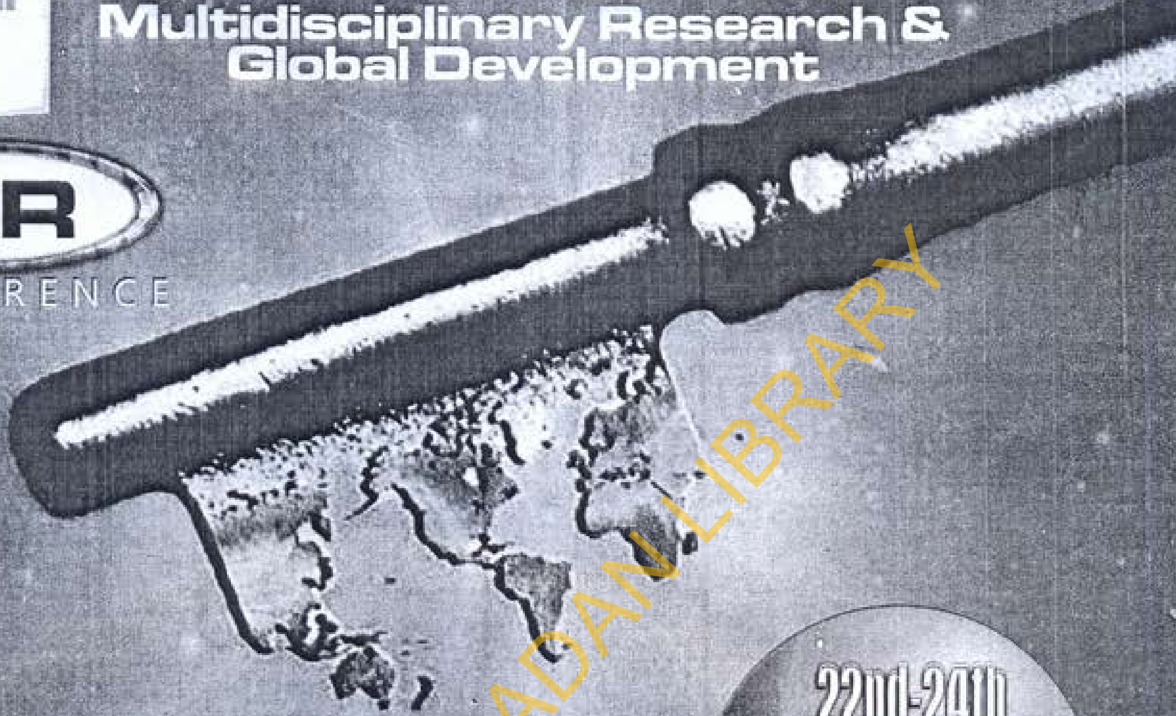

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OPTIMAL PARAMETER IN THE ECONOMIC PIPELINE DISTRIBUTION OF JATROPHA OIL

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Abstract

Due to gradual depletion of world petroleum reserves and the environmental pollution of increasing exhaust emissions, there is an urgent need o develop alternative energy resources, such as biodiesel fuel. One way of reducing the biodiesel production costs is to use the less expensive feedstock containing fatty acids such as inedible oils, animal fats, waste food oil and by products of the refining vegetables oils. The fact that Jatropha oil cannot be used for nutritional purposes without detoxification makes its use as energy or fuel source very attractive as biodiesel. Due to its high flash point, Jatropha oil has certain advantages like greater safety during storage, handling, and transport. However, this may create problems during starting. The viscosity of Jatropha oil is less as compared with other vegetable oils but it is higher than diesel. To lower the viscosity and density of Jatropha oil, preheating is necessary prior to pumping. However, additional costs are incurred through heating and heating cost increases with temperature. This suggests the existence of an optimum temperature to which the fluid can be heated at minimum cost. This work is therefore, a study carried out to determine the optimum heating temperature for a given pipe diameter. The study of fluid flow was carried out and modified to incorporate cost concept to produce a mathematical model that predicts the economic heating temperature. The effect of pipe diameter on these temperatures was investigated via a computer code developed in Matlab 7.3 programming language. The result obtained showed that as the pipe diameter increased from 0.042m to 0.062m, the optimum heating temperature is maintained at 30°C. Results of this nature can be utilized in industries where pumping of Jatropha oil as an alternative fuel is *sine-qua-non*.

