



Analysis of K, Na and Ca-based Catalysts on the Steam Gasification Reactions of Coal

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ABSTRACT

The clean coal technologies include a number of potential techniques, one of which is catalytic coal gasification. Synthesis gas is produced at a higher process rate as a result of the addition of a catalyst. As a result, the focus of this study was on the catalytic gasification of low-ranking coal, which is suitable for use in the gasification process due to its high reactivity. As catalytically active ingredients, 0.85, 1.7, and 3.4%, respectively, of potassium and calcium cations were utilized. Steam was used as a gasifying agent for the isothermal tests, which were conducted at 900 C under a stress of 2 MPa. The presentation of the essential gasification elements as well as the degree of carbon conversion was checked with the help of active arches. The estimates made it conceivable to determine the type and amount of pulses that will ensure the most effective gasification of coal in a hot climate.

KEYWORDS: Gasification, Catalyst, Coal, Thermovolumetry, Steam, Carbonaceous raw material.

INTRODUCTION

The carbonaceous raw materials, gasification technology offers one of the cleanest processes. With the advancement of large-scale coal gasification technology from the 21st century, the syngas-based C-1 chemistry sector has been developing rapidly, especially in a country with abundant coal resources. As gasification technology has advanced, the feedstock for gasification has steadily increased from coal to petroleum coke, biomass and solid waste [1]. The wide range of available raw materials gives gasification technology a wide range of possible applications in the fields of process engineering and energy.

Utilizing solid waste from the chemical sector has received a lot of attention recently. About 25–30% of the feed is made up of coal liquefaction residue, which is the system's solid waste [2]. It is best to deal with this residue thermally through gasification because it is crucial to economic efficiency. It should be mentioned that because iron-based catalysts are inexpensive and have low volatility, they are frequently utilized in the liquefaction of coal. As a result, iron-based catalysts are always present in the liquefaction leftovers. It is important to research how iron-based catalysts, particularly those utilized in the coal liquefaction process, affect coal gasification. One of the cleanest and best energy sources is gaseous petrol, which made up 21% of the worldwide energy blend in 2010.

As of late, manufactured petroleum gas has been delivered utilizing a coal gasification technique because of the rising

interest for flammable gas and its excessive cost. Future energy request can be met by gasification innovation, which additionally offers ecological other options [3,4,5]. The annihilation of important unstable gas because of high working temperatures is one of the central concerns with business coal gasification in the age of fuel gas. To deliver high-fixation methane, the cycle would essentially be isolated into high-temperature gasifier and methanation stages in a business SNG (engineered flammable gas) creation plant. One of the most engaging strategies for the effective utilization of coal, be that as it may, is the immediate making of methane through gasification using an alkali and alkaline-earth impetus. The upsides of synergist steam-coal and burn gasification incorporate the accompanying: (1) no oxygen is taken care of into the gasifier; (2) all responses happen at low temperatures (600-800 C); and (3) the gasifier's essential intensity information can be brought down (warm unbiased). In the first place, research on response properties might be pivotal for creating objective gases. It has been broadly researched how an alkali and alkaline-earth salts, especially potassium carbonate, can catalyze the gasification of coal. Notwithstanding, most of central examinations have zeroed in on the system of CO age, while little consideration has yet been paid to the pathway of CH₄ produced during the catalyzed steam-scorch association.

LITERATURE REVIEW

The mass of coal particles divided by the volume that is actually occupied by solid material gives coal its true density.



It indicates that it does not include any possible particle pores or interparticle gaps [6]. This is helpful in supplying details regarding the physical-chemical composition of coal. Van Krevelen has demonstrated in his groundbreaking work how real density may be utilized to assess complicated coal properties, including structural metrics like aromaticity and ring condensation index. Due to the complexity involved, real density needs to be precisely defined and measured with the highest level of accuracy. Various authors have reviewed its application.

Franklin has started a systematic examination of coal densities and reported that chemical composition, molecule structure, and molecular packing all affect the true density of coal as measured with helium. Dryden has talked on the close connection between coal hydrogen content and real density [7]. Franklin has noted that hydrogen, among the atoms in coal, has the biggest specific volume and thus the greatest impact on the real density. The vitrain of Japanese coals exhibits distinct variances in actual densities, as demonstrated by Fuji et al.. These variations are attributed to a certain rank level's higher hydrogen concentration.

The fine construction of coals has likewise been totally explored by Bond and Spencer. Since the helium particle is adequately little and there are no accessible pores into which it can't enter, they have estimated that I the thickness estimated involving helium as the test gas will precisely mirror the genuine thickness of a coal and (ii) the van der Waals powers are sufficiently frail to consider the disregard of helium adsorption on the coal surface.

