Textile Product Design and Development
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Lecture - 29
Joining Techniques

So, today's lecture is on joining techniques. How are the textile fabrics joined together? Many of the textile products need joining due to the limitation of the required shape at the manufacturing stage itself. So, it is necessary to join the pieces. Sometimes, we need to join two pieces, and, in some cases, we need to join multiple pieces in the layer form. So, what are the joining techniques which we have?

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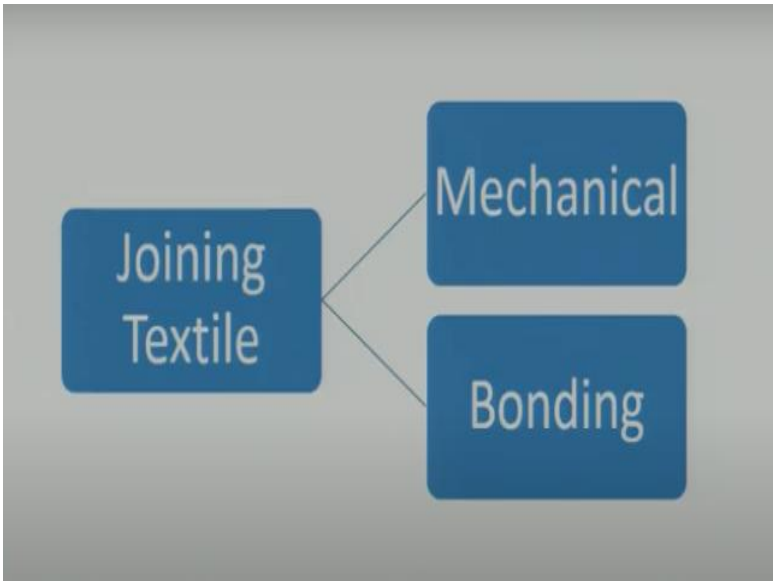

There are broadly two ways to join the textiles: one is the mechanical way of joining and the other one is the bonding.

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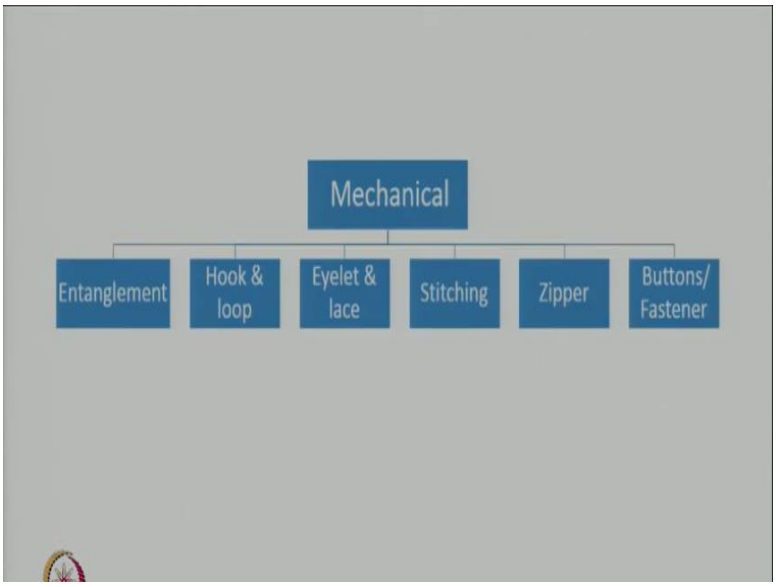

What is the mechanical way of joining? Within the mechanical way, it is further classified based on the mechanism of joining as entanglement, hook & loop, eyelet & lace, stitching, zipper and buttons/fasteners. The joining material may not always be fabrics; the product may be yarn, a braided structure, or a twisted rope.

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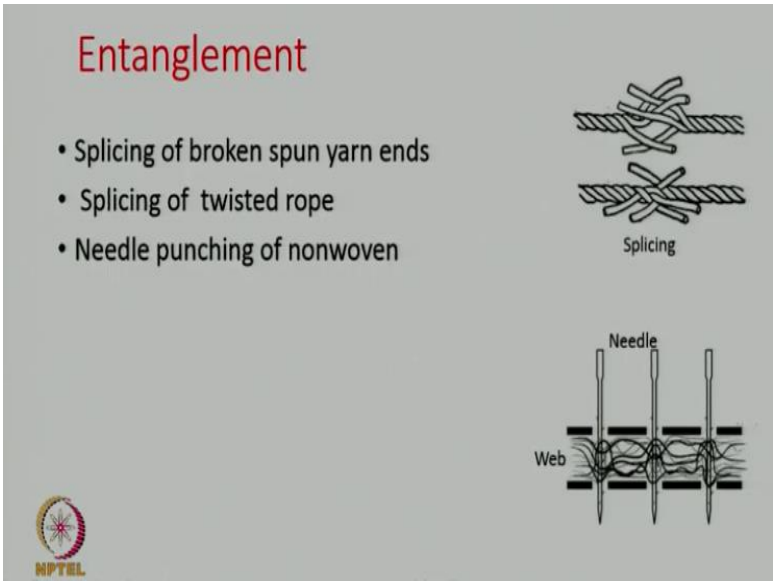

The first mechanism is the entanglement. It is well known that entanglement is a mechanism to join the broken spun yarns using splicing technology during yarn winding. The splicing of twisted ropes is also a kind of joining.

The other one is punching, i.e., needle punching to make nonwovens. In needle punching, we need to create an entanglement between the fibres so that the fibres hold each other by frictional contact. We can join two nonwoven fabrics by placing them on top of each other and then punching them, creating entanglement between the layers.

