

Title	Feasibility Studies for the Preparation of Secondary Fuel Mixture from Indigenous Coals for Industrial Firing Purpose
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Feasibility Studies for the Preparation of Secondary Fuel Mixture from Indigenous Coals for Industrial Firing Purposes

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Abstract

The present research work is emphasized on exploring alternative uses of low rank indigenous coals, particularly Tigyit coal and Samlaung coal as Secondary Fuel Mixtures (SFM). The characteristics such as moisture, ash, volatile matter, fixed carbon, sulphur contents and calorific value of Tigyit and Samlaung coals were determined. The morphological nature and elemental composition of Tigyit and Samlaung coals were also evaluated based on the monographs of Scanning Electron Microscopy (SEM) method and Energy Dispersive X-Ray Fluorescence (EDXRF) method. The sulphur content of run- of- mine coal was reduced using washing operation The quality of prepared fluid carbon is related to its ingredients, such as, size of coal, amount of water added and nature of stabilizer being used. Among the various laboratory tests available for fluid carbon performance test: settling, specific gravity and viscosity were chosen as basic tools for the present work. An appropriate amount of (-200) mesh size coal to water, 60:40, and stabilizer and initiator would have a viscosity such that it would behave like a truly fluid mixture in the piping system during test-firing. The combustion characteristics of prepared fluid carbon were simulated by two diverse firing systems: improvised static firing in make-shift cylindrical furnace and continuous dispersion / injection system. In the test-firing of prepared fluid carbon by continuous dispersion system, water vapour in the flame catalyses and accelerates the combustion of the carbon residue and exhibited continuous self-sustaining complete combustion.

Key words: Secondary Fuel Mixture, Fluid carbon, Stabilizer, Additives, Pyrolysis

Introduction

Fuels are the principal source of energy for the people in the world. Most fuels are fossil fuels which are coal, or oil, or their derivatives. Coal is clearly the most abundant fossil resource and plays a key role in supplying energy and chemicals. Powdered coal were mixed with the right amount of water, gives off more heat and burns more cleanly than solid fuel. In various countries it is being used intensively as another post-petroleum alternative and as a more economical fuel. That will burn in power stations, industrial boilers, blast furnaces and even in engines for vehicles. Fluid carbon creates less pollution, such as sulphur dioxide, than oil because of coal washing in the tanks of bubbling water.

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Additives exploited the chemistry of coal's surface to create a single layer of molecules around each particle, keeping them apart. The precise amount of additive needed to keep a mixture fluid depends on the size and total surface area of the particles. Fluid carbon is a slurry, consisting essentially of low rank coal, water and additive promoted a hindered settling effect of coal particles and enhanced suspension of fluid carbon. . The aim of this research work was to utilize the low rank indigenous coal as a Secondary Fuel Mixture (SFM) for alternative substitute liquid or gaseous fuels if the need arises and to evaluate the combustion characteristics of prepared Secondary Fuel Mixture.

Materials and Methods

Materials

Tigyit and Samlaung coals were used as raw material for the preparation of secondary fuel mixture. Tigyit coal mine is situated in Pinlong Township, Southern Shan State and Samlaung coal mine is situated in Thipaw Township, Northern Shan State in the Republic of the Union of Myanmar.

Preliminary Preparation of Tigyit and Samlaung Coals

Size Reduction —— Grinding and Screening

Small lumps of coal sample, (1) kg was ground in an Edge Grinder, for (15) minutes which produced reasonably fine coal and then ground coal was screened by 40, 100 and 200 mesh size screens.

Characteristics of Tigyit and Samlaung Coals

The characteristics such as moisture, ash, volatile matter, fixed carbon, sulphur contents and heating values of Tigyit and Samlaung coals were analysed and the results are shown in Tables (1) and (2).

Scanning Electron Microscopy (SEM) Method

The topographical information of Tigyit and Samlaung coals, porosity were determined by SEM (Model, Jeol-JSM-5610) such that their data would be used in determining their respective coal ranks. The monographs of Tigyit and Samlaung coals are shown in Figures (1) and (2).

Coal Washing Operation (Flotation Method)

(1) kg of Tigyit coal sample was mixed with (10) litre of water and the mixture was poured carefully into a cylindrical column (30 cm diameter and 160 cm length). The cleaning of coal was conducted counter currently with air induced from the bottom of the

column and water flowing down by gravity from above and the whole flotation activity in the column carefully examined and weight lost after (10) minutes interval of washing time for (40) minutes duration was recorded in Table (3). In the same manner the cleaning of Samlaung coal was conducted and its results are also recorded in Table (3).

