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AN AUTONOMOUS INSTITUTION



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DEPARTMENT OF AGRICULTURE ENGINEERING

COURSE CODE & NAME: 16AGT301 & HEAT POWER ENGINEERING

III YEAR / V SEMESTER

UNIT : 1 FUELS AND COMBUSTION
TOPIC 6 : Power Alcohol and Biodiesel



POWER ALCOHOL



- When ethyl alcohol is used as fuel in internal combustion engine, it is called as "power alcohol". Generally ethyl alcohol is used as its 5-25% mixture with petrol.
Advantages of power alcohol:
- Ethyl alcohol has good antiknocking property and its octane number is 90, while the octane number of petrol is about 65. Therefore, addition of ethyl alcohol increases the octane number of petrol.
- Alcohol has property of absorbing any traces of water if present in petrol. If specially designed engine with higher compression ratio is used, then disadvantage of lower calorific value of ethyl alcohol can be overcome. Ethyl alcohol contains 'O' atoms, which helps for complete combustion of power alcohol and the polluting emissions of CO, hydrocarbon, particulates are reduced largely.
Use of ethyl alcohol in petrol reduces our dependence on foreign countries for petrol and saves foreign considerably.
-Power alcohol is cheaper than petrol.



Disadvantages of power alcohol:

- Ethyl alcohol has calorific value 7000cal/gm much lower than calorific value of petrol 11500cal/gm. Use of power alcohol reduces power output upto 35%.
- Ethyl alcohol has high surface tension and its atomisation, especially at lower temperature, is difficult causing starting trouble.
- Ethyl alcohol may undergo oxidation reaction to form acetic acid, which corrodes engine parts.
- As ethyl alcohol contains 'O' atoms, the amount of air require for complete combustion of power alochol is lesser and therefore carburettor and engine need to be modified, when only ethyl alcohol is used as fuel.



PRODUCTION OF ETHANOL



The basic steps for large scale production of ethanol are: microbial ([yeast](#)) [fermentation](#) of sugars, [distillation](#), [dehydration](#) (requirements vary, see Ethanol fuel mixtures, below), and [denaturing](#). Prior to fermentation, some crops require [saccharification](#) or [hydrolysis](#) of carbohydrates such as cellulose and starch into sugars. Saccharification of cellulose is called [cellulolysis](#). Enzymes are used to convert starch into sugar.

- **Fermentation**

- Ethanol is produced by [microbial fermentation](#) of the sugar. Microbial fermentation will currently only work directly with [sugars](#). Two major components of plants, [starch](#) and cellulose, are both made up of sugars, and can in principle be converted to sugars for fermentation. Currently, only the sugar (e.g. sugar cane) and starch (e.g. corn) portions can be economically converted. There is much activity in the area of cellulosic ethanol, where the cellulose part of a plant is broken down to sugars and subsequently converted to ethanol.



- **Distillation**

- For the ethanol to be usable as a fuel, the majority of the water must be removed. Most of the water is removed by [distillation](#), but the purity is limited to 95–96% due to the formation of a low-boiling water-ethanol [azeotrope](#) with maximum (95.6% m/m (96.5% v/v) ethanol and 4.4% m/m (3.5% v/v) water). This mixture is called hydrous ethanol and can be used as a fuel alone, but unlike [anhydrous](#) ethanol, hydrous ethanol is not miscible in all ratios with gasoline, so the water fraction is typically removed in further treatment in order to burn in combination with gasoline



Dehydration

- There are basically three dehydration processes to remove the water from an azeotropic ethanol/water mixture. The first process, used in many early fuel ethanol plants, is called azeotropic distillation and consists of adding benzene or cyclohexane to the mixture.
- When these components are added to the mixture, it forms a heterogeneous azeotropic mixture in vapor-liquid-liquid equilibrium, which when distilled produces anhydrous ethanol in the column bottom, and a vapor mixture of water, ethanol, and cyclohexane/benzene.
- When condensed, this becomes a two-phase liquid mixture. The heavier phase, poor in the entrainer (benzene or cyclohexane), is stripped of the entrainer and recycled to the feed, while the lighter phase together with condensate from the stripping is recycled to the second column.
- Another early method, called extractive distillation, consists of adding a ternary component which will increase ethanol's relative volatility. When the ternary mixture is distilled, it will produce anhydrous ethanol on the top stream of the column.



