Technologies for Clean and Renewable Energy Production
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Lecture - 38
Energy from Biomass and Wastes 3 (Physical Route)

Hi friends, now we will discuss on the topic renewable energy, biomass and waste part 3. So, previously we have discussed on biomass and waste in part 1 and part 2 and chemical routes and biological routes we have discussed, and here will discuss on physical routes which is used for making the biomass and waste suitable for its application in reactors or in say thermal applications like if I want to use the biomass and waste incinerator or in gasifiers, then we need to make it in a usable form. That means, normally the biomass and waste are having less density and it is difficult to handle in reactive system. So, this physical process helps to make it harder to give some particular strength and save also and it becomes easy to use in the conversion process like incineration, gasification, etc.

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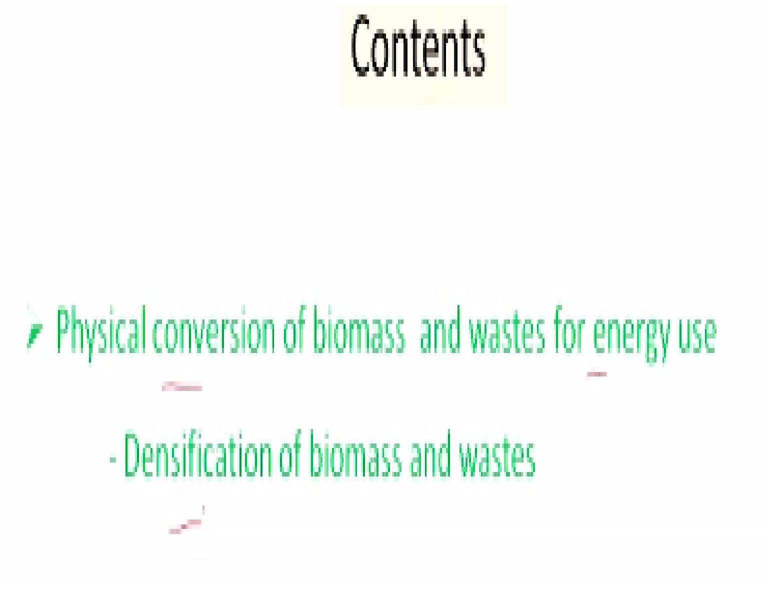

So, the content of this class is the physical conversion of biomass and waste for energy use and that will be giving some focus on the densification of biomass and waste. So, our objective will be to densify the biomass and waste to give certain strength, certain properties, which are more desirable for applications in energy production by this feedstock.

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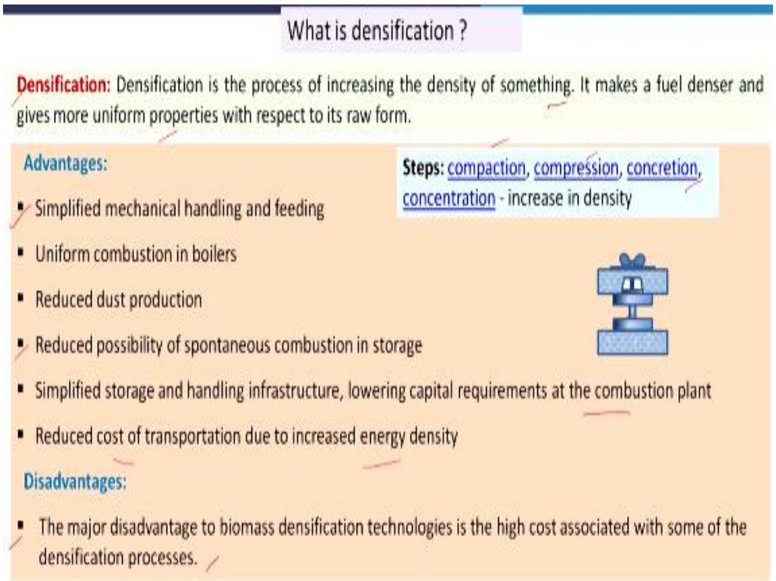

So the definition of densification will be like this. The densification is the process of increasing the density of something, it makes a fuel denser and gives more uniform properties with respect to the raw form. So, this is the main objective of the densification and densification can be done by some mechanism that is your compaction or compression, and concentrations and concretion. So, these are the steps which help to perform the densification process.

So, here we will put some material here and we press it, then it will be densified. Advantage of this process is that this is very simplified mechanical handling and feeding, and uniform combustion in boilers, the feed will be having almost uniform properties, then reduced dust production, reduced possibility of spontaneous combustion in storage, then simplified storage and handling infrastructure, lowering capital requirements at the combustion plant, and reduced cost of transportation due to increased energy density.

So, these are the advantage. Disadvantage is that the major disadvantage to biomass densification technologies is the high cost associated with some of the densification processes. So, we will see that densification processes are costlier in some cases. In some cases, it is not that costlier and people use that also.

