Technical Textiles
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Lecture - 08
Textile Reinforced Composites (contd.,)

Hello everyone. So we will continue with our present topic, fibre reinforced composites. So, in earlier classes I have discussed the basic understanding of composite, then different existing manufacturing techniques and also the hybrid yarn manufacturing techniques for producing composites. Today we will discuss another method of manufacturing composite which is thermally bonded roving methods of manufacturing composite mainly from natural fibres.

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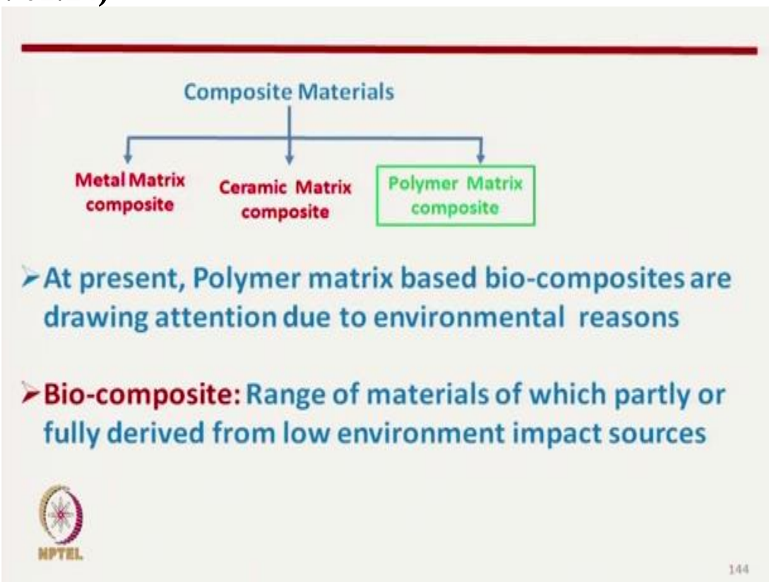

So, if we see the composites, as I have already mentioned, these are mainly 3 types based on the matrix that is metal matrix composite, ceramic matrix composite and polymer matrix composite. So, advantages and disadvantages of thermoplastic and thermoset matrix we have discussed and main advantage of thermoplastic matrix is that we can reuse the matrix once again and also in absence of the biodegradable polymers at present we can produce bio composites using thermoplastic matrix, at least to some extent we can save our environment, so that is why we may call it as bio composite.

So, what is bio composite then? It is a range of material of which partly or fully derived from low environment impact sources. So, at present, what we will discuss of manufacturing method of composite where component like at least 50% of the composites are made of natural fibre.

So, at present we will discuss the flax fibre which is biodegradable and the matrix component here we will discuss the thermoplastic fibre that is polypropylene, where if we want we can reuse the matrix once again.

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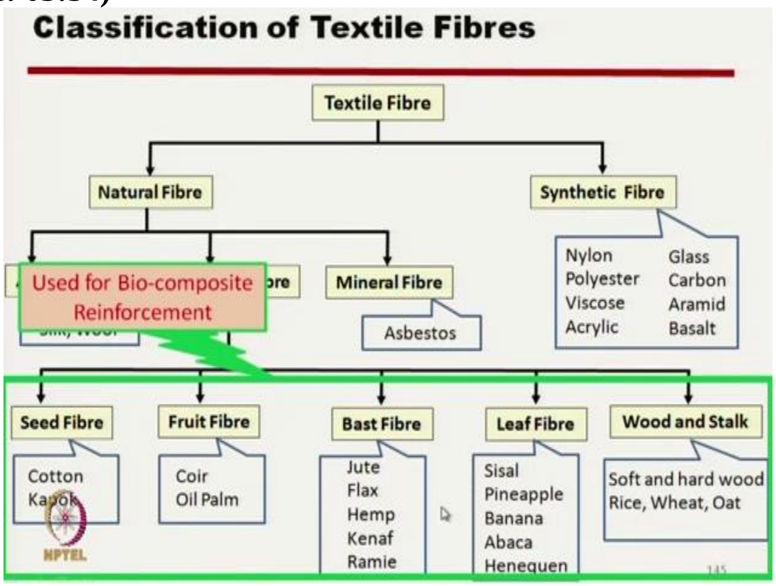

So, as it has already been mentioned, a textile fibre we can divide into 2 broad classifications. So, these 2 classes, one is natural fibre, and other is synthetic fibre. So at present what we will be discussing on natural fibre and that is vegetable fibre. So, natural fibre is subdivided into 3 categories animal fibre, vegetable fibre, mineral fibre. So, the present day bio-composites we manufacture mainly from natural fibre, which is natural vegetable fibre and here we will discuss the flax fibre which is used as reinforcing material in manufacturing bio composites.

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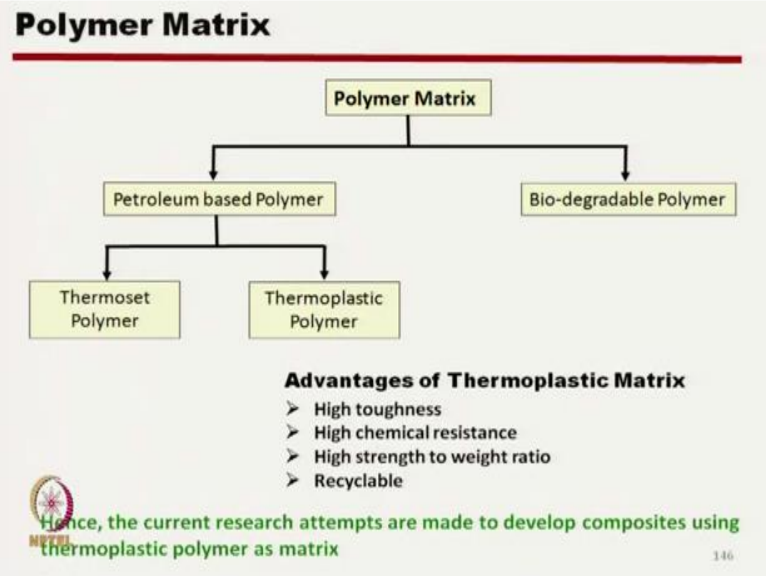

So, as far as matrix is concerned polymer matrix particularly so, there are mainly 2 types one is petroleum based polymer, another is biodegradable polymer. So, petroleum based as already been discussed. It is 2 types, one is thermoset another is thermoplastic. So, thermoset the limitations are they are non-recyclable. So, once the composite is manufactured, they cannot be reshaped or reused again, limited storage time, longer curing cycle and corrosive to handling.