The mass of a single coal particle divided by its volume is a simple formula for determining particle density. In other words, it comprises pores but not interparticle gaps. The apparent density or envelope density is other names for it. Another one of the most significant essential characteristics of coal is particle density [8]. Many scholars have made significant efforts to periodically quantify the particle density of coal because to its significance and utility in a variety of fields. It is useful for determining the coal's porosity and void space. On the other hand, coal porosity has a significant impact on the processes of mining, preparation, exploitation (including the creation of coal bed methane), and usage, including coal combustion and gasification.

Mercury intrusion is typically used to calculate particle density [9, 10]. Particle densities of a variety of coals and carbonized products have been calculated by Agrawal. The actual and particle densities of many American coals, ranging in rank from anthracite to lignite, have been calculated by Ganet al.. By introducing mercury, Nelson et al. have also assessed the particle density of coal, carbon samples, and polystyrene.

RESEARCH METHODOLOGIES

Material Characteristics

These reviews zeroed in on the second rate coal from

the Piast mine [11]. The reactivity of the feedstock, which depends on coal rank, is the essential determinant affecting how the gasification interaction will unfurl. The coal from the "Piast" mine was picked as a feedstock for research on the grounds that a lower coal rank impacts the gasification cycle. The size of the functional assets given by the mine "Piast," which guarantees a decades-in length activity, was likewise an extremely critical component. Table 1 gives a synopsis of the coal test qualities.

Table 1. Coal's characteristics

Parameter	Value (%)
Proximate analysis	
Moisture -M ^{ad}	5.2
Ash-A ^{ad}	8.5
Volatile matter -VM	37.5
Fixed Carbon	34.7
Carbon	87.2
Hydrogen	4.82
Sulfur	1.723

The research samples were created by physically combining coal with either potassium or calcium nitrates at the proper weight ratio. The added cations were weighted at 0.75, 1.7, and 3.4 percent, and the entire mixture was then crushed to verify that the catalyst was evenly dispersed. These samples were then dispensed into the installation's dispensing system.

Methodology of Examinations

Earlier publications^{29, 30} frequently displayed a description of the laboratory tools used to conduct the measurements of coal gasification [12]. Figure 1 shows a schematic chart of this plan. The establishment's essential frameworks incorporate a high tension reactor with a warming framework, a framework for providing the reactor with steam, coal, and inactive gases, as well as a framework for get-together and breaking down the gas delivered during the gasification cycle. The valve providing compressed argon to the coal feeder is opened following the adjustment of the picked boundaries, permitting the confirmation of the tried example into the reactor. In the wake of cooling and drying, the created gas was ceaselessly assessed for the presence of methane, carbon monoxide, and dioxide utilizing a programmed analyzer. Tests were assembled at a few areas for an exhaustive investigation of the resultant gas [13].

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and latent gases, as well as a framework for get-together and examining the gas delivered during the gasification interaction. The valve providing compressed argon to the coal feeder is opened following the adjustment of the picked boundaries, permitting the affirmation of the tried example into the reactor. In the wake of cooling and drying, the created gas was consistently assessed for the presence of methane, carbon monoxide, and dioxide utilizing a programmed analyzer [14, 15]. Tests were taken during the estimation at foreordained times, and the subsequent gas was then completely tried for hydrogen content utilizing a gas chromatograph.

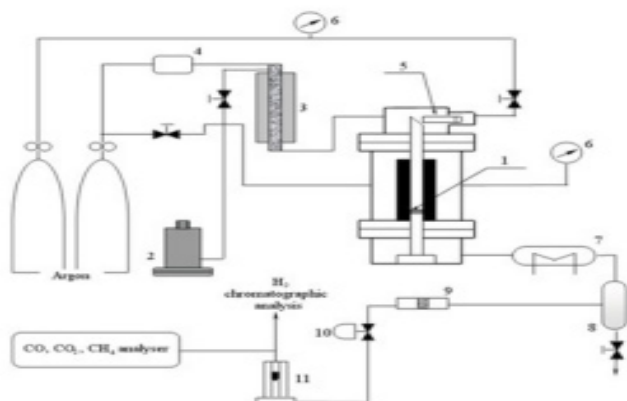


Fig 1. Device for coal gasification

Fig.1. the accompanying lab device was utilized to gauge the energy of coal gasification: Reactor, water siphon, and steam generator are recorded in a specific order. Condenser, mass stream meter, coal feeder, pressure measure, and condenser. Tar separator, gas channel, backpressure controller, and rotameter are additionally included.

