Effect of Sisal Nanoparticles on Single Cylinder Spark Ignition Engine Combustion

G. Arun Manohar, Raghuveer Dontikurti, G. Indu Priya, D. Nageswara Rao

Abstract: Turbulence is an important parameter to be considered for effective combustion inside a cylinder. Heat transfer inside the cylinder affects the combustion process. Insufficient turbulence leads to incomplete combustion, resulting in pollution. Effective flame propagation leads to higher combustion rates in SI engines which in turn requires enough turbulence. Effective combustion efficiency can be achieved through higher flame propagation velocities. In the present work an attempt has been made to enhance the turbulence inside the cylinder of a single cylinder spark ignition engine by injecting solid nanoparticles into the air fuel mixture.

Keywords: Equivalence Ratio, Nanoparticle, Turbulence

I. INTRODUCTION

Internal combustion engines are devices that generate work using the products of combustion as the working fluid rather than as a heat transfer medium. Combustion produces a rise in pressure and temperature as the energy contained in the fuel is released and the chemical reaction is completed. Most of the energy goes into the power stroke, where the gases expand under high pressure and push the piston down to the bottom center position. The average efficiency of an internal combustion engines is about 18%-20 % [1].

A. Combustion in SI Engines

Combustion in SI engines is divided into three categories. Ignition and flame development is the first phase of combustion where only about 5% of the air-fuel mixture is consumed. During flame development combustion has barely started and there is very little pressure rise, so there is no significant work done. The second phase consists of the propagation of the flame. This phase consumes about 80-90% of the air-fuel mixture. During this phase there is significant pressure rise, which provides the force that produces the work in the expansion stroke. The third and final phase of the combustion process is the flame termination. This phase consumes only about 5% of the air-fuel mixture.

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Ignition and Flame Development

Ignition of the air-fuel mixture is initiated by an electrical discharge across the electrodes of a spark plug about 10-30° degrees before TDC. At this instant the flame is very small and travels at a very low velocity which is not sufficient to generate enough energy for combustion. When 5-10% of the mixture is burnt along with a pressure rise due to the compression stroke, flame propagation starts.

Flame Propagation

Effective flame propagation leads to proper combustion in the cylinder. Characteristics like swirl and squish are desired because they induce the turbulent flow of the flame front.

As the flame propagates throughout the combustion chamber the temperature and pressure increase constantly. This rise in temperature and pressure cause the chemical reaction to increase which causes the flame front to increase. The effects on combustion not only come from turbulence, swirl, and squish, but also from the type of fuel used and the air-fuel ratio.

Flame Termination

At 15-20º after TDC about 95% of the combustion process would have been taken place and the flame front reaches all corners of the combustion chamber. The termination of the flame consumes roughly 5% of the air-fuel mixture.

B. Nanoparticles application in IC Engines

Nanotechnology can be an ideal building block for automotive industries, under constant evolution offering a very wide scope of activity. It possesses huge potential and is still in the embryonic form of research and development[2]. Due to the size of nano material, their physical, chemical properties can be manipulated to over all properties. In recent years the use of nanofluids in automobile industries for various applications has increased.

Nanoparticles in coolant

Singh et al., [3] have investigated that using high thermal conductivity nanofluids in radiators reduce the area of the radiator by up to 10% and the fuel efficiency. Ravikanth et al.,[4] stated that CuO and Al_2O_3 nanofluids in radiator increased the average heat transfer co-efficient and reduced the required pumping power upto 80%.

Nanoparticles in Lubricants

J. A. Eastmanet.al.,[5]surface modified nanoparticles dispersed in mineral oils reported to be effective in wear reduction while enhancing load carrying capacity.. Osorio et al.,[6] investigated the tribological properties CuO nanoparticles in polyalphao- lefin (PAO6). and reduced friction with respect to base oil by tribosinterization. Mu-Jung Kao et al., [7] TiO2 nano particles mixed in paraffin oil, could fill rough cracks in a metal wall surface to reduce the coefficient of friction.