Keywords: Jatropha oil, pumping, heating temperature, pipe.

INTRODUCTION

Jatropha belongs to the family Euphorbiaceae. The word Jatropha is derived from two Greek words 'Jatros' meaning doctor and 'trophe', which meansnutrition. Jatropha curcas is a drought-resistant perennial shrub or a small tree. It grows wild in tropical and sub-tropical climatic regions and can be successfully grown in problematic soils and arid regions. It can produce seed for fifty years. Jatropha curcas has a wide range of uses and promise various significant benefits to human and industry. Extracts from this plant have been shown to have anti – tumor activity, the leaves can be used as remedy for malaria and the seed can be used in the treatment of constipation and the sap was found to be effective in accelerating wound healing (1). However, this plant can be used as an ornamental plant, raw material for dye, potential feedstock, pesticides, soil enrichment manure and more importantly as an alternative for biodiesel production. Jatropha produces seeds with oil content of about 33 to 37%. The oil can be combusted as fuel without being refined. It burns with clear smoke-free flame. The methods that are used for the extraction of the oil are oil presses, oil expeller, traditional method and the modern concept, which involves using the method of ultrasonication. The production of this biodiesel from non edible oil will in return reduce the overall dependence on petroleum diesel, thereby saving the environment from hazards. Several research work have been carried out using vegetable oil and animal fats in the production of biodiesel, this have become a great concern because they compete with food material. The use of jatropha oil in the production of biodiesel is justified since this oil is non edible and it can be used in the production of biodiesel which in the long run will reduce the consumption and demand for petroleum products.

Pipeline transportation is one of the most economical means of transportation, which has found applications in the distribution of many industrial fluids. These include oil, water, liquid and gaseous fuels (2-4). Many researchers have reported difficulties encountered with the use of straight vegetable oil in diesel engine. These problems are mainly attributed to high viscosity of vegetable oil. The issue of high viscosity needs to be resolved for its long term utilization in diesel engine. Due to high viscosity, there are two strategies for using Jatropha oil as fuel for use in diesel engine. The first one is to modify the engine to adapt to the fuel and the second one is for processing the fuel to adapt to the engine. The literature suggests that modifying existing diesel engines to preheat Jatropha oil could be first strategy. The second option is modification of Jatropha oil to biodiesel through process of transesterification. Many products of pharmaceutical, chemical and food industries such as syrups, petroleum jelly, fats and oil exhibit laminar flow, characterized with low Reynold's Number (very high viscosity), making pumping under normal temperature a difficult task (5 and 6). If the fluid is heated up prior pumping, the otherwise high frictional losses and hence the overbearing pumping cost resulting from the additional stresses imposed on pumping equipment by these fluids, will be considerably reduced (7). Heating cost however increases, as the fluid is heated up. Therefore, an optimum heating temperature at which the total cost of heating and pumping is minimum must exist. The optimum heating temperatures for pipeline pumping of vegetable oil have been determined (7, 8, 15, and 16). Researchers have developed series of equations governing fluid flow in pipelines, leading to the widely used Scobey equation, Hazen-Williams and Darcy-Weisbach Formula (9-113). In this work, the concept of cost was integrated into theories of laminar fluid flow, to develop a computer program, written in Matlab language, for determination of the economic heating temperature to aid pipeline pumping of jatropha oil. Besides, this work establishes the possible relationship between the optimum heating temperatures and the pipe diameter, using the results from the program at varying internal pipe diameter.