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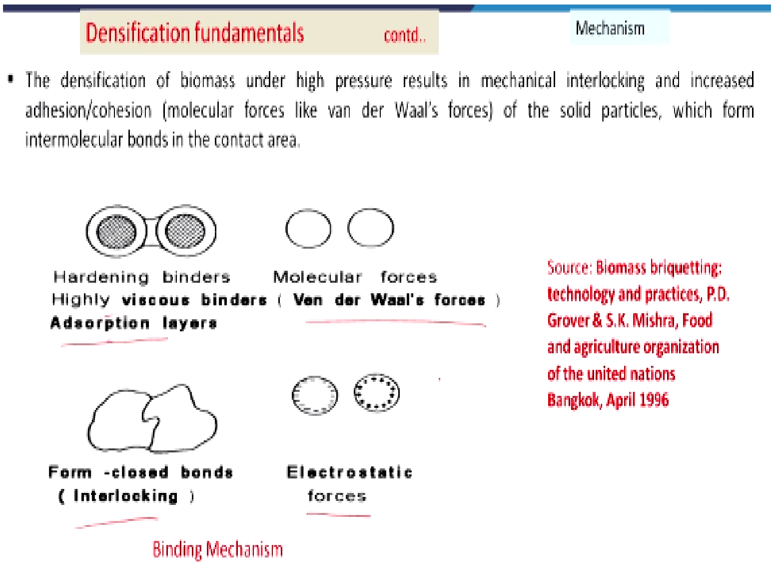

Then we will see the mechanism. So, you see the figure here. The molecular forces, van der waal's forces can be responsible for the binding, electrostatic forces can be responsible for the binding or interlocking, there will be some particles and those can be under pressure that can be interlocked or there will be some, if we add some additives, then hardening binders highly viscous binders, then also makes some adsorption layer and binders connect the particles of the biomass and waste and makes them strong. So, these are different processes, which are responsible for the densification of the biomass and waste.

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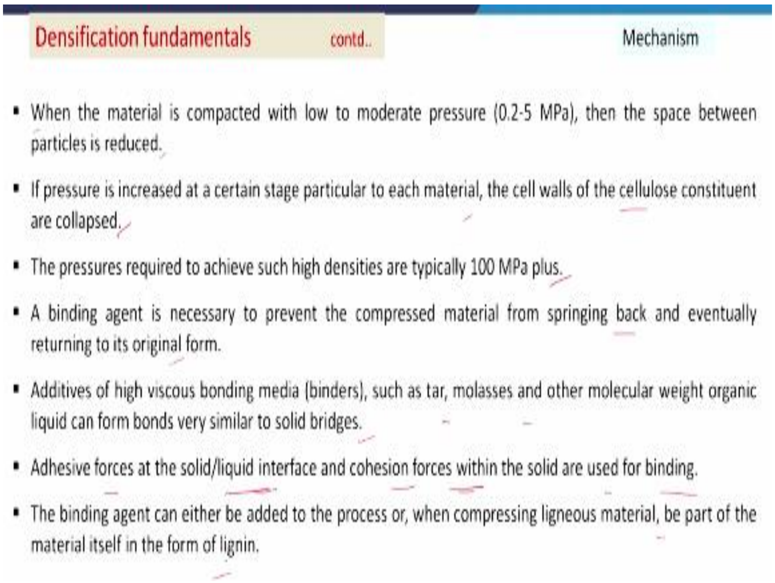

So, for this process, for densification process, we need some pressure, high pressure is required or we may add some binder. When we use binder, then the pressure requirement is less, and when we do not use binder, then pressure requirement is high. So, when the material is compacted with low to moderate pressure, then the space between the particles is reduced.

If pressure is increased at certain stage particular to each material, the cell walls of the cellulose constituent are collapsed.

Then the pressures required to achieve such high densities are typically 100 megapascal. So if we apply very high pressure, then the cellulosic materials maybe coming out and they can help for binding the particles. A binding agent is necessary to prevent the compressed material from springing back and eventually returning to its original form. If we do not use binders for at low pressure if it is initially, the particulars may be compressed and again it will be springing back. So, that is why binder is required.

Additives of high viscous bonding media such as tar, molasses, and other molecular weight organic liquid can from bonds very similar to solid bridges, so these the mechanism and adhesive forces at solid liquid interface and cohesion forces with the solid are used for binding. So, there are if it is a solid and liquid interface, there are adhesive forces and solid-solid interface, there will be some cohesive forces. So, these forces are responsible for the binding.

The binding agent can be either be added to the process or when compressing ligneous material, be part of the material itself in the form of lignin, that we are talking about that if we apply very high pressure, then lignin material can help to bind the biomass and waste particles.

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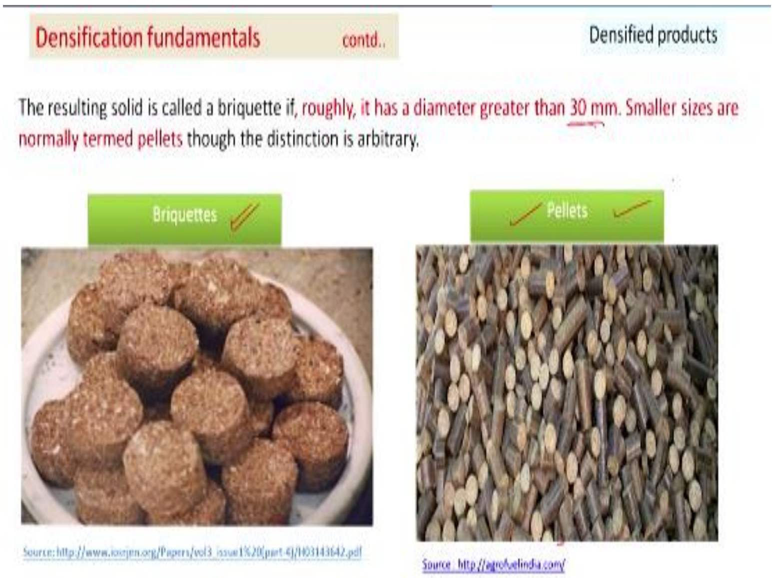