Nanoparticles in Fuels

After the invention of nanotechnology, combustion efficiency, combustion speed and the combustion stability increased by adding metallic nanoparticles to the fuels.[8] Jung Kao et al.,[9] investigated the effect of aqueous aluminum nanoparticles in compression ignition engine and observed that there is a reduction in the fuel consumption. Arul Mozhi Selven et al.,[10] investigated the performance and emission characteristics of C.I engine using cerium oxide nanoparticles with diesel and biodiesel mixture fuel and reported combustion enhancement. Guru et al.,[11] concluded that manganese as fuel additive has a greater effect in reducing CO emissions. Valentine et al.,[12] experimentally observed that bimetallic platinum and cerium diesel fuel reduce the emissions of diesel engine.

Stephen Taylor et.al.,[13] opined that nanotechnology is likely to emerge as a key technology in automotive manufacture, specially with regard to materials replacement.

Adding cerium oxide nanoparticles to fuel can help decomposition of unburnt hydrocarbons and soot, reducing the amount of these pollutants emitted in the exhaust and reducing the amount of fuel used. Cerium oxide also decreases the pressure in the combustion chamber, which reduces the production of NO and makes combustion reactions more efficient.[14]

Y. Gan and L. Qiao [15] investigated nanoparticles and microparticles of aluminium as a potential fuel additive. The characteristics of nanoaluminium in suspension are more conductive to the formation of microexplosions during combustion, which assist in the airfuel mixing and leads to cleaner, more efficient combustion.

D. Ganesh & G. Gowrishankar et.al.,[16] found that oxygen atoms in cobalt oxide particles can moderate the combustion reactions, much like cerium oxide. As a result, the combustion was cleaner when using the cobalt oxide additive, and emission of carbon monoxide and unburnt hydrocarbons were reduced. It was also noted that the magnalium particles acted as heat sink within the combustion chamber reducing the overall temperature, helping to avoid hotspots and reducing NO production.

Will Soutter[17] stated that the main concern with nanomaterials,which will have to be dealt with, before fullcommercial deployment of nanoadditives,is their e nvironmental impact.Whilst nanoadditives have demonstrate d the potential to improve fuel efficiency and thequality of e xhaust emissions, they may also cause environmental issues if they are carried into the exhaust gases themselves.

H. Soukht Saraee et.al.[18] used silver nanoparticles as additives in diesel fuel. The presence of the nanoparticles inside the combustion chamber enhanced the heat transfer to fuel and shortened the ignition delay through an acceleration of the burning process. All of these features altogether improved combustion and hence the unburned carbons and other pollutants decreased.

Abhishek Kumar Sharma[19] analyzed the performance of a 4-stroke Multi Cylinder petrol engine using self-synthesised ZnO nanoparticles with petrol blends and found that blend containing up to 50 ppm ZnO nanoparticles performed successfully in engine without any design modifications. Improved thermal efficiency up to 6.8% along with a decrease in fuel consumption to 6.20% are reported.

However the role of these particles towards pollutants is questionable. Hence there is a need to test the use of biodegradable nanoparticles which may enhance the combustion while not contributing for the production of pollutants. In the present work an attempt has been made to enhance the combustion efficiency in a single cylinder spark ignition engine by adding sisal nanoparticles in the cylinder.

II. EXPERIMENTAL SETUP

The experimental setup consists of a single cylinder spark ignition engine provided with an air and fuel measuring units, in-cylinder temperature measuring unit and a nanoparticle regulating unit. The Spark ignition engine considered for the experimentation is a TVS- Fiero Fx make. The specifications of the engine and the complete testrig are shown in the figure 2.1 below.