MATERIALS AND METHODS

Analysis of fluid flow theories and cost concept

For flow of any incompressible fluid through a closed conduit, the power delivered to the fluid by the pump is (7):

$$W = P_d m_f / 10^3 \rho \qquad (1)$$

Where: W = pumping power, (kW)

P_d = pump pressure drop, (Nm^{-2})

m_f = mass flow rate, (kgs^{-1})

The total pressure loss along a closed conduit is given, through Darcy-Weisbach formular, as (8):

$$P = \left(\rho u^2 / 2\left[\left(fL / d + \sum k\right)\right]\right) \qquad (2)$$

Where: f = friction factor

L = pipe length, (m)

d = diameter of pipe, (m)

u = linear fluid velocity along the pipeline, (m/s)

For laminar flow (high viscosity), friction factor is given as:

$$f = 16\mathrm{Re}^{-1} \qquad (3)$$

Where: $$\mathrm{Re} = \rho u d / \mu \qquad (4)$$

Re = Reynolds Number (<2100) (11)

Substituting equations (3), (4) and (2) in equation (1), the power developed by the pump becomes:

$$W = \left(m_f u^2 / 2\times10^3\right)\left[16\mu L / \rho u d^2 + \sum k\right] \qquad (5)$$

Using plot of Lewis and Squires, a set of practical data of known temperature values with corresponding viscosities and fluid density for various fluids can be obtained (10). The overall pump efficiency is: (2)

$$\eta = P_2 / P_1 \qquad (6)$$

Where: P_2 = output power of the pump, (W)

P_1 = the pump power input, (W)

Combining equations (5) and (6) the pump power input takes the form:

$$P_1 = \left(m_f u^2 / 2\times10^3 \eta\right)\left[16\mu L / \rho u d^2 + \sum k\right] \qquad (7)$$

While the linear fluid velocity, u, along the pipeline is given as:

$$u = 4m_f / d^2 \rho \qquad (8)$$

Pumping Cost

Let C_e = cost per kWh of electrical energy, (#kWh^{-1})

C_1 = cost of electrical energy needed for pumping (#h^{-1})

C_3 = any other cost associated with pumping, (#h^{-1})

The cost of electrical energy consumed by the pump to generate the power, P_1, can be written as:

$$C_1 = C_e P_1 + C_3 \qquad (9)$$

Cost of Heating

Let Q = quantity of the heat consumed by the fluid, (Js-1)

C = specific heat capacity of the fluid, (Jkg-1K-1)

T_2 = temperature to which the fluid has been heated to ease pumping, (^{0}C)

m_s = mass of steam used in heating the fluid per second, (kgs^{-1})

Table I : Viscosity and Density of Palm oil at different Temperature

L_s =latent heat of vaporization of steam.

C_s = unit cost of steam, (#kg^{-1})

The quantity of heat gained per seconds by the fluid while being heated from the room temperature to the required pumping temperature can be obtained from: (14)

$$Q = m_f C(T_2-T_1) \quad (10)$$

Neglecting heat losses to the surrounding, this quantity of heat is supplied to the fluid from the steam. Hence:

$$Q = m_s L_s \quad (11)$$

The cost of generating steam therefore can be written as:

$$C_h = C_s m_s \quad (12)$$

The total pumping and heating cost is therefore given by the sum of equations (9) and (12) thus;

$$C_p = C_e P_1 + C_3 + C_s m_s \quad (13)$$

Computer Simulation

The analysis of the preceding section was developed into a computer program, written in Matlab language for a quick and precision estimate of the temperature to which highly viscous compressible fluid can be heated at minimum operational cost. The room temperature for the fluid was assumed to 20^0C in the computer code developed. The program was structured in a manner that outputs the heating temperatures, the cost of electrical energy, cost of heating and the total operational cost. The heating temperature corresponding to the minimum point of the total operational cost function would be taking as the optimum.

Validation through a case study

The validity of the program was ascertained using the data of a practical problem involving the flow of vegetable oil pumped along a well-insulated horizontal pipeline (7 and 14). Thus:

L_s=35914.9Jkg^{-1} , L=500m, m_f =1.56kgs^{-1}, m_s=3.54 kgs^{-1}, d =0.042m, C = 1830Jkg^{-1}K^{-1},Number of Valves = 4, Number of bends at 90^0 = 5. For 90^0 elbow K_e = 0.9, for Valve fully opened $K_v = 4.0$, Electric bill C_e = #4.34kWh^{-1}, C_3 = #2.43, C_s = #0.43 and η= 0.6.

Keeping all other parameter constant, the pipe diameter was varied from 0.042m to 0.064m using a step of 0.002, yielding different optimum heating temperatures.