So, after the application of pressure, we will be getting the dense biomass and waste and that will be either in pellet forms or maybe in briquettes forms. The pellets are relatively smaller diameter, smaller size, and briquettes are bigger size. So, that is typical definition or we can say there is a typical limit of the diameter on the basis of which this can be said as briquettes or pellets that is equal to 30 millimeter. If diameter is greater than 30 millimeter, we can say it is briquettes, and if it is less than 30 millimeter, it is pellets, but this is the rough distinction and it is arbitrary also.

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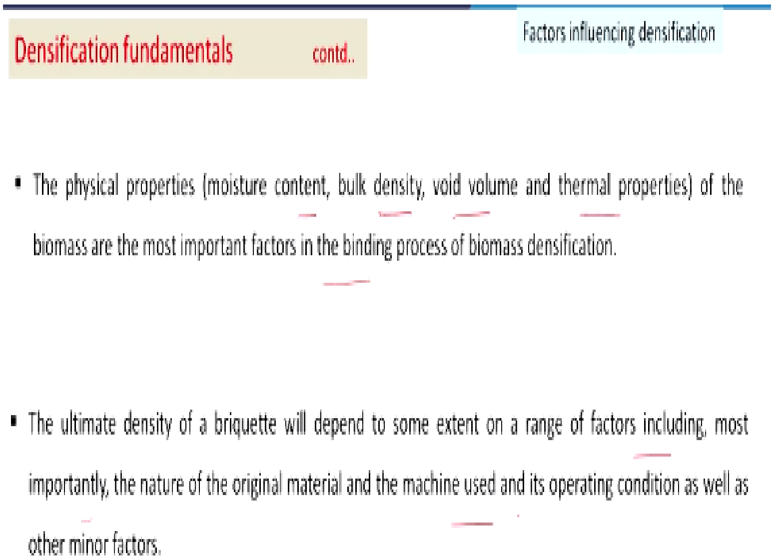

So, the factors which influence the densification we will discuss now. Under the physical properties, there is moisture content, bulk density, void volume as well as thermal properties of the biomass are the most important factors in the binding process or the biomass densification. So, what are the moisture content, bulk density, void volume and the thermal properties also are responsible for this.

The ultimate density of a briquette will depend on to some extent on a range of factors including most importantly the nature of the original material and the machine used for this operation and the conditions we have used.

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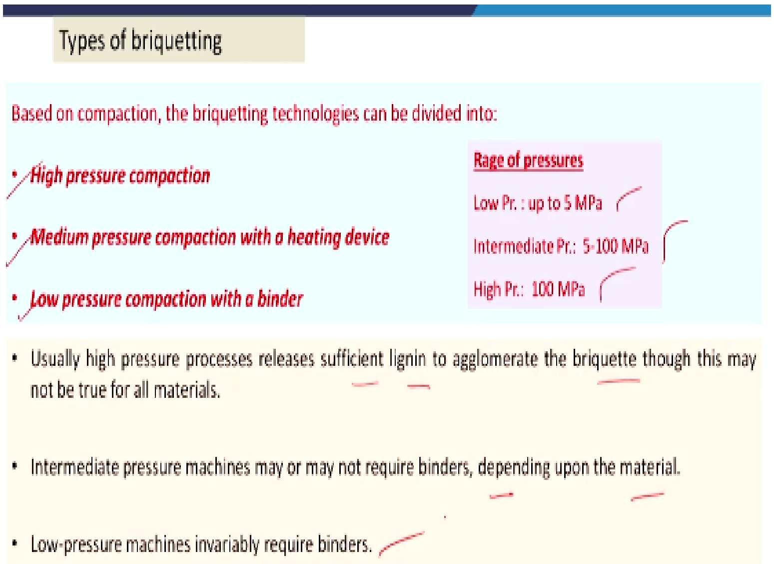

On that basis, we can have 3 types of briquetting process. One is your low pressure compaction with a binder, then medium pressure compaction with a heating, and high pressure compaction. So, there are 3 options the people have used for this binding process. In case of low pressure up to 5 megapascal, then up to intimidate it is 5-100 megapascal and high pressure means 100 megapascal pressure or more. So, when we use a high pressure, then sufficient lignin is released which helps to agglomerate the particles to and from the briquette.

An intermediate pressure machines may or may not require binders depending on the nature of the material, and low pressure machines positively require binders. So, these are 3 types of briquetting machines and briquetting processes.