Specifications of the Engine

Item	Specification
Volume of Engine	147cc
Compression Ratio	9.4
Brake Horse Power	8.8 KW
Cylinder Bore	58mm
Stroke Length	72mm

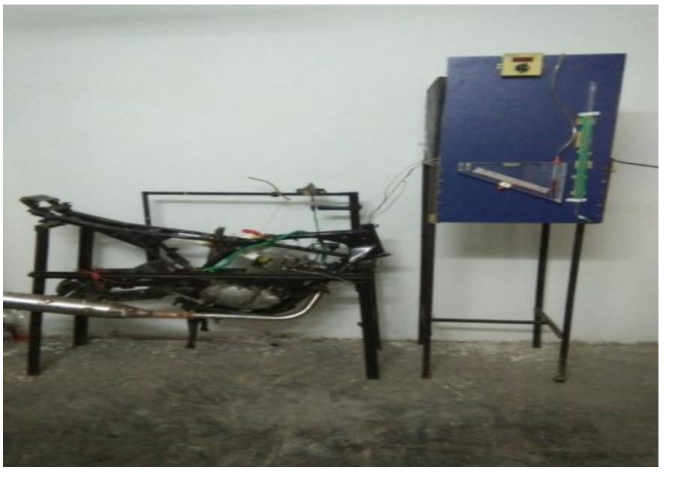


Fig.2.1 Complete Experimental Testrig

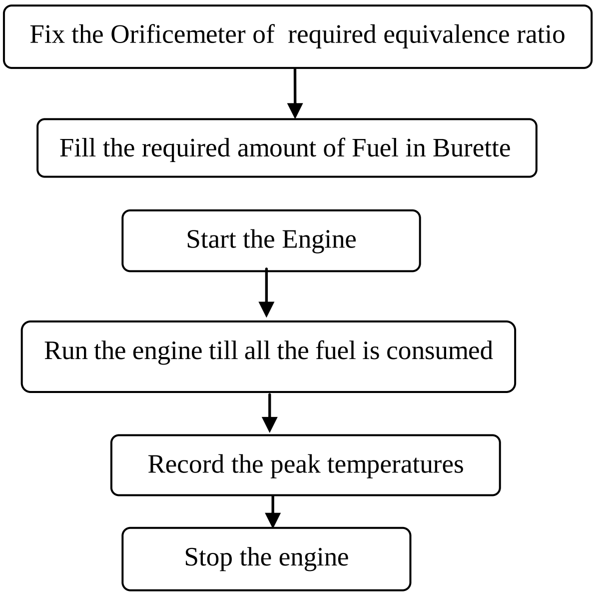
The air flow measuring unit consists of air box and inclined manometer, the temperature measuring unit consists of temperature sensors and a digital temperature indicator. The air box is provided with a facility to control the mass of air entering into the engine, through an orifice. One side of the air box is provided with an orifice plate. Five orifice plates of diameters 4mm, 4.97mm, 5.74mm, 6.5mm, and 7.02mm are used for controlling the amount of air entering into the cylinder and thereby the equivalence ratio.

The fuel supply to the engine is provided through a burette. The end of the burette is connected to the carburetor through a pipe. Temperature sensors are provided near the combustion chamber, exhaust plenum and near the fins. Temperature sensors are fixed firmly in their positions. All the three temperature sensors are connected to the digital temperature indicator.

The air measuring unit, temperature measuring unit and the fuel supply unit are fixed to the engine and the entire structure is firmly grounded. The temperature indicator is switched on to check the initial temperatures in the engine and is maintained at room temperature. Each experiment is run for a fuel capacity of 20cc.

III. EXPERIMENTATION

An orifice plate corresponding to equivalence ratio considered is fixed to the air flow measuring unit. The fuel is supplied for running the engine. During this period the peak temperature attained in the combustion chamber is recorded. Once the fuel is consumed, the engine is stopped and allowed to cool down till the combustion chamber temperature reaches room temperature. The process is repeated by changing the orifice plate for each experiment so that the mass of air entering into the cylinder changes, thereby the air fuel ratio changes. The methodology is shown in the flowchart below



The experiments are conducted for equivalence ratios of 0.4,0.6,0.8,1.0,1.2 and 1.3. From the experiment it is noticed that the combustion chamber temperature increases with increase in equivalence ratio. At an equivalence ratio of 1.3 the engine ceased to operate. Hence the observations made upto equivalence ratio 1.2 are presented in Table 3.1

Table 3.1 Temperature values at various equivalence ratios from experiment

Equivalence Ratio (Φ)	Combustion Chamber Temperature (Experiment)(K)
0.4	418
0.6	423
0.8	428
1	433
1.2	447

From the table 3.1 it can be seen that at an equivalence ratio Φ =1.2 the combustion temperature is maximum i.e, 447^{o}K. This indicates that maximum fuel might have been burnt while the engine is operated at equivalence ratio Φ =1.2. Graphical representation of the experiment values are shown below.