So, these are the disadvantages due to that the present day composites are focused towards the thermoplastic polymer and if we try to use 100% biodegradable polymers, the main drawbacks are their limited availability, they are not available in large quantity and another drawback is that they are cost. So, high material costs to service life ratio so, their service life also low and at the same time, high cost.

So, the alternate way, the only way at present we can use thermoplastic polymer as the matrix material. So, their advantages are high toughness, high chemical resistance, high strength to weight ratio. So, if we take the certain mass their strength we get is relatively high and most important is that it is they are recyclable. So, hence in the present development we have used thermoplastic polymer as matrix to manufacture composite.

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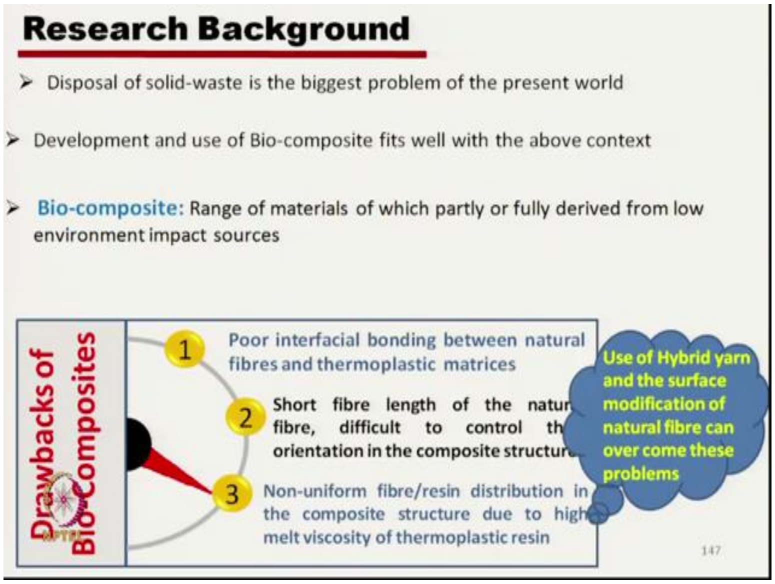

So, the basic driving force towards this direction is that disposal of solid waste. So the disposal of solid waste is the biggest problem. So, once we manufacture for composite from thermoset polymer after use the disposal is main concern, so we cannot reuse them. Other driving forces are development and use of bio-composite fits well with the protection of environment and bio-composite we can reuse again and again.

But, before we go for manufacturing bio-composite using natural fibre, natural vegetable fibre, there is different drawbacks also. What are these drawbacks? The main 3 drawbacks are, poor interface bonding between natural fibre which is basically they are generally hydrophilic fibre and thermoplastic matrices they are in general hydrophobic. So, their interface bondings are relatively weaker. So, that is the main concern. Next problem is that short fibre.

So, natural vegetable fibre if we talk about we always get in short form not continuous form. So, their orientation it is not along the axis. So, the control of orientation of this natural fibres are very important because we can only get continuous strand from natural fibre is by twisting. Once we twist, the fibres are aligned at certain angle, so that we do not get the proper strength realization and third point is that non-uniform fibre resin distribution in the composite surface.

Because in the composite structure, due to high melt viscosity and the fibre s are being twisted. So, due to high melt viscosity the penetration of molten polymer inside the core of the yarn is very difficult. So, we have to overcome all these 3 drawbacks before we go for manufacturing bio-composites using natural vegetable fibre. So, the approach is that we have produced hybrid yarn, hybrid yarn means as we have already discussed where the matrices fibre and reinforcing fibres are mixed evenly together.

So that the flow of polymer it is very short, the flow length is very short so, they are already inside the structure and the first problem, poor interface between the natural fibre and thermoplastic composite is overcome, this problem is overcomed using the surface modification. So this problems we can overcome.

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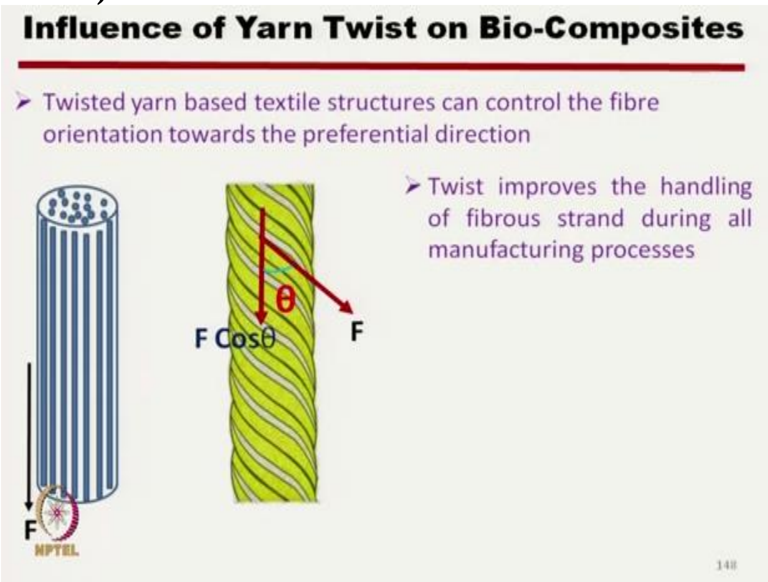

So, as I have mentioned, we cannot form continuous strand from staple natural fibre without any twist. Ideally, if we get the fibre strand, like this strand of parallel fibre, in that case the penetration of polymer will be easy. Now, let us see

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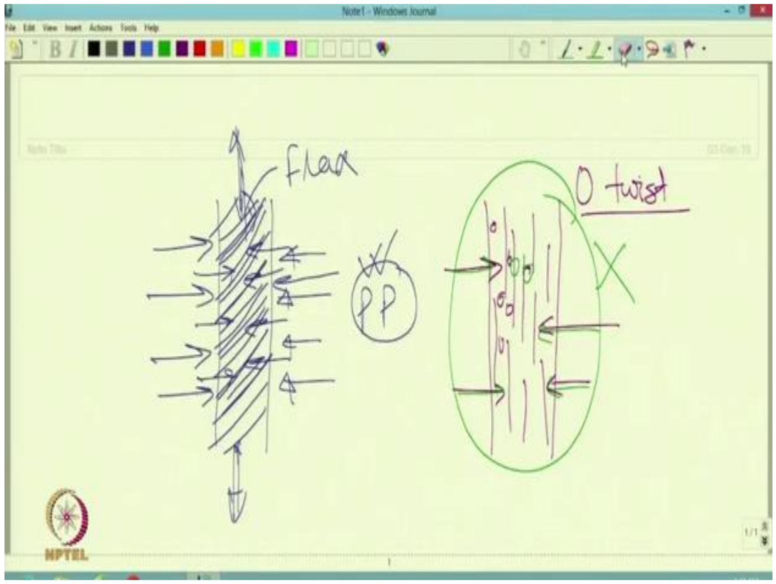

At the present stage our approach is that suppose this is normal staple yarn, staple yarn as I have mentioned, we cannot manufacture a staple yarn without twist. Now, suppose this is flax now, suppose we want to now manufacture composite using polypropylene. So polypropylene matrix, if we try to push inside the structure it will be very difficult because the melt flow index of polypropylene is very high so it is not easy for the matrix to penetrate inside the structure.