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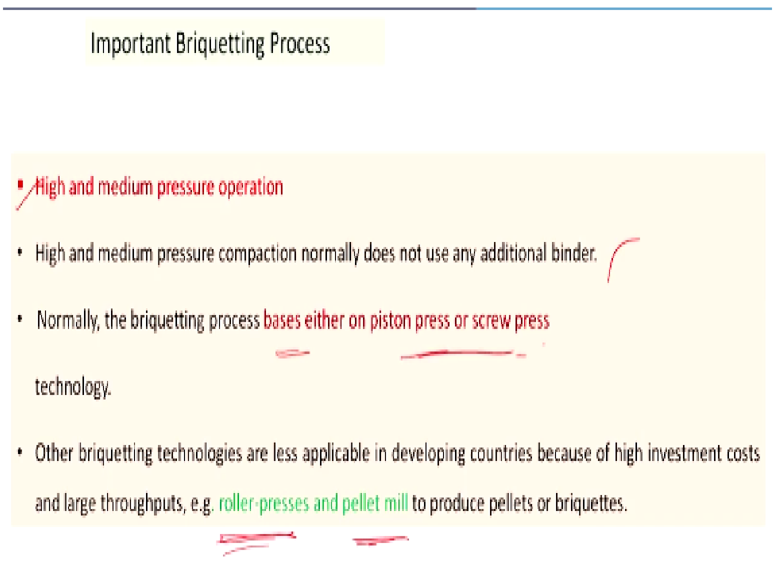

So, high and medium pressure operation if you consider, then high and medium pressure compaction normally does not use any additional binder as we have discussed. Then the briquetting process is based either on piston press or screw press. So mostly, piston press or screw press. Apart from these, there are some other also, roller press and pellet mill. So roller press and pellet mill can also be used, but these are having initial high investment cost, these require high initial investment costs and that is why this is not implemented in developing countries.

So these are also having high capacity, but biomass and waste are scattered source, so these are collection of these and then to convert it into this, that is not practices in a small sector, these collected and produce. So bigger scale machines is not used in developing countries. In this case, we get the piston press or screw press based machines.

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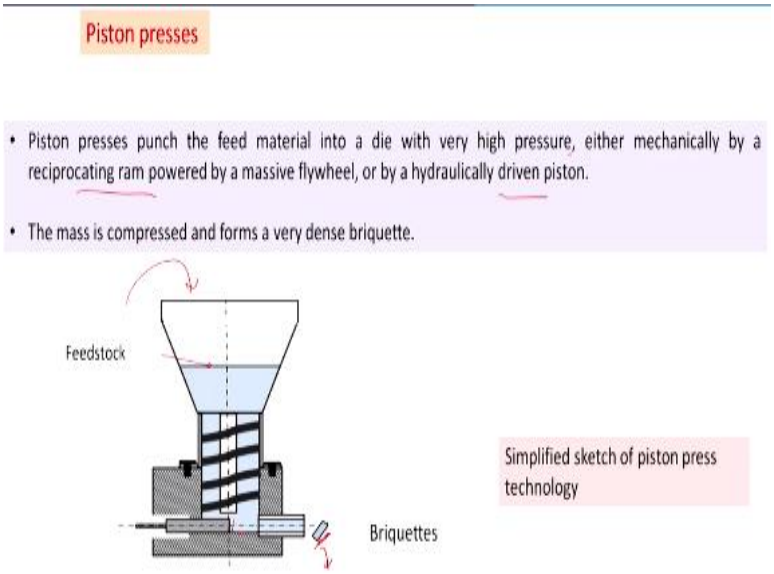

Now we will see the piston press. So here the figure shows the piston press. So this is the piston, so here if we put the feedstock, so feedstock under gravity it will go down and when it will come entering here, so this piston will have back and forth movement and this will be pressed here. So this, we are getting the briquette. So here, the piston can give us very high pressure. So the density of this material will be very high with respect to other method.

Something piston press punch the feed material into a die with very high pressure, either mechanically by reciprocating ram powered by the massive flywheel or by hydraulic driven piston. So, hydraulic driven pistons any mechanical arrangement is made and in this pressure developed here, and we get the briquette.

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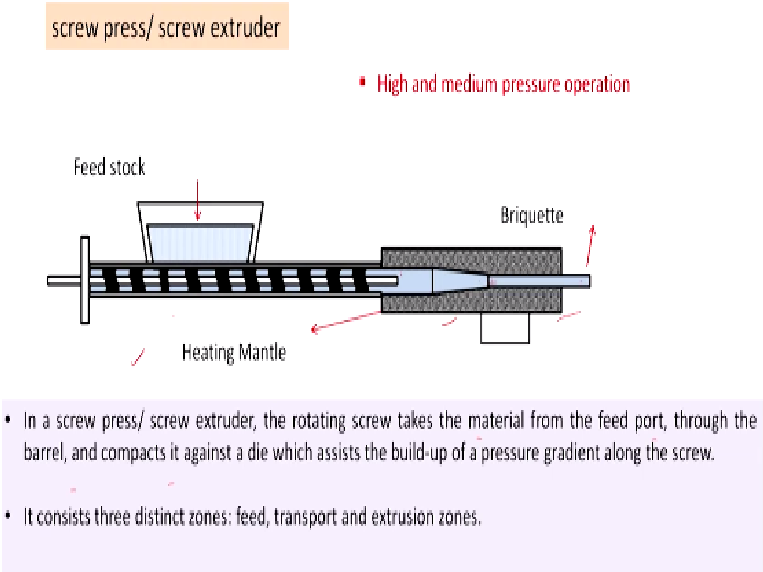

Now we will see the screw press. So, this is a figure which shows the operation of screw press. So we will feed the feedstock here and then the screw is moving. So, when the screw moves, then it gives some forward movement to the materials and materials moves towards this where the die is there. So, here the material is coming and pressure is developed. So, high pressure developed, then here, there is some briquette arrangement. So, briquette is going out due to the pressure.