The above washed coal samples (at 10 minutes washing intervals) of Tigyit and Samlaung coals were determined by proximate and ultimate analyses and the results are tabulated in Tables (1) and (2).

Energy Dispersive X-Ray Fluorescence Spectrometry (EDXRF) Method

The elemental composition of Tigyit and Samlaung coals before and after washing were analysed by EDXRF method and their relevant analysis data are shown in Tables (4) and (5).

Preparation of Fluid Carbon (FC)

A (-100) mesh size of washed, dewatered and air-dried Tigyit coal sample, 60% w/w , was mixed with 40 % w/w of water and followed by an addition of 1 % w/w of sodium stearate as additive and stirred with a suitable stirrer for (15) minutes, after which a fluid carbon was obtained.

Characteristics of Prepared Fluid Carbon (FC)

***SettlingTest* (ASTM. D- 244-71)**

Separate (500) ml portions of fluid carbon from Tigyit coal, based on (-100) and (-200) mesh size and the most favorable ratio of coal to water (60:40) and sodium stearate fixed at 1 %, were poured into different (1) liter measuring cylinders and covered with a glass plate and allowed to stand undisturbed at room temperature and observed daily and its settling behavior are recorded in Table (6).

In the same manner, the settling behavior with respect to mesh size of fluid carbon from Samlaung coal was conducted and its results are recorded in Table (6).

Specific Gravity

A suitable measuring cylinder was carefully filled with prepared fluid carbon from Tigyit coal (-100 and -200 mesh size) and placed upright on the table and stirred thoroughly and air bubbles released. About (30) minutes later a hydrometer was immersed carefully into the fluid carbon from Tigyit coal and it sank slightly below the level. It naturally sank and floated freely without the walls of the cylinder being touched. The specific gravity of prepared fluid carbon was directly read from the hydrometer to the third decimal place and the results are recorded in Table (6).

In the same manner, the specific gravity behavior with respect to mesh size for fluid carbon from Samlaung coal was conducted and its results are recorded in Table (6).

Viscosity

A Brookfield viscometer in conjunction with spindle number (3) and (30) rpm were employed for viscosity measurement of each Tigyit coal based fluid carbon, Samlaung coal based fluid carbon and their respective values are recorded in Table (6).

Evaluation of the Combustion Characteristics of Tigyit and Samlaung Coals based Fluid Carbons

Static Firing in Make-shift Cylindrical Furnace

(100) g each of Tigyit and Samlaung coals were weighed in clean, dry and tared porcelain crucible (10 cm diameter and 5 cm depth) and placed in a make-shift cylindrical combustion chamber. And then gradually carbonized for (60) minutes and physical appearances with changes in temperature were continuously recorded at (5) minutes intervals with a pyrometer using Chromel-Alumel Thermocouple. The data based on carbonization of Tigyit and Samlaung coals are shown in Tables (7) and (8).

The optimum weight ratios of Tigyit and Samlaung coals based fluid carbon were tested in the same manner and physical appearances with respect to changes in temperature are recorded in Tables (7) and (8).

Continuous Dispersion/ Injection System with Conventional Burner

The Tigyit coal based fluid carbon for test firing in a continuous dispersion/ injection system, was prepared based on the optimum compositions of fluid carbon, previously test fired in cylindrical furnace and by fixing coal at 60%w/w but liquid portion, water, was varied accordingly from 32% to 38 % with respect to combustion initiator such as diesel oil or kerosene, and their mixing ratios were as shown in Table (9).

In an improvised firing unit, the reservoir was of the capacity of (5) US gallon with adjoining piping assembly —— (7) cm. diameter pipe of (10) meter length fitted with a nozzle of (2) mm. orifice, for good dispersion of the mixture. The whole piping assembly was maintained at (500 ± 10°) C with a thermostatically controlled electrical heating unit. The actual temperature of the Tigyit coal based fluid carbon and Samlaung coal based fluid carbon were determined with an Infrared Thermometer. The preheated Tigyit coal and Samlaung coal based fluid carbon were ignited and the flame temperature was again determined and the results are shown in Table (9).