So, another problem is that, once we twist the fibres are at certain angle with the load direction, so we do not get proper strength utilization. On the other hand, if we can align the fibres parallel to the axis, that means 0 twist. In that case, the penetration of matrix will be easier because the fibre to fibre distance is high. So there are space, this spaces, is they can, the matrix can enter easily. But the problem is that it is not possible because we have to have certain strength for handling the material. So what is the alternative? In the present approach, what has been done?

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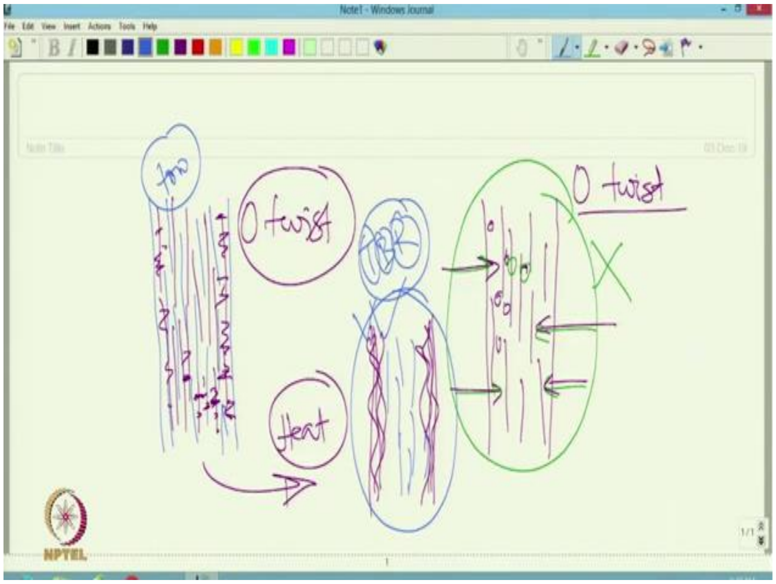

The rovings made of flax and polypropylene fibres, these are the flax fibres, here these are polypropylene fibres and here if you see again we have 0 twist. But after making that polypropylene and flax roving, we treat with heat, this heat treatment melts the polypropylene, this PP they get melted at least surface polypropylene fibres were melted. So, they form a continuous strand. These are say melted polypropylene and the flax fibres.

So, this prepreg or towpreg, because if we can call it as tow this is a towpreg. So, this towpreg we call it as TBR that is thermally bonded roving. This thermally bonded rovings they have got proper flexibility and we can use in the weaving machine and they have got certain strength also. So, as been explained the twist.

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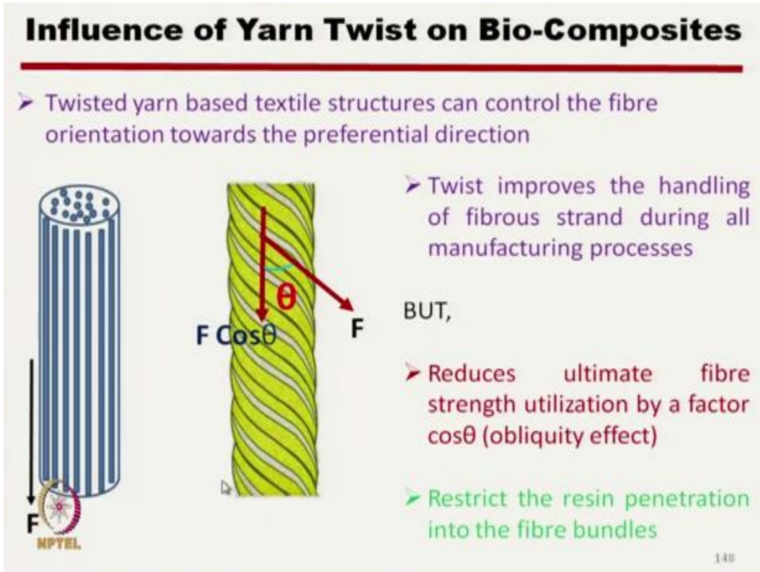

Twisted based yarn so, this twisted yarn here due to the alignment, the strength relation is low although the twist improves the handling of the material, but it reduces ultimate fibre strength utilization by a factor cos theta, also it restricts the resin penetration into the bundle.

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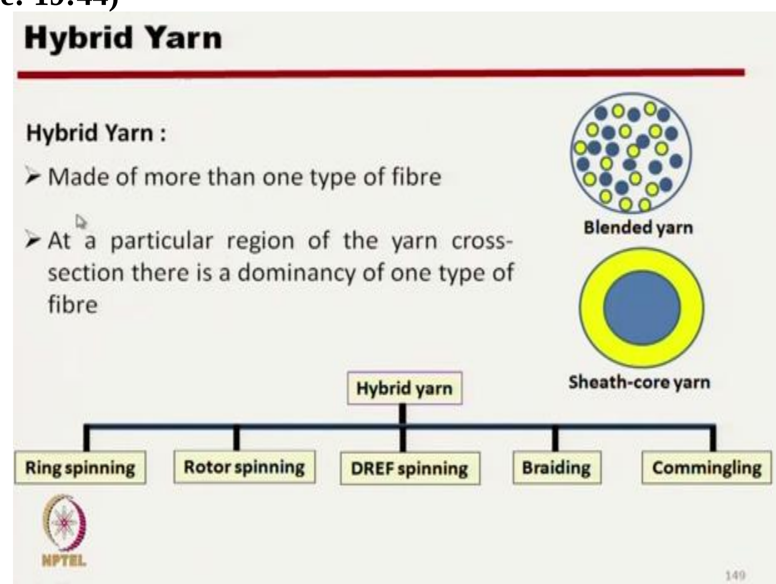

As, has already been mentioned, that hybrid yarns can be manufactured using ring spinning. That is core-sheath structure we can manufacture, rotor spinning, DREF spinning, braiding, commingling. These are the different methods of manufacturing hybrid yarn. So, basically hybrid yarns are the yarns where more than one component are there.