With increasing attention being paid to saving energy, many methods have been proposed that avoid distillation altogether for dehydration. Of these methods, a third method has emerged and has been adopted by the majority of modern ethanol plants. This new process uses [molecular sieves](#) to remove water from fuel ethanol.

- In this process, ethanol vapor under pressure passes through a bed of molecular sieve beads. The bead's pores are sized to allow absorption of water while excluding ethanol. After a period of time, the bed is regenerated under vacuum or in the flow of inert atmosphere (e.g. N₂) to remove the absorbed water.
- Two beds are often used so that one is available to absorb water while the other is being regenerated. This dehydration technology can account for energy saving of 3,000 btus/gallon (840 kJ/L) compared to earlier azeotropic distillation.



BIODIESEL



- A fuel derived from organic oils, such as vegetable oil, rather than petroleum. Biodiesel's use and production are increasing. It's typically used for aircraft, vehicles and as heating oil.

Transesterification

- Animal and plant fats and oils are composed of triglycerides, which are esters containing three free fatty acids and the trihydric alcohol, glycerol. In the transesterification process, the alcohol is deprotonated with a base to make it a stronger nucleophile.
- Commonly, ethanol or methanol are used. As can be seen, the reaction has no other inputs than the triglyceride and the alcohol. Under normal conditions, this reaction will proceed either exceedingly slowly or not at all, so heat, as well as catalysts (acid and/or base) are used to speed the reaction.
- It is important to note that the acid or base are not consumed by the transesterification reaction, thus they are not reactants, but catalysts. Common catalysts for transesterification include sodium hydroxide, potassium hydroxide, and sodium methoxide.



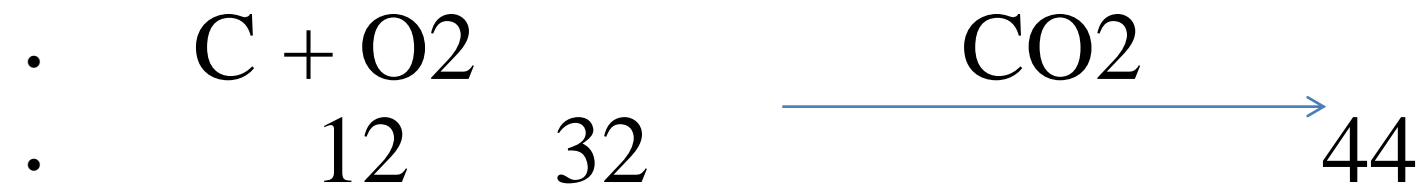
- Almost all biodiesel is produced from virgin vegetable oils using the base-catalyzed technique as it is the most economical process for treating virgin vegetable oils, requiring only low temperatures and pressures and producing over 98% conversion yield (provided the starting oil is low in moisture and free fatty acids). However, biodiesel produced from other sources or by other methods may require acid catalysis, which is much slower.



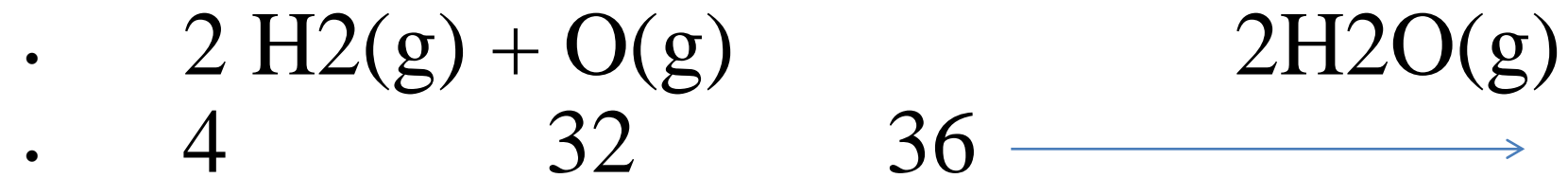
Theoretical calculation of calorific value



1. Elements always combine in definite proportions to give the products. For example 12 gm of carbon combines with 32 gm of oxygen to give 44 gm of CO₂



Similarly, 4gm of hydrogen combines with 32gm of oxygen to give 36gm of H₂O.