Results and Discussion

From the proximate analysis and morphological nature of Tigyit and Samlaung coals, it can be clearly indicated that Samlaung is a soft coal of lignite rank as its porosity is much greater than Tigyit which is of a relatively higher rank, sub-bituminous rank as shown in Tables (1), (2) and Figures (1), (2) respectively. The characteristics of washed Tigyit and Samlaung coals with (10) minutes interval for (40) minutes duration were determined. From the results in Tables (1) and (2), it can be seen that the reduction of ash content which enhanced flotation and aids fluid carbon suspension; reduction of sulphur content and an increment of fixed carbon content and higher heating value of washed Tigyit and Samlaung coals and would gave a better performance in industrial firing purposes. The elemental composition of Tigyit and Samlaung coals (unwashed and washed) were determined by EDXRF method. The results in Tables (4) and (5) indicated that an increment of fixed carbon from 85.96 % to 99.239 % for Tigyit coal and from 95.724% to 98.602% for Samlaung coal after 40 minutes washing.

The relationship between settling tendency and coal particle size of fluid carbon, based on (-100, -200) mesh size, could be evaluated and (-200) mesh size particle was found to be the most favourable size fraction amongst them since it gave the lowest amount settled for settling period of (10) days as shown in Table (6). Tigyit and Samlaung coals to water (60:40) weight ratio and (-200) mesh particle size of fluid carbon have viscosity of (1000) cP which match quite well with literature value.

The combustion characteristics of prepared Tigyit and samlaung coals based fluid carbon in Make-shift Cylindrical Furnace were determined and the results are shown in Tables (7) and (8) respectively. The results obviously confirmed that considerable volatilization of volatile compound took place, at the mentioned temperature range of 185°C to 345°C. Based on this temperature range test-firing of both run-of-mine Tigyit and Samlaung coals, Tigyit coal based and Samlaung coal based fluid carbons (ratio of 60:40 percent) samples indicated that combustion initiated at (340 ± 10)°C and carbonised completely at (900 ± 10)°C with no trace of carbon residue inside the crucible. The test results of continuous dispersion/injection system for Tigyit coal based fluid carbon as shown in Table (9) illustrated that among the four samples being test-fired, sample no. III using (6) percent by weight of diesel oil exhibited continuous self-sustaining combustion whereas (6) percent by weight of kerosene initiator illustrated flash combustion, only (1) min. and thus suggested that diesel oil is a better initiator. All the test results and

follow-up test-firing of fluid carbon samples, type I to IV, positively suggested that, the optimum composition such as 60 %w/w coal, 34 % w/w water and 6 %w/w diesel oil as initiator of fluid carbon would have smooth flowing characteristics in the present piping system fitted with a conventional nozzle and proper selection of an initiator further enhances continuous self-sustaining combustion and the need for atomization is not the first choice.

Table (1) Proximate and Ultimate Analyses of Tigyit Coal before and after Washing

Washing Time / Analyses	Initial	10 min	20 min	30 min	40 min	Remarks
Proximate						
Moisture , (%w/w)	15.10	15.15	15.21	15.27	15.28	Negligible
Ash content, (%w/w)	6.05	4.94	3.79	3.13	3.03	18.3 %, 37.3 %, 48.2%, 50.0% (reduced)
Volatile matter, (%w/w)	27.85	27.76	27.68	27.61	27.52	Negligible
Fixed carbon, (%w/w)	53.00	53.38	59.47	65.24	73.09	4.5%, 12.2%, 23.1%, 37.9 % (increased)
Ultimate						
Sulphur content, (%w/w)	0.86	0.71	0.59	0.51	0.44	17.5%, 31.4%, 40.1%, 48.8 % (reduced)
CV (Btu/lb)	9985	10418	10855	11402	11950	4.3%, 8.7 %, 14.2 %, 19.7% (increased)

Table (2) Proximate and Ultimate Analyses of Samlaung Coal before and after Washing

Washing Time / Analyses	Initial	10 min	20 min	30 min	40 min	Remarks
Proximate						
Moisture , (%w/w)	15.08	15.12	15.20	15.21	15.26	Negligible
Ash content, (%w/w)	7.25	5.78	4.87	4.20	3.67	20.3%, 32.8%, 42.2%, 49.4% (reduced)
Volatile matter, (%w/w)	31.54	31.46	31.41	31.38	31.32	Negligible
Fixed carbon, (%w/w)	46.13	49.41	54.06	59.88	67.76	7.1%, 17.2%, 29.8%, 46.9% (increased)
Ultimate						
Sulphur content, (%w/w)	2.02	1.61	1.33	1.12	0.95	20.3%, 34.2%, 44.6%, 53% (reduced)
CV (Btu/lb)	9032	9379	9725	10354	10982	3.8 %, 7.7 %, 14.6 %, 21.6 % (increased)

