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Combustion Characteristics of alcohol-diesel blends: ASTM Distillation and Flash point

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Abstract: Alcohol-diesel blends as an alternative fuel have gained attention due to their potential for reducing emissions and improving combustion efficiency. However, mixing alcohol with diesel significantly alters fuel volatility, ignition characteristics, and safety properties. This study investigates the impact of the addition of alcohol on the ASTM distillation profile and flash point of diesel blends, aiming to establish correlations that predict combustion behavior. Experimental analysis includes ASTM D86 distillation curves, ASTM D93 flash point testing, and combustion trials to evaluate ignition delay, flame propagation, and emissions. The findings will contribute to optimizing alcohol-diesel blends for improved performance and safety in compression ignition engines.

Keywords: Alcohol-diesel blend, combustion characteristics, ASTM distillation, Flash point, Ignition delay, Emission reduction

Introduction

The increasing global energy demand and concerns about environmental pollution have driven research towards alternative fuels for internal combustion engines. Diesel fuel widely used in transportation and industrial sectors, is associated with high particulate matter(PM) and NOx emissions, contributing to air pollution and global warming[1].Alcohol such as ethanol, butanol have emerged as potential blending agents with diesel due to their renewable nature, oxygen content, and ability to improve combustion characteristics[2]. Alcohol-diesel blend exhibit distinct combustion properties due to differences in volatility, ignition delay, and heat release rate compared to conventional diesel[3]. The ASTM D86 distillation test is crucial for evaluating fuel volatility and its effect on engine performance. The distillation curve provides insights into how alcohol blending alters the boiling range, influencing fuel atomization, evaporation, and combustion efficiency[4]. Additionally, the ASTM D93 flash point test determines the minimum temperature at which the fuel forms a flammable vapour-air mixture, a key parameter for assessing fuel safety and storage requirements [5].

Blending alcohol with diesel significantly affects the flash point due to their lower boiling points, making the blend more volatile and susceptible to ignition risks[6]. However, this increased volatility can also enhance fuel-air mixing, potentially improving combustion efficiency and reducing emissions. The correlation between ASTM distillation characteristics and flash point is crucial in understanding how alcohol-diesel blends behave under different engine conditions and safety considerations.

This study investigates the combustion characteristics of alcohol-diesel blends by analyzing their ASTM distillation profiles, flash point variations and combustion behavior. The result will contribute to optimizing blend compositions for improved engine performance, safety and environmental sustainability.

2. Theoretical Aspects

2.1 Flash Point

Flash point of a liquid is the lowest temperature at which its vapors ignite momentarily when exposed to an ignition source under specified test conditions. (ASTMD92, ASTM D93). It indicates the flammability and volatility of the substance, making it a critical parameter in fuel safety and handling. [7-8]

Significance

- Determine fire hazards levels for storage, transportation, and handling.[9]
- Used to classify fuels as flammable (Low flash point) or combustible (high flash point) according to safety regulations.[10]
- Low flash point fuels evaporate quickly while high flash point fuel is more stable.[11]
- Mandatory for transportation safety regulations.[12]
- Flash point deviations can indicate contamination or adulteration with low boiling components like solvents.[13]
- Effects on internal combustion engines.[14]
- Improper flash point fuels can cause engine knocking, incomplete combustion, and emissions issues.[14]

ASTM Distillation

ASTM distillation refers to a set of standardized methods developed by ASTM International for determining the boiling range characteristics of petroleum products through controlled laboratory conditions. These methods are essential for assessing the volatility and performance of fuels and other petroleum-based substances [15].

Significance[16]

- Optimization of refining processes
- Quality control and ensuring safety in handling and use of petroleum products
- Prediction in performance characteristics and in meeting industry specifications

3. Materials and Methods

The experimental samples taken were diesel and ethanol. Diesel was taken from local commercial station. Ethanol was taken from laboratory. It was dried using molecular sieves before the preparation of blends. Blends of diesel with varying percentages of ethanol were made in Laboratory. The percentwise composition of ethanol-diesel was (5%, 10%,20%,40%,60%,80%,100%).The flash point was measured using a Cleveland Open Cup apparatus. Apparatus includes Test cup, Heating plate, Test flame applicator and Thermometer. Before starting the experiment, it is ensured that all components of Open cup are clean and free from contaminants. Apparatus was placed on stable surface and well-ventilated area. Sample was taken in open cup up to the marked fill line. Heat plate was utilized to provide uniform heat to the test cup, ensuring controlled and consistent temperature increase. Thermometer was inserted into its holder, ensuring sensing element is immersed in the sample without touching the cups bottom. Heating source was activated to raise temperature at a rate of 5 to 6 ℃ per minute. Temperature was continuously monitored throughout the process.Flash was checked by using test flame applicator in a specific interval of time. Recorded the temperature at which this flash occurs as the flash point.and the temperature recorded where the sample sustain the combustion for at least 5 seconds and it is recorded as fire point. Thermometer taken was calibrated according to ASTM specifications, capable of accurately measuring the temperature within the expected flash point range.