Here, the diameter is high, here diameter is less, so there is some pressure. So, this pressure will also help to get the material out, we will get the briquette here. So, this is the mechanism of the operation of the screw press or the screw extruder. In a screw press/screw extruder, the rotating screw takes the material from feed port through the barrel and compacts it against a die which assists the buildup of a pressure gradient along the screw.

So, that we have discussed just now. It consist 3 distinct zones, here we are getting the feeding zone, then it is your transport zone and this zone is our extrusion zone here, this extrusion zone.

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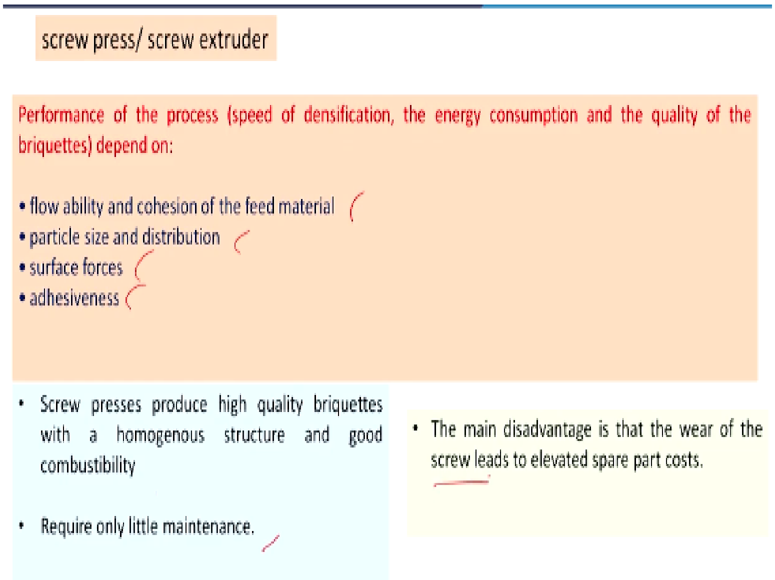

Now, the performance of the process will depend upon some factors that is your the ability and cohesion of the feed material, then the particle size and its distribution, surface forces and adhesiveness. So, these are the factors which influence the performance of the process. The screw presses produce high quality briquettes, this also produce high quality briquettes with a homogeneous structure and good combustibility and require only little maintenance.

So, the main disadvantage is that the wear of the screw leads to elevate the cost of the spare parts okay. So, the operating costs may be higher because of that wear of the screw.

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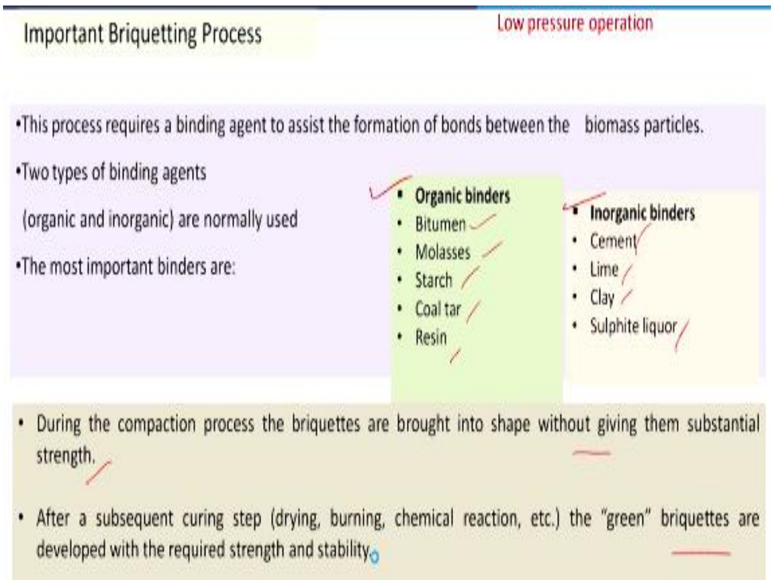

Then we are coming to low pressure operation. So under low pressure operation as we have mentioned that, we need to add some binder. So, here biomass and waste will be mixed with some binder and then initially some step will be given and then there will be some curing time. So that way, we have to use some binder and organic binders may be used or inorganic binders may be used.

So, different types of organic binders are provided here that is bitumen, molasses, starch, coal tar, and resin and inorganic cement, lime, clay, and sulphite liquor. So, these have been reported and used for the briquette formation. During the compaction process, the briquettes are brought into shape without giving them substantial strength, and after that, a subsequent curing step, drying, burning, chemical reaction, etc., the green briquettes are formed. So, these green briquettes developed and with the required strength and stability.