Table (3) Effect of Washing Time on the Weight of Washed Tigyit Coal and Samlaung Coal using Flotation Method

Sr. No.	Weight of Coal before Washing (g)	Washing Time (min)	Weight of Coal after Washing (g)	
			Tigyit	Samlaung
1	1000	-	1000	1000
2	1000	10	910.18	900.25
3	1000	20	840.032	810.054
4	1000	30	770.539	720.316
5	1000	40	620.651	530.913

Table (4) Elemental Composition of Run-of-Mine Tigyit Coal and Washed Tigyit Coal as Analysed by EDXRF Method

Sr. No.	Properties	Run-of-Mine Coal (%w/w)	Washed Coal (%w/w)
1	Sulphur content	0.407	-
2	Calcium content	0.850	0.402
3	Iron content	0.444	0.180
4	Silica content	11.900	-
5	Potassium content	0.307	0.131
6	Titanium content	0.121	0.043
7	Zirconium content	0.008	0.003
8	Strontium content	0.004	0.001
9	Carbon content	85.960	99.239

Table (5) Elemental Composition of Run-of-Mine Samlaung Coal and Washed Samlaung Coal as Analysed by EDXRF Method

Sr. No.	Properties	Run-of-Mine Coal (%w/w)	Washed Coal (%w/w)
1	Sulphur content	2.283	0.476
2	Calcium content	0.781	0.453
3	Iron content	1.058	0.296
4	Potassium content	0.097	0.112
5	Titanium content	0.039	0.038
6	Arsenic content	0.008	-
7	Strontium content	0.007	-
8	Zirconium content	0.003	0.003
9	Carbon content	95.724	98.602

Table (6) Composition and Characteristics of Prepared Fluid Carbon

Coals	Particle Sizes (Mesh)	Compositions			Characteristics		
		Coal (%w/w)	Water (%w/w)	Sodium Stearate (%w/w)	Specific Gravity	Viscosity (cP)	Settling Period (days)
Tigyit	-100	60	40	1	1.038	960	7
	- 200	60	40	1	1.087	1000	10
Samlaung	- 100	60	40	1	1.014	960	7
	-200	60	40	1	1.035	1000	10

Table (7) Combustion Characteristics of Run-of-Mine Tigyit Coal and Fluid Carbon from Tigyit Coal Employing the Makeshift Cylindrical Furnace

Time (min.)	Temperature			Combustion Characteristics
	Furnace (°C)	Furnace with Run-of-Mine Coal (°C)	Furnace with Fluid Carbon (°C)	
5	105	105	60	1st stage of combustion, water evaporated
10	185	185	142	1st stage of combustion, volatile compounds evaporated
15	265	285	289	
20	345	395	430	
25	425	469	525	2nd stage of combustion; volatile compounds burned
30	505	550	605	
35	585	617	672	
40	665	698	732	
45	745	770	790	3rd stage of combustion, char burned
50	825	825	831	
55	905	905	905	
60	985	985	985	

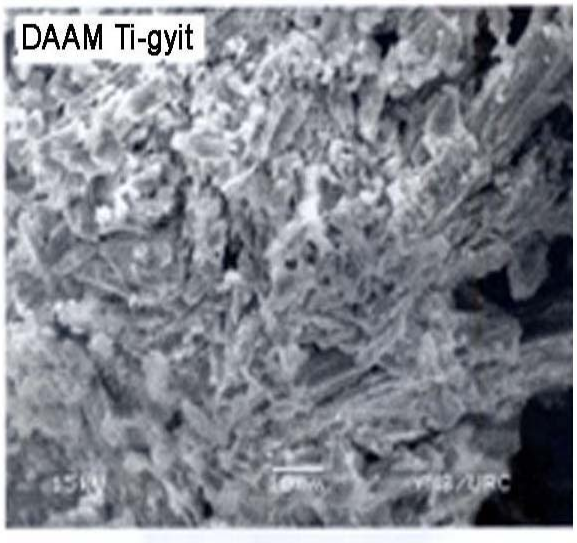
Table (8) Combustion Characteristics of Run-of-Mine Samlaung Coal and Fluid Carbon from Samlaung Coal Employing the Makeshift Cylindrical Furnace