Table1: Viscosity and Density of Jatropha oil at different Temperature

Temperature (Heating) ^{0}C	20.00	30.00	40.00	50.00	60.00	70.00	80.00
Viscosity,μ (Ns/m^2)	0.0350	0.0350	0.0230	0.0180	0.0120	0.0090	0.0060
Density, Kgm^{-3}	910.2	900.1	890.5	885.1	880.2	870.4	865.7

RESULTS AND DISCUSSION

Results from the program are presented (Tables I to XII) and illustrated in the logarithmic chart (Fig.1).For each of the flow rate investigated, increase in the temperature of the fluid leads to increase in the total operational cost but a critical point is observed at 30°C corresponding to a minimum operational cost. Any further increase in temperature above this point is useless and this temperature is therefore taking as the optimum temperature. Results obtained are in good agreement with works of other researcher (4, 7, 15, and 16).

The fluid conduit diameter with the associated heating temperature, are also presented (Fig.1).

Table II: Result of the program for case 1

Diameter of pipe =0.042

HT(0C)	EEC (N)	CGSU(N)	TPC(N)
20	3.6900	0	3.6900
30	3.5404	4.8756	8.4160
40	3.3836	6.5008	9.8844
50	3.1369	8.1260	11.2629
60	2.9217	9.7512	12.6729
70	2.8189	11.3764	14.1953
80	2.7079	13.0016	15.7093

Table III: Result of the program for case 2

Diameter of pipe =0.044

HT(0C)	EEC (N)	CGSU(N)	TPC(N)
20	3.4761	0	3.4761
30	3.3318	4.8756	8.2274
40	3.2217	6.5008	9.7225
50	3.0169	8.1260	11.1429
60	2.8382	9.7512	12.5894
70	2.7529	11.3764	14.1293
80	2.6607	13.0016	15.6623

Table IV: Result of the program for case 3

Diameter of pipe =0.046

HT(0C)	EEC (N)	CGSU(N)	TPC(N)
20	3.3057	0	3.3057
30	3.2017	4.8756	8.0773
40	3.0927	6.5008	9.5935
50	2.9213	8.1260	11.0473
60	2.7717	9.7512	12.5229
70	2.7003	11.3764	14.0767
80	2.6231	13.0016	15.6247

Table V: Result of the program for case4

Diameter of pipe =0.048

HT(0C)	EEC (N)	CGSU(N)	TPC(N)
20	3.1680	0	3.1686
30	3.0809	4.8756	7.9565
40	2.9890	6.5008	9.4898
50	2.8444	8.1260	10.9704
60	2.7182	9.7512	12.4694
70	2.6580	11.3764	14.0344
80	2.5929	13.0016	15.5945

Table VI: Result of the program for case 5

Diameter of pipe =0.050

HT(0C)	EEC (N)	CGSU(N)	TPC(N)
20	3.0573	0	3.0573
30	2.9828	4.8756	7.8584
40	2.9048	6.5008	9.4056
50	2.7819	8.1260	10.9079
60	2.6748	9.7512	12.4260
70	2.6236	11.3764	14.0000
80	2.5683	13.0016	15.5699

Table VII: Result of the program for case 6

Diameter of pipe =0.052

HT(0C)	EEC (N)	CGSU(N)	TPC(N)
20	2.9663	0	2.9663
30	2.9025	4.8756	7.7781
40	2.8358	6.5008	9.3366
50	2.7308	8.1260	10.8568
60	2.6393	9.7512	12.3905
70	2.5955	11.3764	13.9719
80	2.5483	13.0016	15.5499

Table VIII: Result of the program for case 7

Diameter of pipe =0.054

HT(0C)	EEC (N)	CGSU(N)	TPC(N)
20	2.8911	0	2.8911
30	2.8363	4.8756	7.7119
40	2.7790	6.5008	9.2798
50	2.6887	8.1260	10.8147
60	2.6099	9.7512	12.3611
70	2.5723	11.3764	13.9487
80	2.5317	13.0016	15.5333

Table IX: Result of the program for case 8

Diameter of pipe =0.056

HT(0C)	EEC (N)	CGSU(N)	TPC(N)
20	2.8287		2.8287
30	2.7813		7.6569
40	2.7317		9.2325
50	2.6537		10.7797
60	2.5856		12.3368
70	2.5530		13.9294
80	2.5179		15.5195