The laboratory ASTM Distillation apparatus includes Heater unit, Condenser unit, receiving cylinder and Thermometer. The sample flask of resistant glass was used for filling sample for distillation. And Condenser was set up ensuring the efficient condensation of vapors. Flask and condenser joints were connected ensuring airtight to prevent vapor loss. Thermometer was placed inside the flask ensuring the bulb is positioned at the specified height above the liquid level as per ASTM D86 guidelines. The temperature recorded was Initial boiling point, 10%, 20%,305 40% 50%,60%,70%,80%, and 90%. After cooling the apparatus, the residue was also measured.

4.Results and discussion

Table 1. ASTM Distillation and Flash point determination of petroleum products

Sample	IBP	T10	T30	T50	T70	T90	Flash point
Diesel	185	220	260	300	350	370	74
5%(Et+D)	175	210	250	290	330	360	41
10%(Et+D)	170	200	240	275	310	340	38
20% (Et +D)	160	180	220	250	280	310	37
40%(Et+D)	140	160	190	200	220	250	35
60%(Et+D)	110	130	150	160	180	200	31
80%(Et+D)	90	100	120	140	160	180	30
Ethanol	78	80	82	82	82	84	29

Table 1.shows Initial boiling point (IBP), T10,T30, T50,T70 and T90 temperatures and flash point across different blending percentages. From the table diesel has highest IBP, and ethanol has lowestIBP. ethanol content increases IBP decreases.Shows ethanol-rich blends evaporate faster than pure diesel.Diesel has highest T90 means it retains heavier fraction but ethanol has lower shown better volatility. Diesel has highest flash point means it’s harder to ignite while ethanol blends shows low flash point means blending makes fuel more flammable.Blends with 40% ethanol and more have flash point close to ethanolshowing higher volatility and easier ignition.From this table it is is observed that higher ethanol content results in lower boiling point

and flash points. Because of lower boiling points, combustion efficiency enhances.and lower flash point causes easier ignition but increases hazards of fire also.

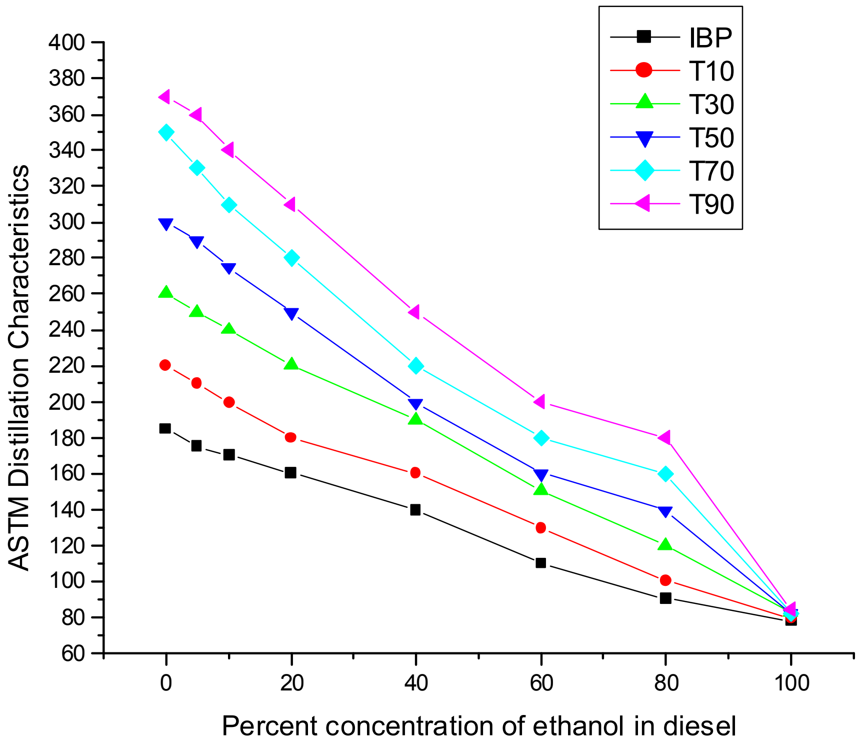

Figure. 1. Percent composition of ethanol-diesel vs ASTM Distillation characteristics