Time (min.)	Temperature			Combustion Characteristics
	Furnace (°C)	Furnace with Run-of-Mine Coal (°C)	Furnace with Fluid Carbon (°C)	
5	105	105	70	1st stage of combustion, water evaporated
10	185	185	137	1st stage of combustion, volatile compounds evaporated
15	265	281	275	
20	345	390	415	
25	425	463	520	2nd stage of combustion; volatile compounds burned
30	505	539	590	
35	585	610	652	
40	665	691	721	3rd stage of combustion, char burned
45	745	750	776	
50	825	825	825	
55	905	905	905	
60	985	985	985	

Table (9) Firing Characteristic of Prepared Fluid Carbon from Tigyit and Samlaung Coals Using Improved Continuous Dispersion System

The flow rate = 0.5 gal/min

Sample No	Composition, (%w/w)					Remarks
	Coal	Water	Additive	Diesel Oil	Kerosene	
I	60	38	1	-	2	No combustion
				2	-	
II	60	36	1	-	4	No combustion
				4	-	
III	60	34	1	-	6	Flash combustion for about 1 min.
				6	-	Continuous self-sustaining combustion Flame temp. 850°C for 10 min. duration.
IV	60	32	1	-	8	
				-	-	



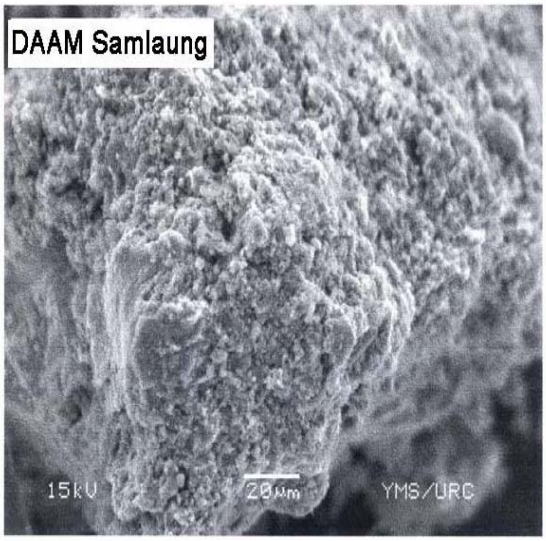
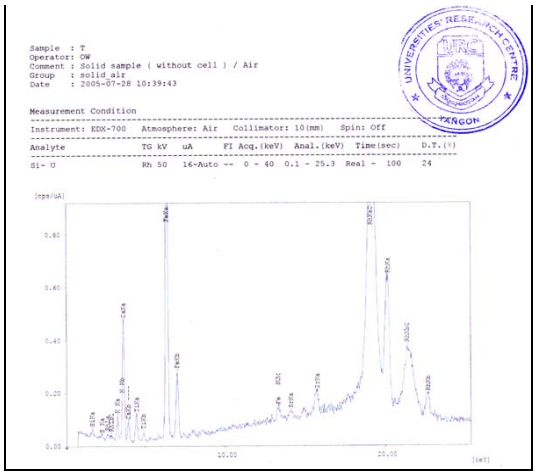