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Comparison of different densification Processes

Parameter	Densification Technology			
	Screw press	Piston Press	Roller press	Pellet mill
Optimum moisture content of the raw material (%)	4 - 8	10 – 15	10 – 15	10 – 15
Particle size (mm)	2 - 6	6 - 12	< 4	< 3
Wear of contact parts	High	Low	High	High
Output from machine	Continuous	In strokes	Continuous	Continuous
Specific energy consumption (kWh/t)	37 – 150	37 – 77	30 – 83	16 – 75
Through puts (ton/hr)	0.5	2.5	5 – 10	5
Unit density (g/cm^3)	1.0 – 1.4	2.5	0.4 – 0.6	1.1 – 1.2
Bulk density (g/cm^3)	0.5 – 0.6	< 0.1	-	0.7 – 0.8
Maintenance	Low	High	Low	Low
Combustion performance of briquettes	Very good	Moderate	Moderate	Very good

Source: A review of biomass densification systems to develop uniform feedstock commodities for bioenergy application, J.S.Tumuluru, Biofuels ,Bio products,Bio refining,2011

Now, we will see the comparison of different machines. So, we have screw press, we have piston press, we have roller press, we have pellet mills. So, these two mills are high initial cost, but these can be used for the production of very large amount of products also. The throughput is high in these two cases. When we compare, then we see the piston press, we see the density, bulk density her, piston press we are having less than 0.1 and here it is having 0.5-0.6, and there is 0.7-0.8.

If we see the specific energy consumption, then this is 37-150, 37-77 here, here 30-83 and 16 to 75. So, this is also different for all the machines. So, these machines energy requirement you see also comparable, here it is higher, but these are comparable with this also, screw press also. These are advantage, but this will be producing more product and initial cost is high. Now if you see about the output of the machine, so this screw press is continuous, this is also continuous, pellet mill also continuous, but piston is our in strokes, that works in strokes.

So particle size, you see 2-6 millimetre, here 6-12 millimetre, less than 4, less than 3 millimetre, so are giving bigger particles in this case. The maintenance is low, here it is high, low, low. So, these are the different process for the densification which have been used and this is a comparison.

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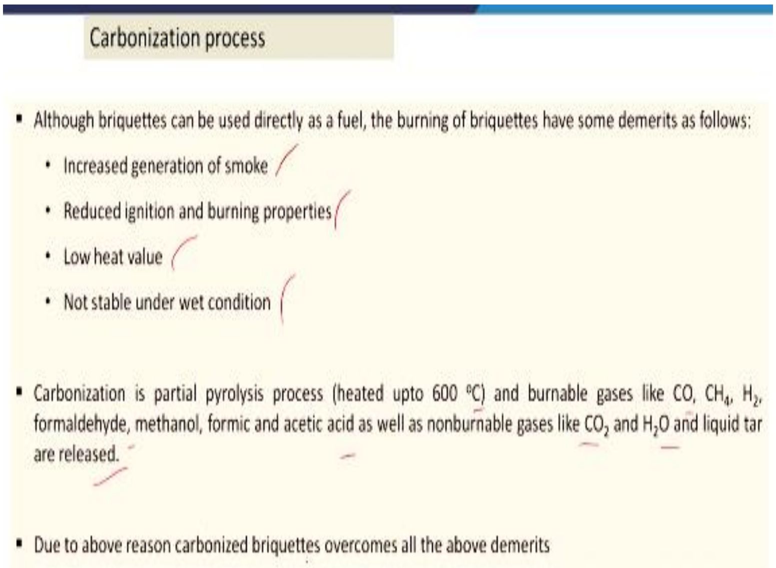

Now, when the briquettes are formed, the briquettes will be densified, it is fine, but still it will be having more volatile matter. So, when we will be using it, then it will be producing more smokes and we need to remove that, so carbonization of the briquettes is done. So, carbonization process is required. As we have mention that it increases the smoke generation, it also reduced ignition and burning properties, then low heat value and not suitable under wet condition.

These are the demerits of the briquettes and carbonization if we do, then these demerits will be reduced. The carbonization is the partial pyrolysis process, is heated up to 600 °C and burnable gases like CO, CH_4, CH_2, formaldehyde, methanol, formic and acetic acid as well as non-burnable gases like CO_2, H_2O and liquid tar are released. So if we heat it in absence of oxygen, then it will be converted to char along with these products.

So, why we do this? By this carbonization, carbon content increases in the briquettes and volatile metal reduces. So when we will use in combustion process, some smoke formation and tar formations will be reduced.

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Carbonization process

- The off-gas of the process is of high energetic value and can be used to balance the energy and heat demand of the carbonisation.
- Carbonised briquettes can be produced from agricultural residues through two possible production sequences:
  - Carbonization→ grinding → briquetting
  - Grinding → briquetting → carbonization.

The off-gas of the process is of high energetic value and can be used to balance the energy and heat demand of the carbonization and this carbonization process can be done either after briquette formation or before briquette formation also the biomass and waste can be converted to char and then it will be made into briquette. So here either carbonization followed by grinding and briquetting or grinding followed by briquetting and carbonization both are possible.

