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WASTE TO ENERGY CONVERSION

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DENSIFICATION OF BIOMASS

- Increase in the density
- Two phases in the densification process :
  - Compression of the loose material
  - Agglomeration/binding so that the product remains in the compressed state
- Two types of densified products
  - Briquettes (>30 mm dia)
  - Pellets (<30 mm dia)
- Advantages :
  - Easier handling and storage
  - Reduced cost of transportation

Densification

https://woodpellet.in/rice-straw-pellet-plant

http://briquettemachine.com/how-to-make-biomass-briquette-and-pellet-biofuel-technology/

Factors affecting densification

- Pressure
  - Increasing P increases density, strength and durability of the products
  - But, higher P ➔ higher energy consumption
- Moisture content
  - Moisture can act as a binder
  - 10 – 20 wt.% moisture is ideal
- Particle size
  - Smaller the particle size, better the quality of densified products
- Temperature :
  - Preheating the biomass up to 70 ^{o}C leads to better densification
  - Heating reduces the resistance to compaction in the biomass
- Binders:
  - Organic binders : Bitumen, molasses, starch, resins
  - Inorganic binders : Cement, clay, lime

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Carbonization

- Slow pyrolysis up to 600 ^{o}C
- Overcomes some of the demerits of direct burning of briquettes
  - Lesser smoke generated from carbonized biomass
  - Better ignition and burning properties
  - Better heating value
- Biomass can be carbonized before and after briquetting
- Hydrothermal carbonization – Pyrolysis in the presence of water

Quality testing

- Friability
  - Measurement of mechanical resistance during handling
  - Friability index of zero means it is a very low quality briquette
- Resistance to humidity
  - Immersion test – Briquettes are dunked in water and the time required to disintegrate is noted
  - Exposure to humid air – After 21 days in 95% humid air, their expanded volume is measured. Less than 30% is acceptable

Efficiency of a power plant

- Thermal efficiency, $\eta = \frac{Energy\ generated * time}{Yield\ of\ fuel * Calorific\ value\ of\ the\ fuel}$
  - Depends on process design on the plant
  - Heat recovery from the products and flue gases
  - Efficiency and quantity of boilers and heat exchangers
- Thermodynamic efficiencies (How much of energy is converted to work in a heat engine or how much of work is used to remove heat in a refrigerator)
  - Carnot cycle, Brayton cycle, Rankine cycle
- Energy recovery ratio, $ECR = \frac{Energy\ consumed\ by\ the\ process}{Energy\ output\ from\ the\ process}$
  - ECR < 1 ➔ Process is energetically feasible

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1) A MSW has the following composition on mass basis: C: 35.5 (%), H: 10.8 %, O: 27.6 %, N: 0.35 %, S: 0.15 %, Moisture: 20.5% and Ash: 5.1%. Determine the heating value of the MSW (0n wet basis). Use the formula HHV in MJ/Kg = 0.3516*C + 1.16225*H - 0.1109*O + 0.0628*N + 0.10465*S for computing heating value.

- 22.011 MJ/kg
- 29.59 MJ/kg
- 391.60 MJ/kg
- 28.391 MJ/kg

Accepted Answers:
22.011 MJ/kg

HHV = (0.3516*35.5)+(1.16225*10.8)-(0.1109*27.6)+(0.0628*0.35)+(0.10465*0.15) = **22.011 MJ/kg**

Basis – 100g of MSW

C = 35.5g, H = 10.8g, O = 27.6g, N = 0.35g,

S = 0.15g, Moisture = 20.5g, Ash = 5.1g

$$\text{Wt. \% of } C = \frac{Wt.of\ C * 100}{100 - Moisture - Ash} = \frac{35.5 * 100}{100 - 20.5 - 5.1} = 47.7\%$$

$$\text{Wt. \% of H} = \frac{Wt.of\ H * 100}{100 - Moisture - Ash} = \frac{10.8 * 100}{100 - 20.5 - 5.1} = 14.5\%$$

$$\text{Wt. \% of } O = \frac{Wt.of\ O * 100}{100 - Moisture - Ash} = \frac{27.6 * 100}{100 - 20.5 - 5.1} = 37.1\%$$

$$\text{Wt. \% of } N = \frac{Wt.of\ N * 100}{100 - Moisture - Ash} = \frac{0.35 * 100}{100 - 20.5 - 5.1} = 0.47\%$$

$$\text{Wt. \% of } S = \frac{Wt.of\ S * 100}{100 - Moisture - Ash} = \frac{0.15 * 100}{100 - 20.5 - 5.1} = 0.2\%$$

HHV = (0.3516*47.7) + (1.16225*14.5) - (0.1109*37.1) + (0.0628*0.47) + (0.10465*0.2) = **29.59 MJ/kg**

2) Tyres can be disposed of using a process known as pyrolysis. 41% by mass of a car tyre can be converted into carbon and 32% by mass can be converted into gas, which is predominantly methane. If a car tyre has a mass of 10kg and if 60000 tyres are treated in this way each year in a city. What volume of methane, at room temperature and pressure, is produced in this process?

- $4.86 \times 10^3\ m^3$
- $2.68 \times 10^5\ m^3$
- $5.28 \times 10^6\ m^3$
- $5.36 \times 10^9\ m^3$

Accepted Answers:

$2.68 \times 10^5\ m^3$

Mass of 60000 tyres = $60000*10 = 6 \times 10^5$ kg

Mass of methane = $0.32 \times 6 \times 10^5 = 1.92 \times 10^5$ kg

Mol wt. of methane = 16

Moles of methane = $1.92 \times 10^5 / 16 = 1.2 \times 10^4$ kmol = 1.2×10^7 moles

1 Mole of gas occupies 22.4 L or 22.4×10^{-3} m^3 of volume at room T and P

Volume of methane = $1.2 \times 10^7 \times 22.4 \times 10^{-3}$

= **$2.688 \times 10^5\ m^3$**

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3) What is the value of pressure in low pressure compaction type briquetting technology?