Figure 1. presents the ASTM distillation characteristics of ethanol-diesel blends, illustrating the effect of increasing ethanol concentration on the boiling behavior of the mixture.The plot includes key distillations temperatures such as Initial boiling point(IBP), T10, T30,T50,T70, and T90, which indicates the percentages of the fuel evaporated at each temperature.It is observed that IBP drops as percent of ethanol increases.Pure diesel has higher IBP than blended diesel.As ethanol percent increases distillation points shifts to lower temperaturesT90 decreases as ethanol increasesshowing the absence of high molecular weight diesel fractions in blends.

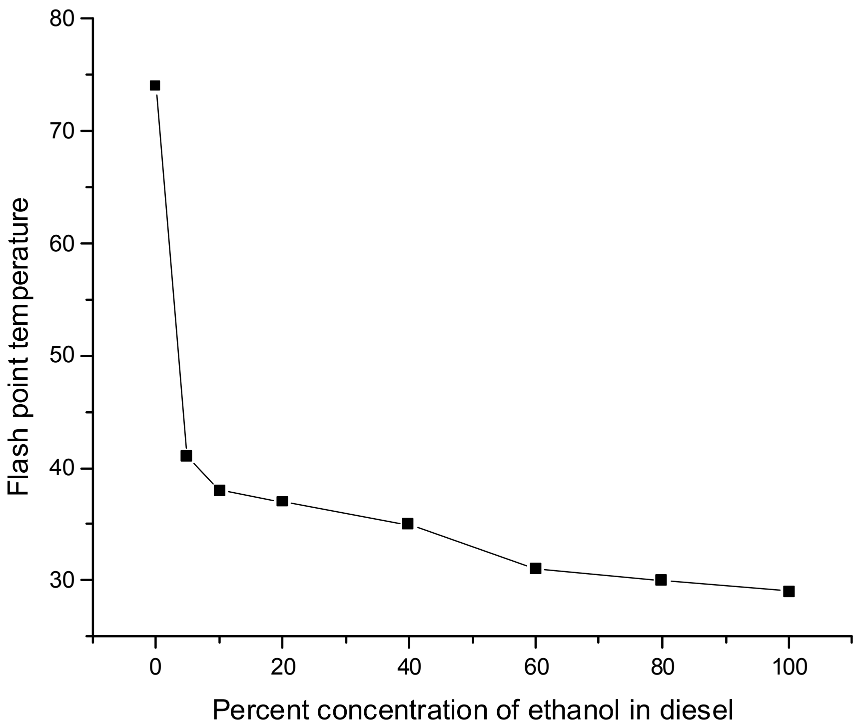

Figure 2. Effect of ethanol-diesel composition on flash point

From figure 2. It can be discussed that Diesel has a high flash point, but even a small amount of ethano, significantly lowers it due to ethanol's lower flash point.As ethanol concentration increases , the flash point continues to decrease but at a slower rate. This could be due to ethanol dominating the mixtures volatility. For ethanol flash point reaches a low value, aligning with ethanol's intrinsic flash point.

5. Conclusion:

The analysis of flash point, distillation characteristics(T10,T30,T50,T70,T90), and ethanol-diesel composition provides valuable insights into the combustion behavior and safety of fuel blends.The sharp decline in flash point with increasing ethanol content highlights the significant impact ethanol on fuel volatility, making it a crucial parameter for assessing ignition properties and handling safety.

So this research confirms the viability of ethanol blending for diesel, offering potential environmental and performance benefits. However, higher ethanol concentrations require careful handling, storage adaptations and engine modifications to mitigate volatility and ignition risk. This study contributes to the ongoing research on alternative fuel blends and provides valuable insights into the feasibility of ethanol as a sustainable diesel additive. These properties are essential for optimizing fuel formulations, ensuring regulatory compliance and predicting combustion performance in engines. By leveraging these parameters, researchers and industry professional can efficiently classify fuel blends, enhance safety protocols, and improve engine efficiency through better fuel selection.

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