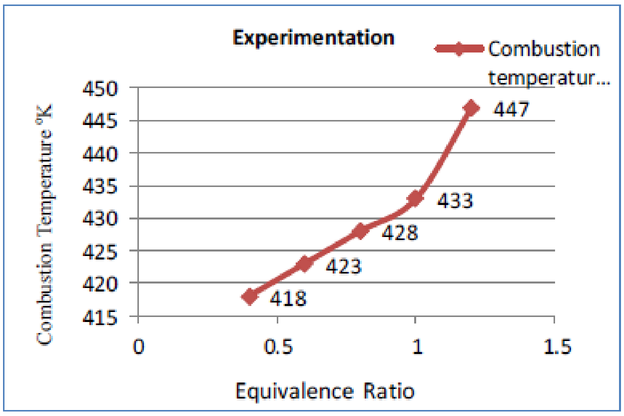


Fig 3.1 Combustion Temperature vs Equivalence ratio (Experimentation)

From the figure it can be seen that the temperature gradually increases from 418K at an equivalence ratio of 0.4 to a temperature of 447K at equivalence ratio Φ =1.2. This shows that the combustion temperature is maximum at equivalence ratio Φ =1.2.

A. Experimentation with Nanoparticles

The test rig is checked and ensured for proper connections. The orifice plate corresponding to equivalence ratio Φ =1.2 is fixed to the air box. The temperature inside the combustion chamber is checked initially by switching on the temperature indicator and it is to be at 30^{o}C. Fuel of 20cc is maintained in the fuel supply unit and is connected to the engine and the engine is started. The engine is kept running until the 20cc of fuel is consumed and the peak temperature is recorded using the temperature indicator,
this is done without the addition ofnano particles. This observation is used as a reference for comparing the temperature rise after addition of the particles. The engine is stopped and allowed to cool down till the combustion chamber temperature reaches room temperature

Nanoparticle Regulating Unit

A regulating unit is provided for the addition of nano particles into the engine cylinder during the experimentation. The complete assembly of the nanoparticle regulating unit is shown in the figure 3.2

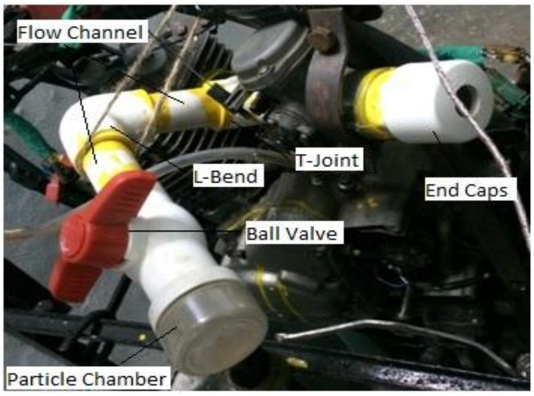


Fig 3.2 Nanoparticle Regulating Unit

A T-Joint is connected to the engine inlet for providing entries for both the air fuel mixture and Nanoparticles. One entry of the T- Joint is fitted to the Engine inlet, other end is fitted with the carburettor. The third entry is connected to the nanoparticle chamber through a channel provided with a ball valve for controlling the flow of the particles. The suction pressure inside the cylinder makes the particles flow into the engine.