RESULT AND DISCUSSION

The impact of adding fluctuating measures of potassium and calcium on the pace of making of the significant gas constituents, to be specific carbon monoxide, hydrogen, and carbon dioxide, as an element of time [16], is portrayed in Figures 2 and 3. Methane creation during the estimations was additionally noted, yet it was microscopic, and none of the tried impetuses seemed to influence the rate at which it was delivered.

As shown in Figure 2c, there was no way to see an effect of expanding how much the reactant fixing on the pace of carbon dioxide age. The rate of CO₂ generation rose with the addition of 1.7 wt% potassium during the pyrolysis stage, but it did not improve during the crucial step of char gasification. The generation rate of carbon dioxide was not only unaffected by the addition of another 3.4 wt% of potassium, but it was slightly decreased when compared to the addition of 1.7 wt%.

No matter what the amount of potassium added, the time expected to finish the gasification cycle was altogether diminished by the incorporation of the impetuses.

Table 1. impact of expansion of different measures of potassium on the development pace

Time	Dv/dt [cm ³ /gm-min]	
10	20	140
20	25	160
30	150	155
40	100	140
50	28	130
60	30	120

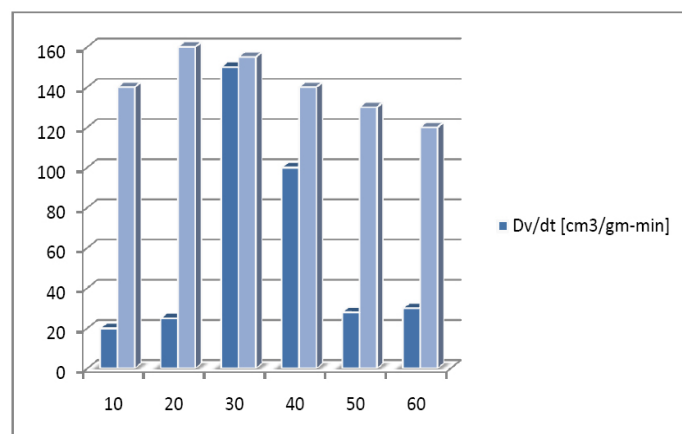


Fig 2 (a). The impact of expansion of different measures of potassium on the development pace of a) CO; b) H₂; c) CO₂ during gasification of the coal 'Piašt'

Table 2. expansions of different measures of potassium on the development pace

Time	Dv/dt [cm ³ /gm-min]	
10	120	138
20	160	160
30	155	155
40	100	140
50	130	140
60	120	160

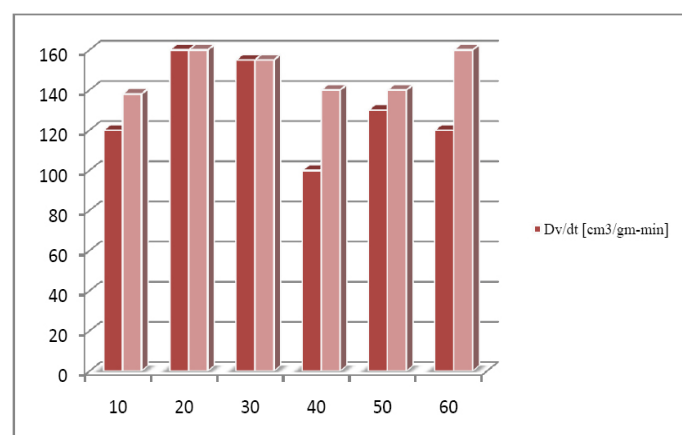


Fig 2 (b). The impact of expansion of different measures of potassium on the development pace of a) CO; b) H₂; c) CO₂ during gasification of the coal 'Piašt'.

Numerous studies have looked into the acceleration of the

gasification process brought on by the inclusion of catalytic additives [17]. Four putative cycles for responses the oxygen move, electrochemical, free revolutionary, and middle of the road pathways were distinguished. One of them, the oxygen move component, is regularly proposed and seems to best mirror the synergist gasification process. In this system, the impetus eliminates oxygen from the reactant gas, H₂O, and moves it to the carbon dynamic destinations through the chemically dynamic alkali and alkaline earth species. Then, CO is let out of the dynamic carbon-oxygen buildings. The last stage is believed as far as possible. A redox component is the primary illustration of such a cycle, and it on the other hand diminishes the impetus with carbon and oxidizes it with the vaporous reactant.

The findings of the calculated yields of specific gases in the gasification process, as shown in Figure 3, supported the conclusions reached based on variations in the rate of creation of gaseous products.