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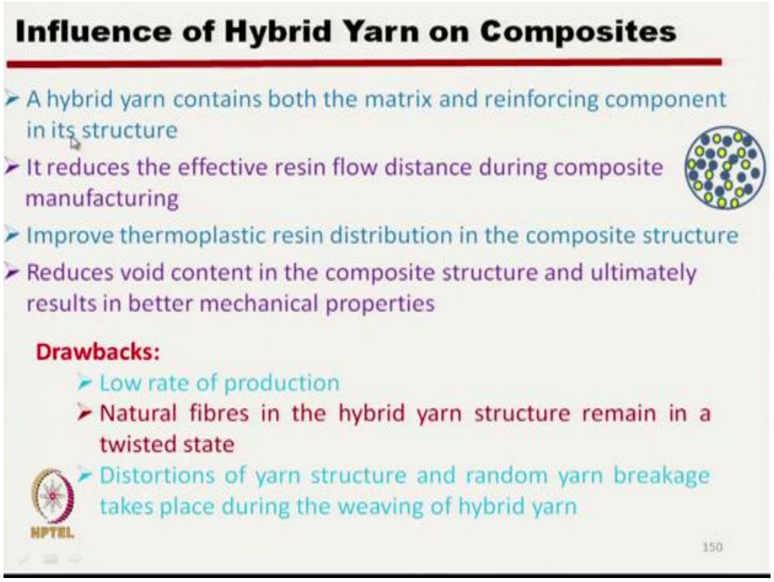

So, hybrid yarn contains both matrix and reinforcing components within the structure and it reduces the effective resin flow distance during composite, which is very important because the thermoplastic composite they have very high melt flow index and the hybrid yarn improves thermoplastic resin distribution in the composite structures. Because both reinforcing fibre and thermoplastic matrix fibre they are already present inside the structure.

So, the void content reduces, why? If we have the matrix fibre within the structure so, the chances of void content will be less because already the penetration of matrix components are there inside the structure, they have already penetrated. Main drawbacks are low rate of production. So hybrid yarn production it is a little bit slower, natural fibres in the hybrid yarn remain in the twisted state at present, but our new approach we have overcome that problem.

And main problem remains is that distortion of yarn structure and random yarn breakage takes during weaving of hybrid yarn. If we want to reduce the twist to have better penetration, the strength reduces and during handling during weaving the hybrid yarn breakage takes place. So, the main solution here is that,

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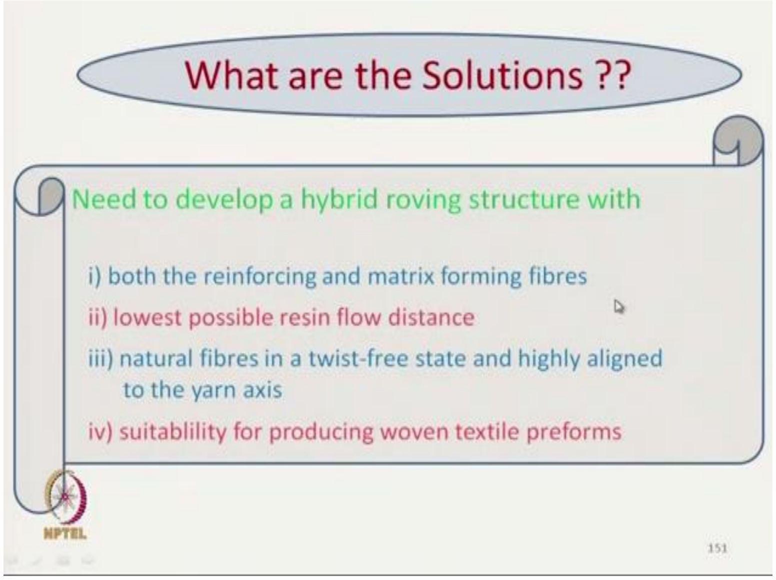

Both the reinforcing and matrix forming fibres should be there in the hybrid roving structure to have lowest possible resin flow distance, the natural fibres in the twist-free state they are highly aligned to the axis of the roving and we have to develop the yarn or roving structure in such a fashion that they are suitable for weaving to make textile preforms.

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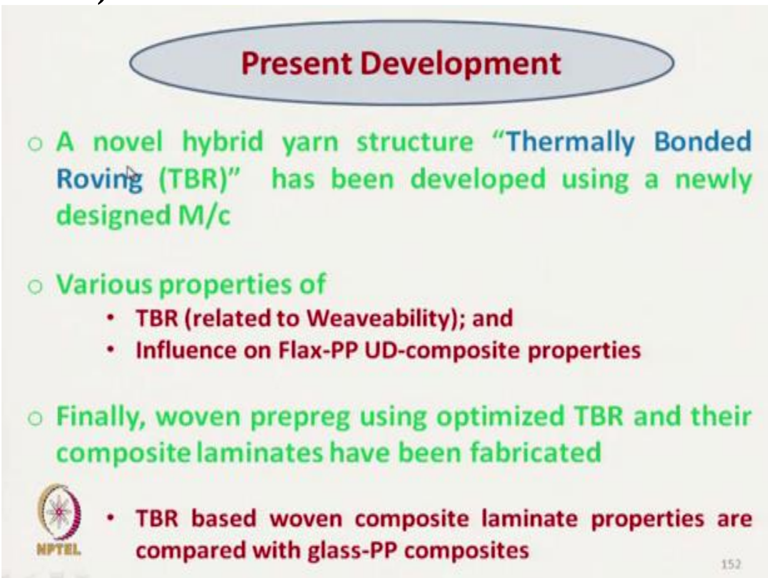

So, this novel structure, which we call it as thermally bonded roving, TBR and it has been developed using a newly designed machine, we have modified the existing setup and what we have done we have evaluated various properties like one question is always asked that thermally bonded roving, can we weave into a woven fabric. So, for that we need to study the weave ability study that has been done and that various other properties we have studied.