This procedure is repeated for various samples by increasing the weight of the nanoparticles. The weight of the nano particle samples considered are 0.5,0.6,0.7,0.8,0.9,1.0,1.1,1.2 and 1.3gm. This process is continued till a drop in the temperature is observed. For reliability and consistency, a set of 6 trials are conducted. The results of the experiments for all the 6 trials are presented and discussed below.

IV. RESULTS & DISCUSSIONS

To avoid the inconsistency in observations the experiment is repeated for 6 times at different weightages of nanoparticles keeping the equivalence ratio constant at Φ =1.2. The average of all the six trials is considered for further evaluation.

Table 4.1 Temperatures of Combustion Chamber at Φ=1.2 and 0.5gm of nanoparticle

Trial No	Temperature without addition of particles ,K	Temperature after addition of particles, K
1	447	456
2	473	488
3	441	448
4	456	463
5	450	460
6	473	485
Average Temperature	457	467

From the above observations (Table 4.1) it is noticed that there is a rise of 10K with the addition of nanoparticles to the air fuel mixture. This indicates that more fuel is burnt and hence the increase in combustion.

Table 4.2 Temperatures of Combustion Chamber at Φ=1.2 and 0.6gm of nanoparticle

Trial No	Temperature without addition of particles ,K	Temperature after addition of particles, K
1	447	453
2	473	493
3	441	457
4	456	469
5	450	463
6	473	491
Average Temperature	457	471

From the above observations (Table 4.2) it is noticed that there is a rise of 14K with the addition of nanoparticles to the air fuel mixture. This indicates that there is a marginal increase in the combustion temperature compared to when the particles added are 0.5gm. This attributes to better combustion.

Table 4.3 Temperatures of Combustion Chamber at Φ=1.2 and 0.7gm of nanoparticle

Trial No	Temperature without addition of particles, K	Temperature after addition of particles, K
1	447	472
2	473	503
3	441	463
4	456	491
5	450	468
6	473	501
Average Temperature	457	483

From the above observations (Table 4.3) it is noticed that there is a rise of 26K with the addition of nanoparticles to the air fuel mixture. This indicates that there is a increase in the combustion temperature compared to when the particles added are 0.6gm and hence better combustion.

Table 4.4 Temperatures of Combustion Chamber at Φ=1.2 and 0.8gm of nanoparticle

Trial No	Temperature without addition of particles, K	Temperature after addition of particles, K
1	447	483
2	473	505
3	441	467
4	456	497
5	450	483
6	473	507
Average Temperature	457	490

From the above observations (Table 4.4) it is noticed that there is a rise of 33K with the addition of nanoparticles to the air fuel mixture. This indicates that there is a increase in the combustion temperature compared to when the particles added are 0.7gm. This attributes to better combustion

Table 4.5 Temperatures of Combustion Chamber at Φ=1.2 and 0.9gm of nanoparticle

Trial No	Temperature without addition of particles, K	Temperature after addition of particles, K

1	447	505
2	473	516
3	441	482
4	456	502
5	450	492
6	473	515
Average Temperature	457	502

From the above observations (Table 4.5) it is noticed that there is a rise of 45K with the addition of nanoparticles to the air fuel mixture. This indicates that there is a increase in the combustion temperature compared to when the particles added are 0.8gm. This attributes to better combustion.

Table 4.6 Temperatures of Combustion Chamber at Φ=1.2 and 1.0 gm of nanoparticle

Trial No	Temperature without addition of particles, K	Temperature after addition of particles, K
1	447	513
2	473	523
3	441	493
4	456	513
5	450	498
6	473	523
Average Temperature	457	511

From the above observations (Table 4.6) it is noticed that there is a rise of 54K with the addition of nanoparticles to the air fuel mixture. This indicates that there is a increase in the combustion temperature compared to when the particles added are 0.9gm. This attributes to better combustion.

Table 4.7 Temperatures of Combustion Chamber at Φ=1.2 and 1.1 gm of nanoparticle

Trial No	Temperature without addition of particles, K	Temperature after addition of particles, K
1	447	518
2	473	526
3	441	502
4	456	523
5	450	509
6	473	525
Average Temperature	457	517

From the above observations (Table 4.7) it is noticed that there is a rise of 60K with the addition of nanoparticles to the air fuel mixture. This indicates that there is a increase in the combustion temperature compared to when the particles added are 1.0gm. This attributes to better combustion.