2. At STP (273 K, 1 atm) one mole of all gases occupy a volume of 22.4litres. Hence at S.T.P. 22.4 liters of CO₂ will have a weight of 44gm, its molecular weight.

3. Air contains 21 % of oxygen by volume and 23 % of oxygen by weight, Hence 1 m³ of oxygen will be supplied by

$$\frac{1 \times 100}{21} = 4.76\text{m}^3 \text{ of air}$$



- Similarly 1 kg of oxygen will be supplied by $\frac{1 \times 100}{23} = 4.35$ kg of air.
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- 4. Molecular weight of air is 28.94 mol⁻¹.
- 5. Minimum oxygen required = (Theoretical O₂ required) - (O₂ present in fuels).
- 6. The mass of flue gas is calculated by balancing the carbon in the fuel and the carbon in the flue gas.
- 7. Minimum O₂ required is calculated on the basis of complete combustion of fuel. If as a result incomplete combustion or CO is formed then O₂ is calculated for the conversion of CO to CO₂.
- 8. If the fuel contains both O₂ and H₂, the amount of hydrogen and oxygen may be present in the form of as H₂O, which is a non-combustible substance. The remaining available hydrogen takes part in the combustion reaction.
- $2 \text{H}_2(\text{g}) + \text{O}(\text{g}) \xrightarrow{\quad 2\text{H}_2\text{O} \quad}$



- 32 gm of oxygen combines with 4gm of hydrogen, Hence 1 part of hydrogen combines with 8 parts of oxygen.

- Hence, theoretical amount of oxygen required for complete combustion of 1 kg of fuel is given by the equation,
- $\{32/12 \times C + 8[H - O/8] + S\}$ kg

C, H and S are masses of carbon, Hydrogen and sulphur respectively per kg of the fuel. Since 1 kg of air contains 23% of oxygen by weight, the amount of air required theoretically to burn 1 kg of fuel completely is given by equation.

- $100/23 \{32/12 \times C + 8[H - O/8] + S\}$ Kg



- According to Dulong's formula for the theoretical calculation of calorific value is,
$$\frac{1}{100} [8080C + 34500 (H - \frac{O}{8}) + 2240S] \text{ Kcal/kg}$$
- Where C, H, O and S represent the % of the corresponding elements in the fuel. It is based on the assumption that the calorific value or c, H and S are found to be 8080, 34500 and 2240 kcal, when 1 kg of the fuel is burnt completely.
- However, all the oxygen in the fuel is assumed to be present in combination with hydrogen in the ratio H:O as 1:8 by weight. So the surplus hydrogen available for combustion is ' $H - \frac{O}{8}$ '.
- $\text{NCV (or) LCV} = [\text{HCV} - \frac{9}{100}H \times 587] \text{ kcal.kg}$



Theoretical calculation of minimum air requirement for combustion of a fuel



- Combustion is the process of burning any combustible substance in the presence of oxygen, which liberates energy in the form of heat and light. For efficient combustion, it is essential that the fuel must be brought into intimate contact with sufficient quantity of air or oxygen.
- The combustible substance usually present in fuels, which enter into the combustion, are mainly C, H, S and O. But N, CO₂ and ash are incombustible matters present in the fuel, .do not take any oxygen during combustion.
- For the complete combustion of a given quantity of fuel can be calculated by considering the following point. Substances always combine in definite proportions, which are determined by the molecular weights of the substances.



- **i) Combustion of carbon**



- 12 parts by weight-of carbon requires 32 parts by weight of oxygen for complete combustion. 'C' parts by weight of carbon requires $= 32 \text{ C} / 12 = 2.67 \text{ C}$

- $(\text{H} - \text{O}/8)$ parts by weight of hydrogen requires = $\frac{(\text{H} - \text{O}/8) \times 32}{4}$

- $= 8 (\text{H} - \text{O}/8)$

- **ii) Combustion of hydrogen**

- . When oxygen is present in the fuel, it always combines with hydrogen. The combined hydrogen does not take part in combustion reaction. Therefore, the quantity of combined hydrogen must be ~~deduced from~~ the total hydrogen in the fuel.