That is flax fibre content, proportion of flax fibre content and degree of mixing how all these parameters affect the unidirectional composite properties, UD-composite properties. After that, after making the unidirectional composites what we have done, we have produced woven prepreg. So, when prepreg means in that woven structure already the matrix and reinforcing components are present and after that after making the woven prepreg.

We have made the composite laminates by layer technique, so TBR based woven composite laminate properties are compared with the glass-PP composites. So, glass-PP composites they are very common and it is easily available in market commercially. So, what we have done? The developed composite made from the thermally bonded roving of flax fibre so, we have compared with the existing glass-PP composite.

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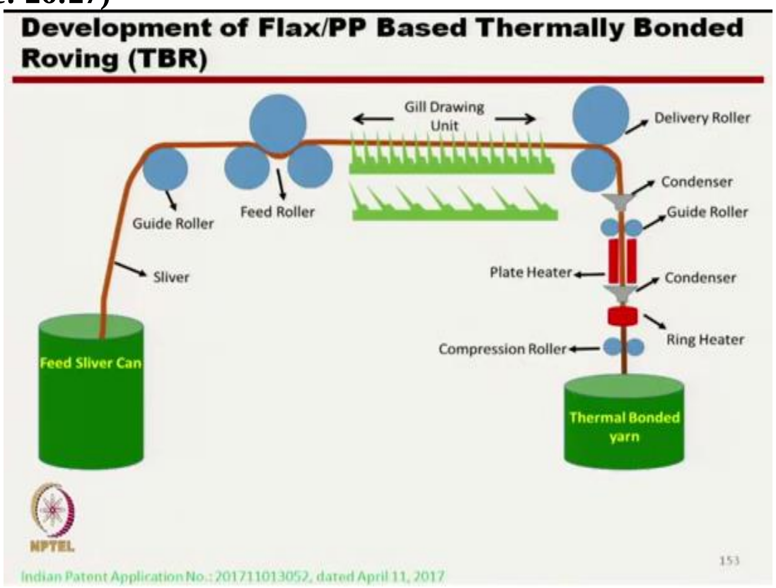

This is the schematic diagram of the setup which has been developed. So, this is here, feed sliver can in this we can have a number of such cans where the flax sliver and polypropylene sliver. They are fed through the, this guide roller and then through the feed roller and ultimately it is going to the gill drawing system which is used for long staple spinning system. So, this gill drawing system is used because we are using long fibre flax fibre.

So, we have taken the polypropylene fibre also in the longer cut length, so that both flax and polypropylene they are compatible and we have processed this flax and polypropylene slivers through the gill box a number of time and that detailed study we have done and we have studied the effect of number of passages. Number of passages means, the more the passages more will be the uniform blending. So, higher blending is required for proper composite manufacturing. So, after that at the last stage what we have done this roving they are processed through the plate heater.

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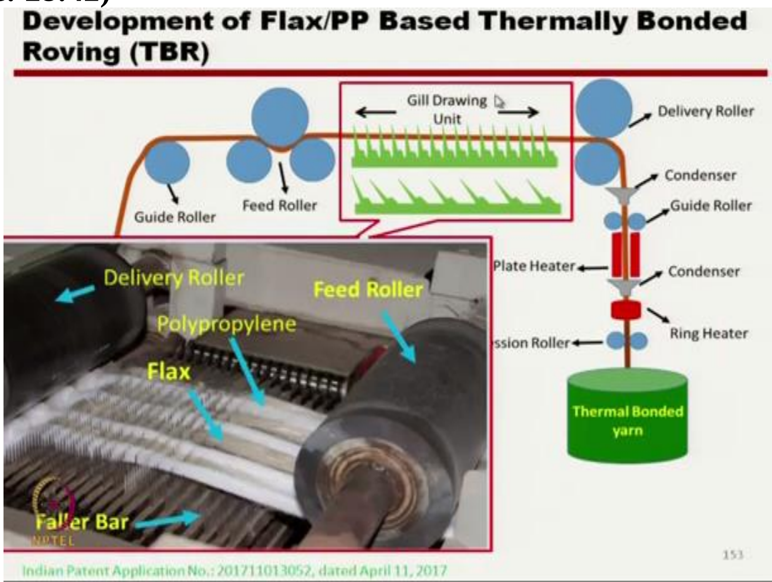

So, this is the photograph of the gill drawing system where we can see this white color slivers are polypropylene and this brown slivers are flax and these combs are faller bar of the gill drawing unit. After the final roving is passed through the condenser and guide roller and when, it is passing through the plate heater and condenser.

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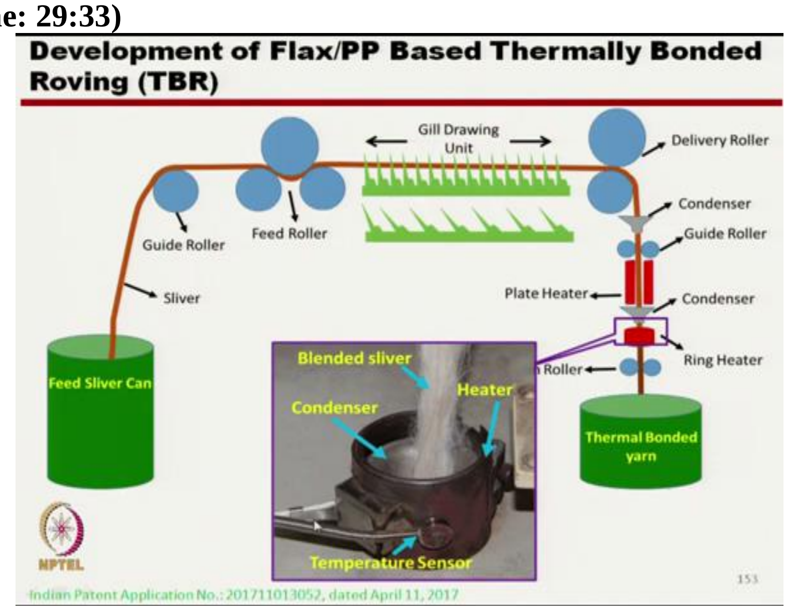

So this is the condenser and blended sliver and here the temperature sensor. so this is the heater and we get