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Change of properties due to carbonization

Characteristics	Pine Needle	Pine Needle char	PNB
Mean Moisture content(%)	9.76	7.500	6.89
Mean Ash content(%)	4.37	5.390	11.21
Mean Volatile Matter Content(%)	70.03	17.960	29.04
Fixed Carbon Content(%)	15.83	69.150	52.85
Picture showing the Proximate Analysis Sampling			

Source: Pine Needle Briquettes: A Renewable Source of Energy, Sudip Pandey; Rabindra Prasad Dhakal, International Journal of Energy Science, 2013

Now we will see how the property changes due to the briquette formations and char formation. So here the pine needle, so then pine needle char, then char to pine needle briquette. So, you see the basically volatile matter content, in the pine needle we are having 70.03%, when it is converted to char it is 17.96%, and then briquette it is 29.04%. So, briquetting process is helping us to reduce the volatile matter content.

Now, we see the fixed carbon. So, here 15.83 for pine needle, for char it is 69.150, and here it is 52.85. So, briquetting process again helping us to get more fixed carbon in it. So when it will burned further in the combustion unit, it will be less amount of material will be required to release same amount of energy also and you see the how the material changes as this is your pine needle and this is your char and then these are the briquettes. The ash content also changes here 4.37, 5.390, and 11.21 because it is converted into briquette form.

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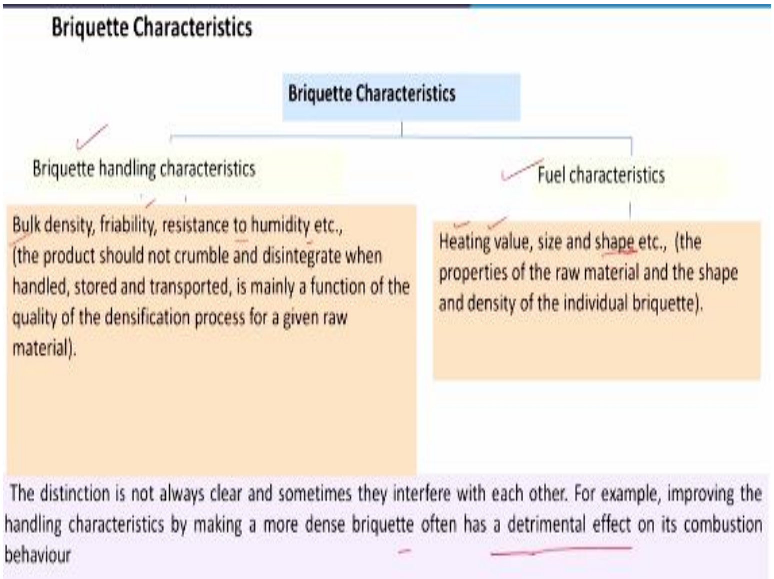

Now briquette characteristics. There are some properties the briquette should have because briquettes have to be transported from one place to other place. So, one will be there is handling characteristics and another will be fuel characteristics. Our main objective for the production of briquettes is to get energy from it, so use it as a fuel in combinations. So heating value, size and shape.

Heating value is the fuel property, size and shape is also the fuel properties, and it also helps to achieve the performance of the reactor system. Then the handling characteristics are bulk density, friability, resistance to humidity, these are very important properties. Now, both are important, but if I want to get one type of property in higher extent, then the other property may be compensative. So the distinction is not always clear, that is these handling properties and fuel characteristic, this distinction is not always clear and sometimes they interfere with each other.

For example, improving the handling characteristics by making a more dense briquette, if I produce more dense briquette so that it will be easy to transport but or easy to handle, but at the same time, it will be detrimental on its combination, because combustion requires porous material, so more combustion we will get, so in that case, we have to compromise.

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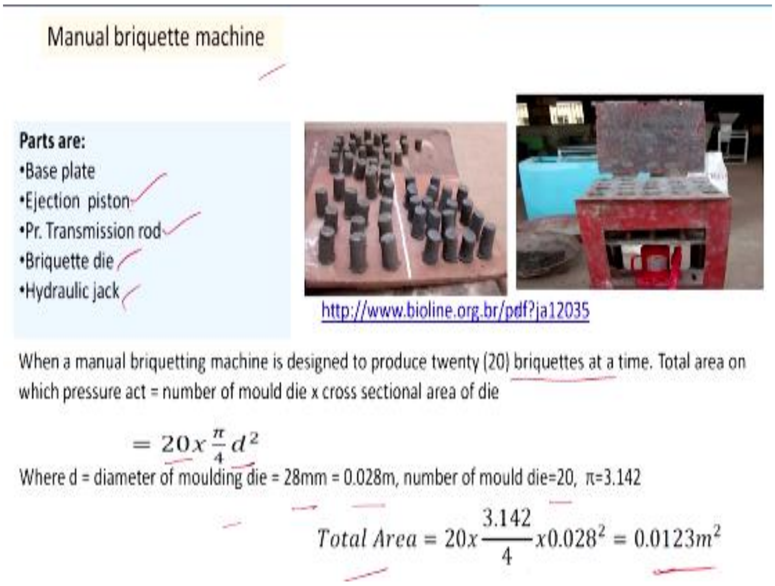

Then we will see the manual briquette machines which are used in small scale, they are small machines and anybody can use it easily. So, here different parts are there. We have one base plate. So, these are base plates and base plates will having some ejection piston. So, if we see here, we have one hydraulic jack here. So, then the pistons are there, and ejection pistons and transmission rod.