Table 3. Variations in the rate of gaseous product production

Yield	No catalyst	Co ₂	Co	CH ₄
1	1.7	4.6	1.0	11.6
1.5	3.7	8.3	4.6	3.7
0.5	5.8	2.9	5.8	5.8
2	2.4	3.3	2.4	3.3
2.5	11.6	6.6	8.2	6.6

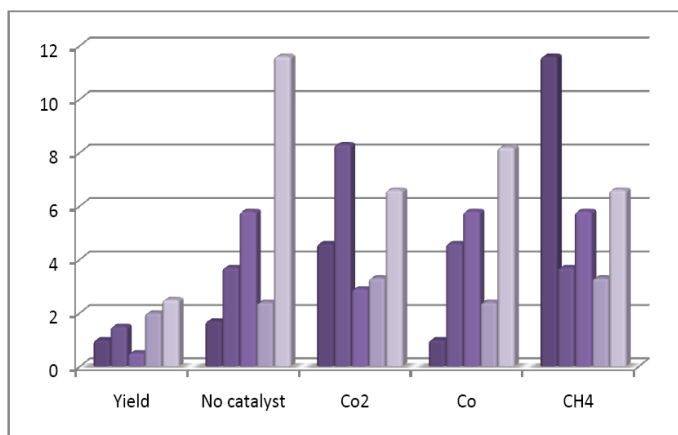


Fig 3. variations in the rate of creation of gaseous products

Because of coal gasification, a gas was created with hydrogen and carbon monoxide as its main constituents, with hydrogen having an almost three-crease higher fixation than CO. An end that this measure of impetus is lacking for a productive cycle can be made on the grounds that the expansion of 0.85 wt% of potassium essentially raised the portion of the resultant CO while at the same time diminishing how much hydrogen. The extent of hydrogen and carbon monoxide in the resultant gas expanded essentially as potassium fixation kept on ascending, with the best outcomes coming from consolidating coal and 3.5% by weight of potassium. Indeed, even at the least impetus focus, 0.75 wt%, a better return of vaporous items was seen for calcium. Contrasted

with the cycle without the impetus, both the portion of carbon monoxide and the portion of hydrogen were bigger [18]. The cycle was emphatically impacted by an expansion in calcium content to 1.6wt%, which made the portion of both tried gases ceaselessly rise. With calcium cations acting as the catalyst, the syngas produced in this method had the highest yields of hydrogen and carbon monoxide of any measurements. Syngas with 3.4 weight percent of Ca added had a composition that was nearly equal to that of gasification without a catalyst. It is therefore useless to increase the calcium level to that point.

It's also important to note that inferences about the selectivity of both catalysts can be made. No matter what how much impetus present, adding potassium delivered a gas with hydrogen content that was roughly two times just that high of carbon monoxide? In any case, it was tracked down that the H₂/CO proportion in the tests utilizing calcium surpassed the worth of 2 and that this worth rose alongside how much the impetus [19]. An alternate impetus can be utilized relying upon the subsequent gas' ideal synthesis. The potassium ought to be utilized as an impetus in the event that the fundamental objective is to create a combination gas with the biggest level of carbon monoxide. Nonetheless, calcium impetuses give off an impression of being a better decision when the objective is than fundamentally increment how much hydrogen in the post-response gas.

CONCLUSION

The adding more of this catalyst led to a higher output of carbon monoxide and hydrogen; adding 0.85 weight percent of potassium did not suffice to boost the process. In the instance of calcium, it was discovered that 0.85 weight percent of catalyst resulted in an improvement. Furthermore, it was noticed that the case that rising the calcium fixation to 3.5wt% would further develop the cycle was false in light of the fact that the yields of the gas parts were practically identical to those in the post-response gas created by gasification without an impetus. The outcomes examination likewise considered the assurance of the impetus' selectivity; it was found that calcium gasification prompted a huge expansion in how much hydrogen in the delivered gas and potassium gasification took into consideration an expansion in the extent of carbon monoxide in the blend gas. Moreover, it was found that the reactant added substances essentially expanded the level of carbon transformation while radically cutting the cycle time — a finding that was displayed on account of potassium as the impetus. Accordingly, the "Piast" coal's synergist gasification is more practical, and both potassium and sodium might be used as the impetuses.

FUTURE WORK

In a follow-up study to this work, the catalytic effect on coal gasification using an iron-based catalyst from a coal liquefaction plant was investigated. Both the process and the composition of the catalyst loading were taken into account [20]. Model-free and model-adapted approaches were used

to study the kinetics of coal gasification. The distributions of catalytic elements, evolution of carbon structure, and interactions between internal minerals have all been discussed in terms of catalytic mechanism.

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