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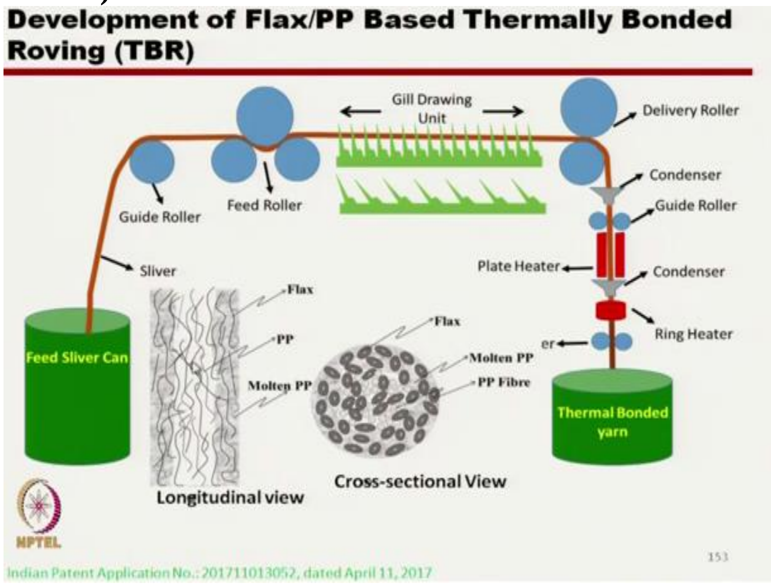

The roving with the flax which is in the form of fibre and polypropylene which is molten. Here we can see that polypropylene fibres at the surface of the yarn are melted and the fibres polypropylene fibres which are in the core, they are still in the staple fibre form. So, there is a partial melting and which helped in having higher flexibility, it retains the flexibility at the same time due to melting the strength of the strand.

That is robbing is such that it can sustain certain load so, this the cross section where flax and flax these are the flax fibre here are the polypropylene. So, these rovings they have certain strength characteristics such that we can develop woven prepreg. This is called TBR thermally bonded roving and if we see here the fibres are almost aligned towards the axis of the roving.

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Box and Behnken Design

Factors and Levels

Factors	Levels		
	Low	Medium	High
	-1	0	+1
No of Drawing passage	2	4	6
Natural Fibre content (%)	40	50	60
Temperature (°C)	180	195	210

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So, we have done detailed study. I will show here in short the study what has been carried out. Now, the main question is that, what about the uniformity in blending? So, to have uniform blending, we have used a number of drawing passages. So, 2 passages, 4 and 6, 3 passages we have used here and also we have varied the natural fibre flax content in the thermally bonded roving so, which is 40%, 50 and 60, 3 different natural fibre content we have varied and also we have used 3 different temperatures. So, that the melting, proper melting of polypropylene takes place this temperature is the temperature at this heater it is a 180 degree Celsius, 195 and 210.

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Experimental Design and Corresponding Responses

Run	Variables			Responses			
	Natural Fibre (%)	No of Passage	Temperature (°C)	Tenacity (g/Tex)	Modulus (g/Tex)	Flexural Rigidity (dyne-cm²)	Weavability (no of cycle)
1	60	6	195	2.35	120.6	38.11	276
2	60	4	210	1.49	99.22	39.12	220
3	50	4	195	0.965	37.81	15.73	197
4	60	4	180	.9562	80.1	20.91	137
5	40	2	195	1.01	82.3	27.73	171
6	50	2	210	0.3392	28.8	9.49	197
7	40	4	180	0.2197	24.73	27.37	182
8	40	4	210	0.7714	35.97	31.72	286
9	60	2	195	1.08	96.44	18.93	159
10	50	4	195	0.964	37.28	14.95	198
11	40	6	195	0.6259	44.68	18.39	206
12	50	4	195	0.958	36.98	13.37	203
13	50	6	210	1.56	52	33.89	257
14	50	2	180	0.8291	28.59	6.017	138
15	50	6	180	0.1998	9.66	6.99	170

After this experimentation, we have got the response and in box banking we have developed 15 samples of different combinations and if we see in this different combinations, tenacity, modulus flexural rigidity and weave-ability that is number of cycles it is it can sustain before it breaks. So, this parameters they vary widely for different combinations and if we see this tenacity in gram per Tex, it is basically it is .1998 as low as .1998 and it can go up to say 1.56, 2.35. So, this is the range of modulus, tenacity see modulus if we see it is as low as say 28 or 9.66 and it is going up to say 120 so this is a range of the responses.

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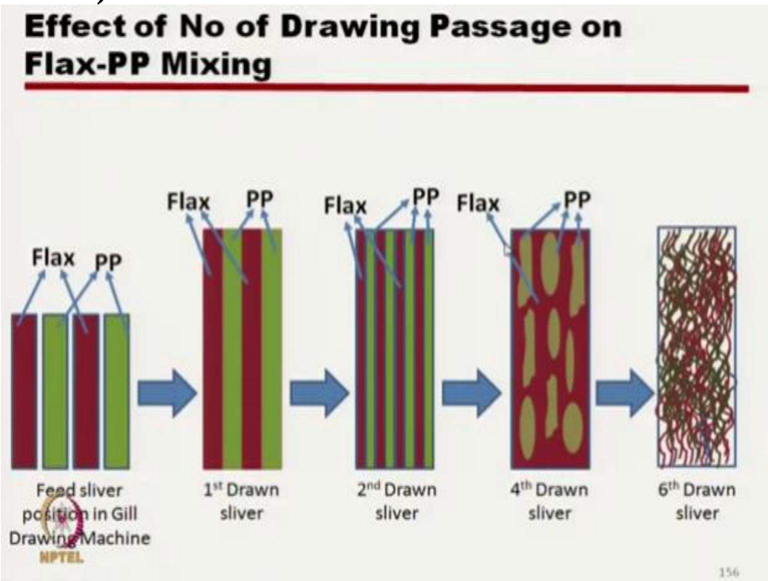

Now what is happening when we change the number of drawing passage? If we see we have placed the flax and polypropylene side by side, so these are the flax the brown color and green color these are polypropylene and after fast drawing if we see they are not mixed enough. So, their identity remains and even after second drawing we can very well see the strands of flax and polypropylene. But once we increase the number of drawing passages to 4 this becomes little bit mixed up, but here the polypropylene rich and flax rich portions can be seen.

It is easily visible here, polypropylene rich segment and flax rich segments. Although their continuity has been broken but if you further increase the number of drawing passage to 6 drawing passage, after 6 drawing passage what has been observed that the flax and polypropylene fibres have they have been mixed uniformly.