- Upto 5 MPa
- 100 MPa
- 5-100 MPa
- 100-120 Mpa

Accepted Answers:
Upto 5 MPa

Rage of pressures
Low Pr. : up to 5 MPa
Intermediate Pr.: 5-100 MPa
High Pr.: 100 MPa

4) The speed of densification, the energy consumption and the quality of briquettes for screw extruder depends on which factors?

- Flow ability and cohesion of the feed material
- Particle size and distribution
- Surface forces
- All of the above

Accepted Answers:
All of the above

5) Which of the following statement is the most appropriate about friability test?

- It tests the durability of briquettes
- Zero Friability index indicates that briquettes are disintegrated entirely after a certain time
- Both (a) and (b)
- None of the above

Accepted Answers:
Both (a) and (b)

6) Which of the following is true about densification of fuel / biomass ?

- Space between particles is reduced
- It gives more uniform properties to fuel with respect to its raw form
- Under high pressure it results in mechanical interlocking of the solid particles
- All of these

Accepted Answers:
All of these

7) Which of the following statement is the most appropriate about the application of briquettes?

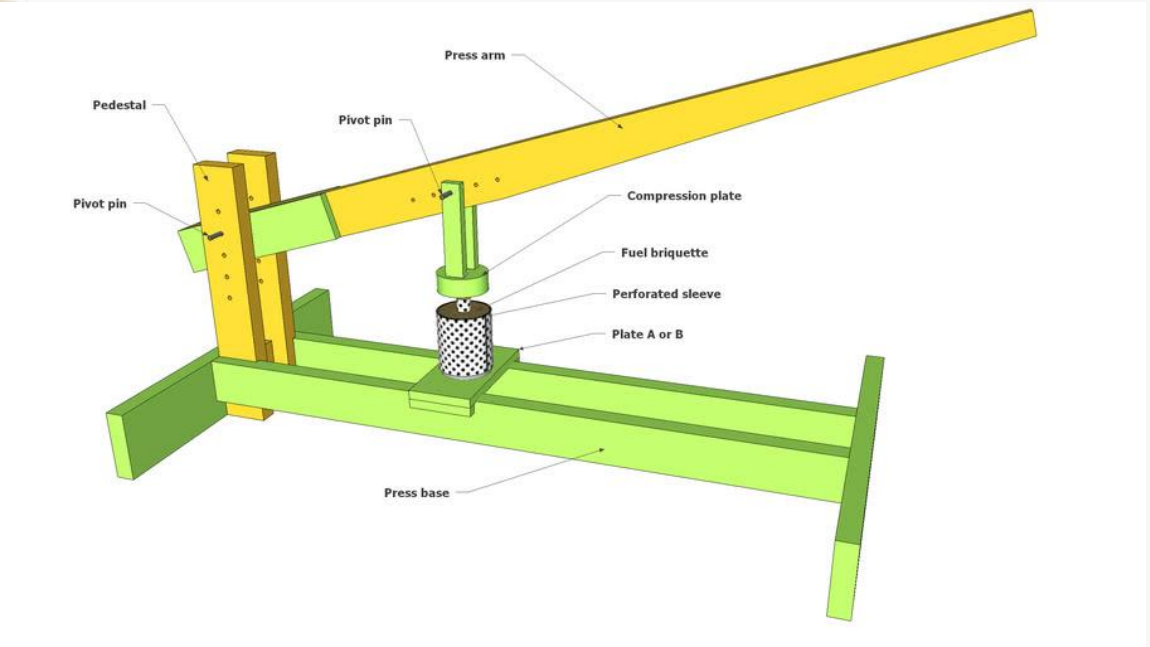
- Can be used in open or semi-open cooking stoves which use wood or charcoal in households or small commercial operations.
- Can be used in kilns of various kinds for brick or ceramic making normally burning wood.
- Both (a) and (b)
- None of these

Accepted Answers:
Both (a) and (b)

8) Which of the following is a part of manual briquette machine?

- Base plate
- Ejection piston
- Briquette die
- All of the above

Accepted Answers:
All of the above



9) Which of the following indicates the formula for thermal efficiency? (Where: MC – quantity of fuel / feed consumed; CV-calorific value of feed)

- Thermal efficiency (η) = (energy generated/ MC * CV) X 100
- Thermal efficiency (η) = (energy generated*time/ MC * CV) X 100
- Thermal efficiency (η) = (energy generated*time/ CV) X 100
- Thermal efficiency (η) = (energy generated*time/ MC) X 100

Accepted Answers:
*Thermal efficiency (η) = (energy generated*time/ MC * CV) X 100*

10) Which of the following option appropriately connects the processes with their meaning as provided in the table below?

Process	Meaning
1) Friability	a. Conversion of an organic substance into carbon or carbon containing residue
2) Carbonization	b. Process of increasing density of something
3) Trigeneration (CCHP)	c. Measurement of the briquette's resistance to mechanical action during handling.
4) Densification	d. Simultaneous generation of electricity and useful heating and cooling from combustion of a fuel

- 1-c 2-a 3-b 4-d
- 1-b 2-a 3-d 4-c
- 1-c 2-a 3-d 4-b
- 1-d 2-a 3-c 4-b

Accepted Answers:
1-c 2-a 3-d 4-b