Table X: Result of the program for case 9

Diameter of pipe =0.058

HT(0C)	EEC (N)	CGSU(N)	TPC(N)
20	2.7765	0	2.7795
30	2.7353	4.8756	7.6109
40	2.6922	6.5008	9.1930
50	2.6244	8.1260	10.7504
60	2.5652	9.7512	12.3164
70	2.5369	11.3764	13.9133
80	2.5064	13.0016	15.5080

Table XI: Result of the program for case 10

Diameter of pipe =0.060

HT(0C)	EEC (N)	CGSU(N)	TPC(N)
20	2.7325	0	2.7325
30	2.6966	4.8756	2.7325
40	2.6590	6.5008	9.1598
50	2.5997	8.1260	10.7257
60	2.5481	9.7512	12.2993
70	2.5234	11.3764	13.8998
80	2.4967	13.0016	15.4983

Table XII: Result of the program for case 11

Diameter of pipe =0.062

HT(0C)	EEC (N)	CGSU(N)	TPC(N)
20	2.6953	0	2.6953
30	2.6638	4.8756	7.5394
40	2.6308	6.5008	9.1316
50	2.5789	8.1260	10.7049
60	2.5335	9.7512	12.2847
70	2.5119	11.3764	13.8883
80	2.4885	13.0016	15.4901

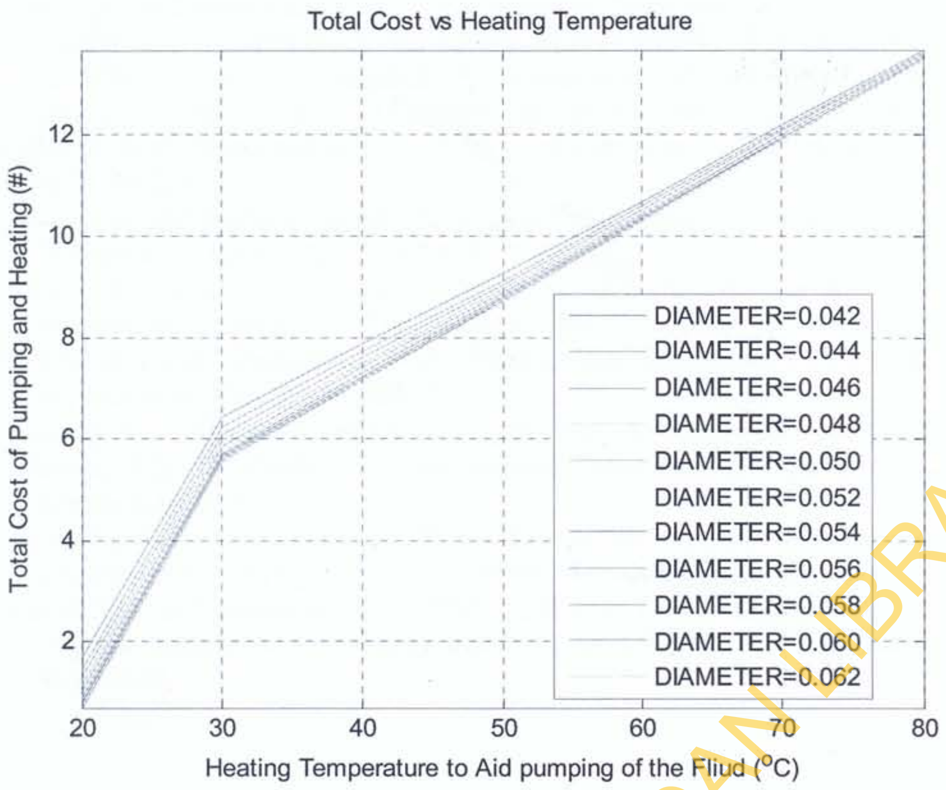

Fig.1: Optimum heating temperature chart for varying pipe size for transportation of Jatropha oil.

Conclusion

Using a computer program developed for the analysis of cost and fluid flow theories optimum heating temperature for economical transportation of Jatropha oil via pipeline was confirmed to exist. This work is in agreement with the work of other researchers (7, 8, 15 and 16).

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