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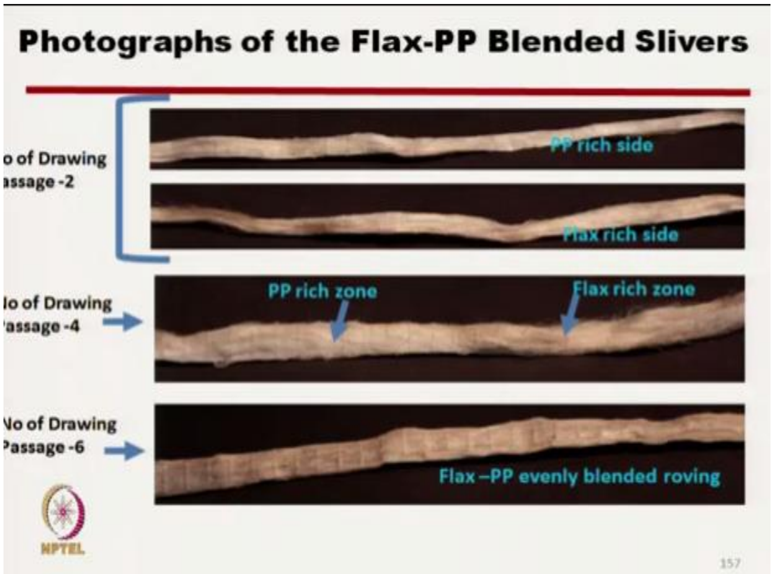

Now, if we see the actual photograph so, after second drawing, so 2 drawing passage, we can see this portion is polypropylene rich portion, this is the flax rich portion. So, I can go back to the earlier slide here see polypropylene rich portion and it is a flax rich portion. So, this identity remains here and after 4th drawing passage, although the continuity has been broken but here, if we see this portion bright portion, whitish portion.

This is polypropylene rich zone, here it is a flax rich zone so, that is shown here. So, polypropylene rich zone and flax rich zone, this type of things happen. But after sixth drawing passage it has been observed that this polypropylene and flax they have been easily evenly blended.

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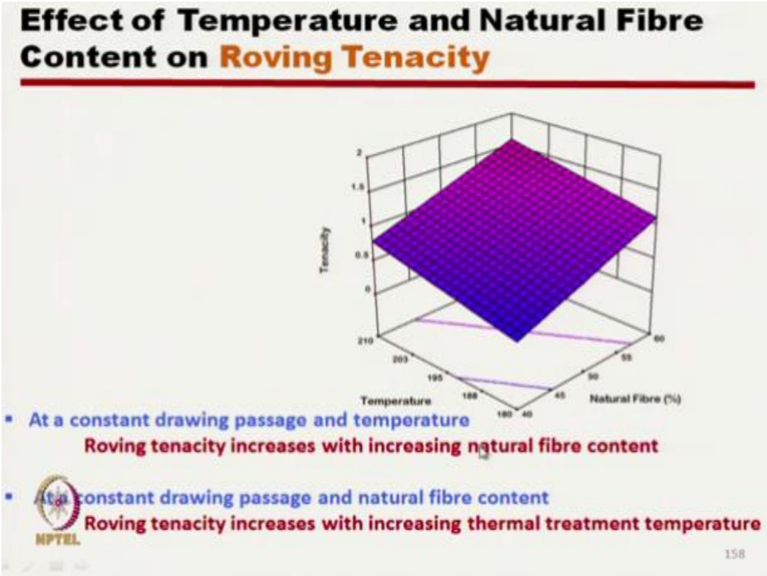

If we see the response curve for all these 3 variables, this is the effect of temperature and natural fibre content on tenacity of roving which is prepreg at constant drawing passage. So, we have kept drawing passage here 6 drawing passage as constant drawing passage and if we increase and in this axis the temperature is constant. So, at this stage if we see, roving tenacity increases with increase in natural fibre content.

So, from 40 to 60 if we increase the natural fibre content which is basically reinforcing component. So, if we increase the reinforcing component up to say 60% so, from 40 to 60 it is continuously increasing. But, this trend may not be same if we further increase to 70, 80% because the matrix has to be there, matrix component has to be there because the fibres are in parallel stage. Now, if you see this axis here at constant drawing passage of 6.

And natural fibre content here say if it is 40% roving tenacity increases with the increasing thermal treatment temperature that means, proper melting of polypropylene are there. So, similarly we can have different trends for different parameters so, I will go quickly.

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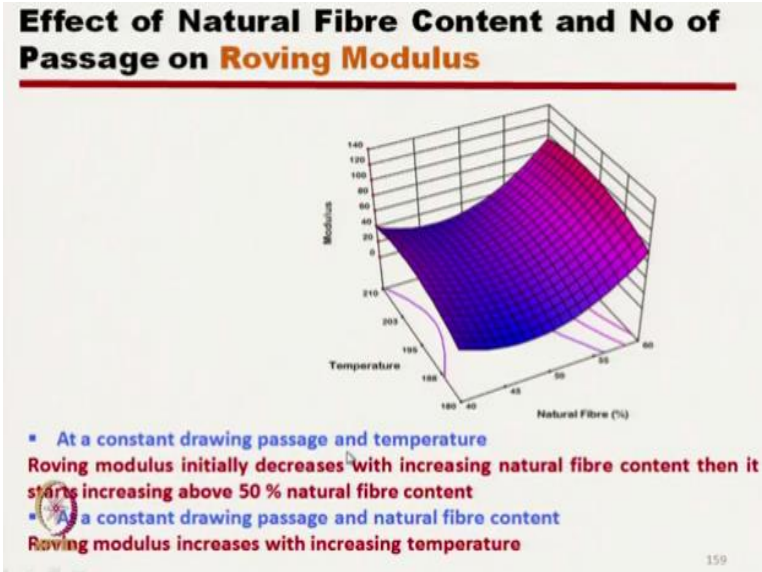

So, here at constant drawing passage of 6 and temperature the roving modulus initially decreases with the increase in natural fibre and after that, after 50% it increases sharply and as far as the temperature is concerned, if we increase the temperature the modulus increases, because again due to proper binding of flax fibre with the matrix. Because, as we increase temperature so, melting takes place more and more melting of the polypropylene fibre takes place they are binding the flax closely and properly so, it increases the modules.