Figure (1) Morphology of Tigyit Coal

Figure (2) Morphology of Samlaung Coal



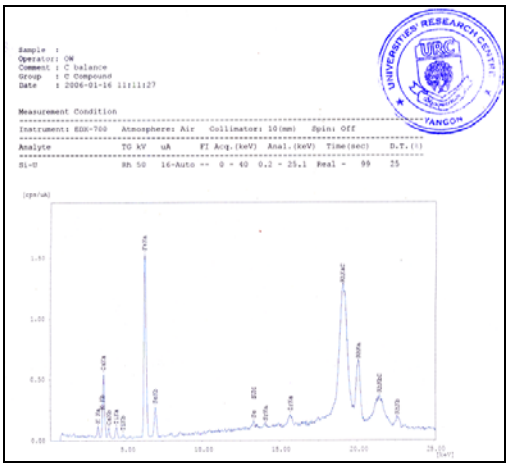


Figure (3) EDXRF Spectrum of Unwashed Tigyit Coal

Figure (4) EDXRF Spectrum of Washed Tigyit Coal

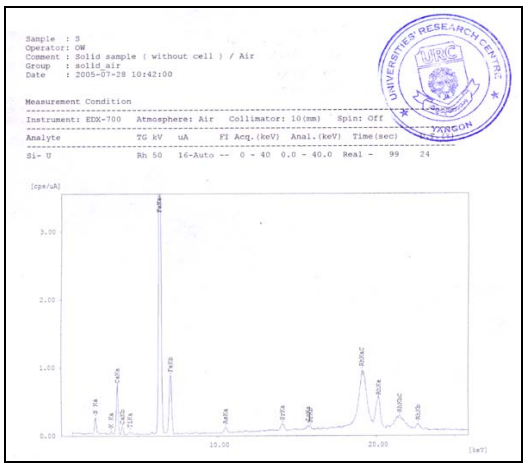


Figure (5) EDXRF Spectrum of Unwashed Samlaung Coal

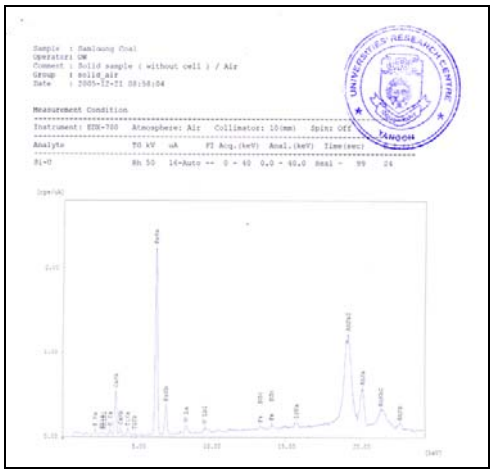


Figure (6) EDXRF Spectrum of Washed Samlaung Coal

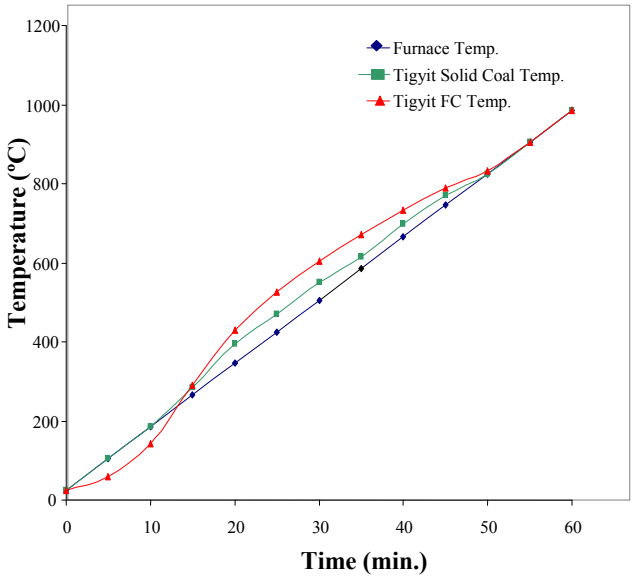


Figure (7) Combustion Characteristics of Fluid Carbon from Tigyit Coal

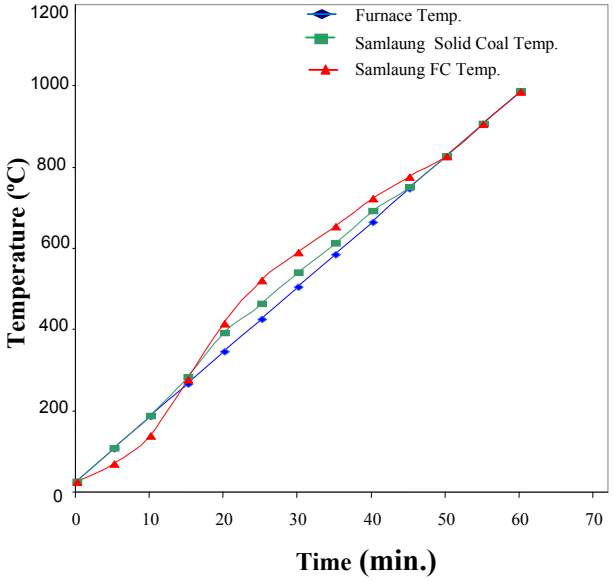


Figure (8) Combustion Characteristics of Fluid Carbon from Samlaung Coal

Conclusion

Fluid carbon is an excellent fuel for use as alternative substitute for liquid (petroleum) and gaseous fuel. In the present research work cleaning of powdered coal was carried out by physical method (flotation), which was more economical than chemical method. The quality of fluid carbon is related to its ingredients, such as, size of coal, amount of water added and nature of stabilizer being used. Among the various laboratory tests available for fluid carbon performance tests: settling, specific gravity and viscosity were chosen as basic tools for the present work. In continuous dispersion/injection system, there is need to install preheating coils and premixing with combustion initiator diesel oil to ignite the fluid carbon essential for continuous self-sustaining complete combustion. Thus it possibly could be used in industries as an alternative fuel at a reasonable price.

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