Table 4.8 Temperatures of Combustion Chamber at Φ=1.2 and 1.2 gm of nanoparticle

Trial No	Temperature without addition of particles, K	Temperature after addition of particles, K
1	447	525
2	473	523
3	441	513
4	456	524
5	450	523
6	473	521
Average Temperature	457	521

From the above observations (Table 4.8) it is noticed that there is a rise of 64K with the addition of nanoparticles to the air fuel mixture. This indicates that there is a increase in the combustion temperature compared to when the particles added are 1.1gm. This attributes to better combustion

Table 4.9 Temperatures of Combustion Chamber at Φ=1.2 and 1.3 gm of nanoparticle

Trial No	Temperature without addition of particles, K	Temperature after addition of particles, K
1	447	521
2	473	518
3	441	508
4	456	521
5	450	518
6	473	516
Average Temperature	457	517

From the above observations (Table 4.9) it is noticed that there is a rise of 60K with the addition of nanoparticles to the air fuel mixture. Though there is a rise in the combustion chamber temperature, compared to the rise that is noticed with the addition of 1.2gm a drop is observed. The incremental rise of the combustion chamber temperature with the increase in the addition of nanoparticles is noticed from the above Table 4.1 to Table 4.9. The rise in temperatures varied from 10K to 64K. The minimum rise is at 0.5gm of particle addition to airfuel ratio and the maximum rise is at 1.2gm of particle addition to airfuel ratio. The variations in the temperature rises with the increase in the addition of nanoparticles are represented in the figure 4.3 below

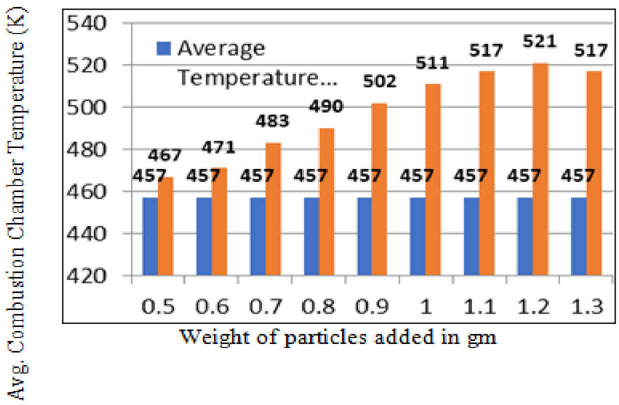


Fig 4.3 Weight of Nanoparticles Vs. Combustion Chamber Temperature

From the figure 4.3 it can be seen that there is a continuous rise in the combustion chamber temperature from 467K at 0.5gm of particle addition to 521K at 1.2gm of particle addition. Whereas the combustion chamber temperature without the addition of particles is 457K.

The increment in the temperature rise with the addition of nanoparticles ranging between 0.6gm to 1.0gm appears to be in the range of 1.5% to 2.5%. By increasing the addition of particles by 0.1gm at 1.1gm shows 0.7% rise in the temperature. Similarly the rise in the temperature is 0.8% between 0.5gm and 0.6gm of particle addition.

With the addition of 1.3gm of particles though the temperature rises compared to non particle addition, the incremental rise of the temperature compared to 1.2gm particle addition is less by 0.7%. This shows that by increasing the addition of particles the rise in temperature decreases.

V. CONCLUSIONS

Sisal nanoparticles are injected at different weights from 0.5gm to 1.3gm. It is observed that the combustion temperature increased gradually upto a weight of 1.2gm and beyond this a drop in the temperature is observed.

With the addition of 1.3gm of particles though the temperature rises compared to non particle addition, the incremental rise of the temperature compared to 1.2gm particle addition is less by 0.7%. This shows that by increasing the addition of particles the rise in temperature decreases.

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