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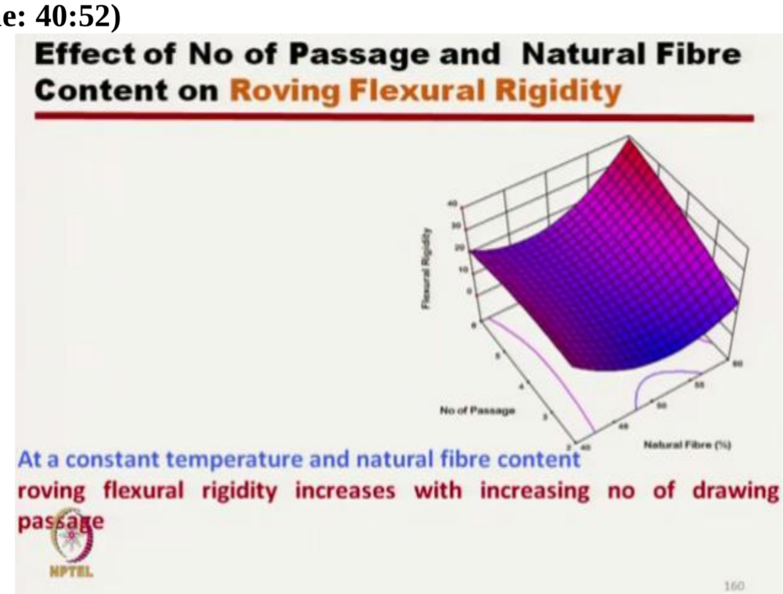

Similarly roving flexural rigidity effect of number of passages and natural fibre content so, here temperature is kept constant at 210 degrees Celsius, the roving flexural rigidity increases with increase in number of drawing passage. So, flexural rigidity increases as the number of drawing passage increases, the proper blending takes place and proper alignment of flax and polypropylene fibres are there and proper binding of flax fibres will be there.

So, it increases the flexural rigidity and effect of natural fibre content and temperature roving flexural rigidity this is we have discussed again, so at a constant drawing passage and natural fibre content roving flexural rigidity increases with increasing temperature.

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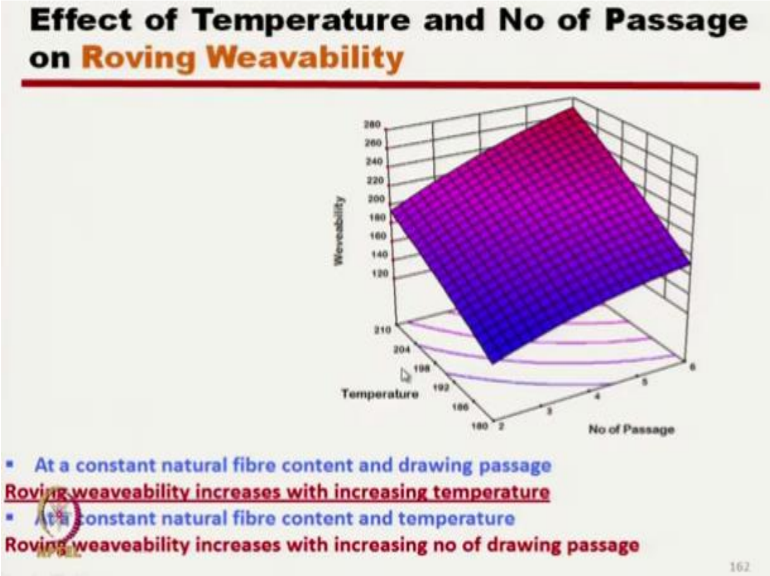

And if we see the roving weave-ability, effect of temperature and no of passages at constant natural fibre constant say, here we have kept the natural fibre content at 60% and at same no of drawing passages, the weave-ability increases with increase in temperature. That means the proper binding of natural fibres are there so, it enhance the strength and thus the weave-ability increases. On the other hand here, with the increase in no of passages we have proper blending and proper binding of the natural fibres are there so, weave-ability also increases here.

Now we will study we will see the effects of the flax PP thermally bounded roving once we produce composite here we have produced unidirectional composite and we will try to see their characteristics. So this roving what we have produced, thermally bounded roving from there what we have done we have initially used this thermally bounded roving for manufacturing unidirectional composites and in next stage we have done that weaving and we have used this woven prepreg to manufacture composite once again.

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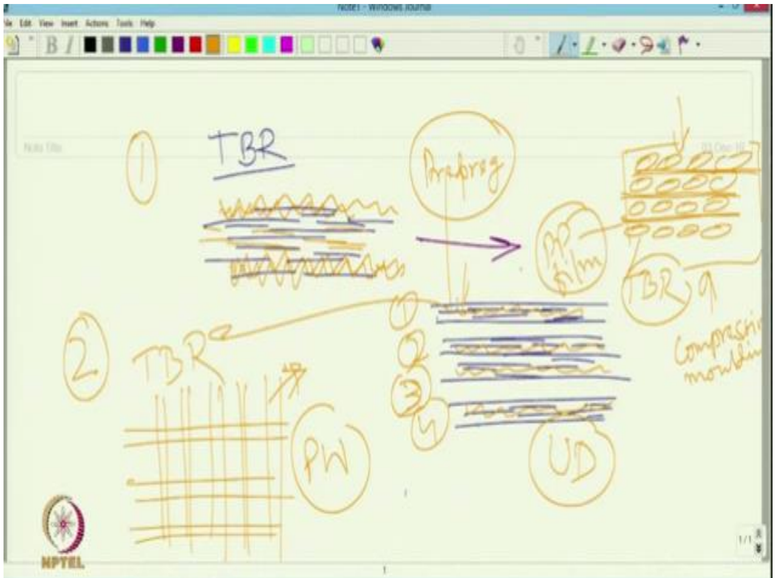

Now if you see here our next approach was at these are the flax fibres, this is thermally bonded roving and these are the matrix component, these are the polypropylenes at the surface it is molten and we will use this is thermally bonded roving for manufacturing unidirectional composites like, this is these are the thermally bonded rovings. So, at 1, 2, 3, 4, 1, 2, 3, 4 such number of rovings we will put together and if we see the cross section so this is 1 layer.

Then after that we will put polypropylene film then another layer polypropylene film another layer this is basically TBR and this is PP film so, and to have certain thickness and after that we will do compression molding. So this compression molding and we will get the composite and second approach this is approach 1 and second approach will be our and this TBR is a prepreg for manufacturing composite.

And second approach is that we will use this TBR this is UD composite, unidirectional composite where fibres are parallel to the access and in the second approach we will use this TBR thermally bonded roving to manufacture woven fabric. So, this is UD composite this is woven, plain woven fabric. So in next class we will discuss this 2 different types of composites. Till than thank you.