So, ejection piston and transmission rod will help the transition of the force from this hydraulic machine to the plate and ejection piston will help to press the materials in the die and when the lid will be opened, it will help to get the material out from it. So, then briquette die is also there. So, these are the briquette die here and then hydraulic jack as I have discussed. So, hydraulic jack, then transmission rod, then your ejection piston, and then we have base plate on it and the lid or just say the cover of it.

So, then it will be covered and then from the bottom, hydraulic jack will work and then that will be pressed, after that, that will be taken out by the ejection piston. So, in this case, if we have say 20 briquettes at a time it can produce, so 20 transmission rod and 20 ejection piston if we have, then the area requirement will be 20 x pie r square, so pi/4 x d square where d is the diameter of the die diameter. So, if the die diameter of each is 28 millimetre for example, then it will be 0.28 metre, the number of mould is equal to 20, so total area = 20 x pie r square or pi d square/4, that is equal to 0.0123 metre square. So, this is the area requirement.

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Manual briquette machine

Mass of one pressure transmission rod used = 450grams.

Number of pressure transmission rods = 20.

Total mass of 20 transmission rods = 450×20 = 9000 g = 9 kg.

Mass of ejection piston= 100g.

Total mass of 20 ejection piston= 100×20 = 2000g = 2kg

Mass of the base plate = 4.5kg

Maximum mass of one wet briquette sample = 50g

Thus, Total mass of briquette samples = number of briquette sample x mass of one sample = 20 x 50=1000g = 1kg

Then in this case, so how much weight the hydraulic jack has to be lifted. Let us see. So mass of one pressure transmission rod equal to say 450 gram, we are assuming this, and the number of pressure transmission rod = 20. So total mass of 20 transmission rod = this x this, 9000 gram = 9 kg. Then mass of ejection piston 20 numbers we have. So 100 gram of it we are assuming, so that 20 x 100, so 2000, that is equal to 2 kg we are getting here. Mass of the base plate is 4.5 kg, we are assuming.

So, maximum mass of one wet briquette sample is equal to 50 gram we are assuming it. So, the total mass of briquette samples that will be number of briquette sample x mass of one sample, that is equal to 20 x 50 = 1000 gram = 1 kg.

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Manual briquette machine

Total mass to be lifted by hydraulic jack is = total mass of transmission rod + mass of base plate + total mass of ejection piston + total mass of briquette samples

= 9 kg + 2 kg+ 4.5 kg + 1kg = 16.5 kg

Assume g (acceleration due to gravity) = 9.81

Weight to be lifted = 16.5 ×9.81 = 161.87 N

So, total mass to be lifted by the hydraulic jack is the total mass of the transmission rod, mass of base plate, total mass ejection piston, and total mass of briquette samples. So, we have got 9 kg + 2 kg + 4.5 kg + 1 kg, so 16.5 kg. So, if g = 9.81 kg per second square. So, then, we are getting weight to be lifted equal to 16.5 x 9.81, that is equal to 161.87 Newton. So, this is the weight we need to lift by the hydraulic jack.

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Manual briquette machine

A 10 tonnes(10,0000N) hydraulic jack was used to lift the machine components and compress the briquettes. The compaction force can be calculated using the pressure. Pressure read from the pressure gauge connected to hydraulic jack (Compaction Pressure)=17.5KN/ m² (Ihenyen,2010). The machine has 20 molds.

Let F_c = Compaction Force, and P_c = Compaction Pressure and A_c = Total Compacted Area.

$$Pressure = \frac{Force}{Area}$$

Where Ac = Number of Briquette produced at a time x cross sectional Area of briquette sample

Where d = diameter of briquett Thus, $A_c = 20x\frac{\pi}{4}d^2$ π =3.142

$$A_c = 20x\frac{3.142}{4}x0.028^2 = 0.0123m^2$$

F_c =17.5 x 0.0123 = 0.2153KN = 215.3N

Then what is the force that we have to calculate. How can you calculate the force that we will discuss now. Say a 10 tonnes hydraulic jack, we are using a 10 tonnes hydraulic jack that is equal to 10,0000 Newton hydraulic jack was used to lift the missing components and compress the briquettes. So if this is the situation, then compaction force can be calculated using the pressure. So, what would be compaction force that can also be calculated?

So, read from the pressure gauge connected to the hydraulic jack is equal to say 17.5 kilo Newton per metre square, that is one example that this is the pressure press the pressure gauge is showing this reading and the machine has 20 moles, then we can calculate what is the compaction force. We are getting the pressure here. So what is the compaction force that I am interested to calculate? So, in that case, what we will do, we will use the formula pressure equal to force area. So, pressure is given here.

So, you have to calculate the area and we get the force. So, in this case area Ac = 20, now 20 number of moles we have. So 20 x pi/4 x d square. So that is equal to 0.0123 metre square. So if Fc is equal to this, Ac x P, which is given here, so that we are getting 0.2153 kilo Newton that is equal to 215.3 Newton. So that way we can calculate what is the preset requirement. So up to this in this class. Thank you very much for your patience.