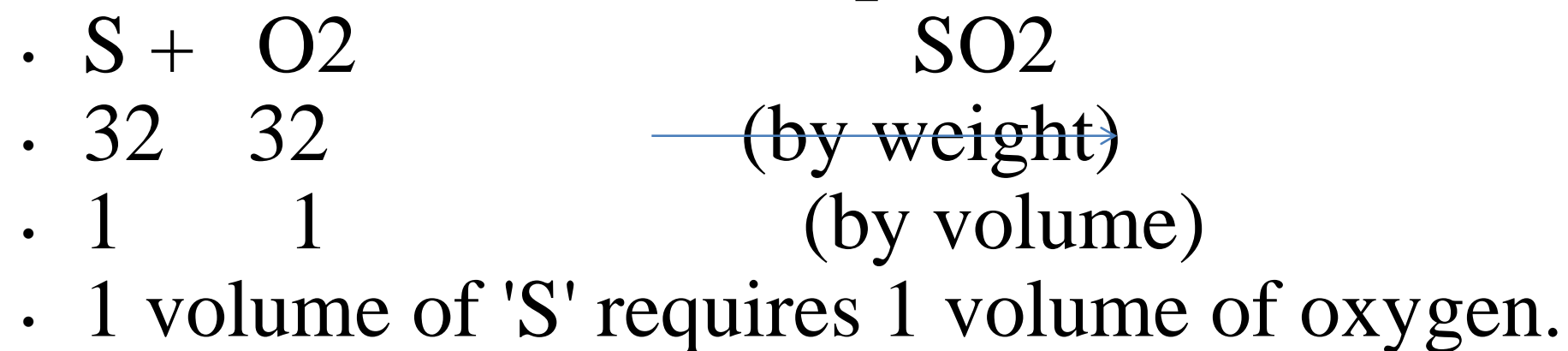
- 4 parts by weight of H₂ requires 32 parts by weight O₂ (or) 2 parts by volume of H₂ require 1 part by volume of O₂
- There fore 'H' parts by weight of hydrogen require $\frac{32x H}{4}$ parts by weight of O₂.



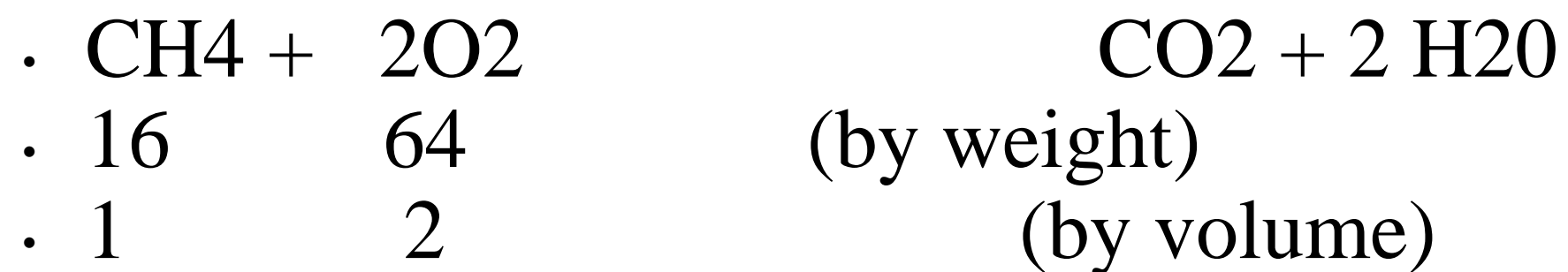
- **iii) Combustion of carbon monoxide**
- $CO + \frac{1}{2} O$ CO_2
-
- 28 16 (by weight)
-
- 1 0.5 (by volume)
- 1 volume of CO requires 0.5 volume of oxygen.



- **iv) Combustion of sulphur**



- **v) Combustion of methane**





Problems For the calculation of Calorific value

- Calculate the gross and net calorific values of a coal sample having the following composition C = 80%; H = 7%; O = 3%; S = 3.5%; N = 2.5% and ash 4.4%
- Solution
- (I) $G.C.V = 1/100[8080*\%C+34500(\%H - \%O/8)+2240*\%S]$ kcal/kg
- $= 1/100[8080*80+34500(7 - 3/8)+2240*3.5]$ kcal/kg
- $= 8828.0$ kcal/kg
- , ,
- (II) $N.C.V = G.C.V - [0.09H*587]$ kcal/kg
- $= 8828 - [0.09*7*587]$ kcal/kg
- $= 8458.2$ kcal/kg



THANK YOU..!!