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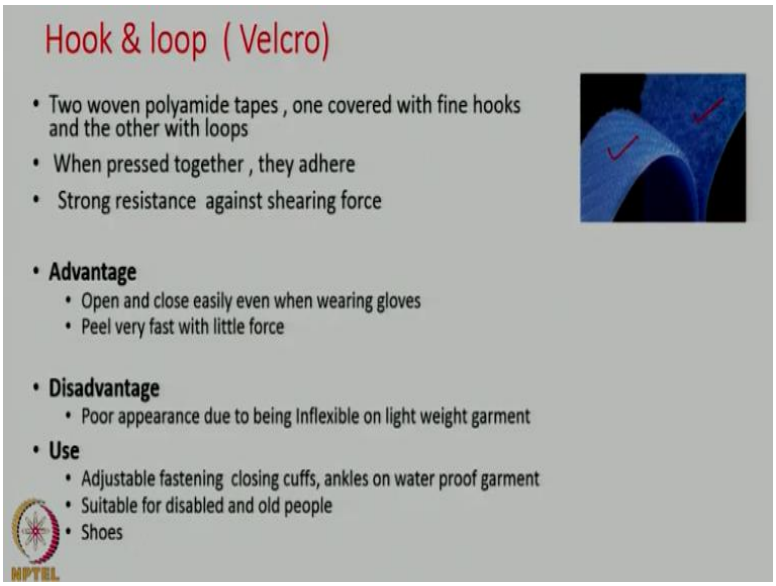

The next mechanism is hook and loop. An example of such a mechanism is Velcro. Most of us are familiar with Velcro. Two woven polyamide tapes, one covered with fine hooks and the other with loops, are pressed against each other, as shown in the diagram. During pressing, they will adhere, and create strong resistance to shear, whereas they offer very little resistance to peeling. The advantages are to open and close easily, even when wearing gloves, and peel very fast with little force.

When a person is wearing gloves in the cold climate and wishes to button and unbutton or wants to open the jacket that is worn, then, if the clothing has buttons, it is very difficult for the person to remove the cloth as the gloves cover the fingers. So, in cold climate clothing, the velcro type of fastener or zipper type will be very easy to operate. The second advantage is that peeling is easy and helpful for old people. Because for them, buttoning is difficult, i.e., pushing the button through the buttonhole is a difficult problem for them.

The disadvantage is poor appearance due to being inflexible on lightweight garments. Because it is additional mass that we must stitch to the garment, and therefore, the part with which it is attached that part becomes a little stiffer. The Velcro type fastening can be used in adjustable

fastening, closing cups, and ankles on waterproof garments, suitable for disabled and old people and very much in use in shoes.

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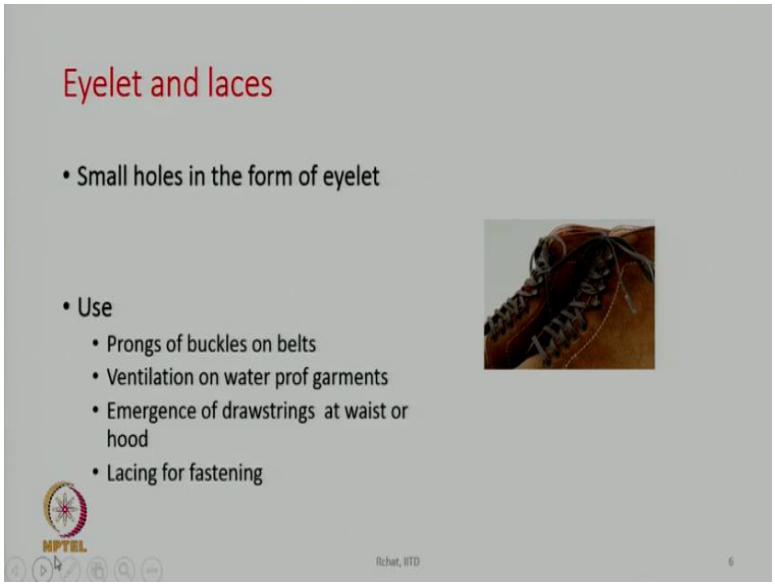

Eyelet and laces: we create holes in the fabric, and we place a hollow ring there, which we call an eyelet. We can pass a lace, as shown in the figure, to join the two pieces. Here, the flexibility of adjustment of tension is possible, and we can open it or close it, tighten it or loosen it; everything is possible. The use is very much in shoes. It is also used in prongs of buckles on belts, ventilation on waterproof garments, the emergence of drawstrings at the waist or hood, and lacing for fastening.

Shoelace sometimes may be difficult for children's shoes as they find it difficult to pass the lace through so many eyelets. So, for them, the easier way of closing or opening would be with the help of Velcro. So, most of the children's shoes have a velcro attachment for fastening.

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Zip fasteners: we are all familiar with zips. It has existed with us for so many years, and with the improvement of technology, zip fasteners have become very reliable nowadays. So, zip fasteners are also often used to join the two pieces of fabric. The zipper consists of two strips of fabric: each one having tens or hundreds of specially shaped plastic or metal teeth, as shown in the figure. There is a slider to join the two sides by pushing the teeth together as it rides or runs over the two sets of teeth.

The zippers are very common in the trousers. Zippers also could be of two types: open end and close end type. The open end zippers can be fully opened at the end, with one side being able to be separated from the other side, and these are used in jackets, cardigans, coats, hoodies, and sweatshirts in such kinds of items.

The close end zipper cannot be fully opened at the end, and the zipper halves won't come apart completely when unzipped. They are used in footwear, tents, luggage, handbags, and bags. So, depending upon the end use, the designer can choose the suitable zipper. This is only a glimpse of the types of various fastening devices that we have, and which are in use in textiles. The details about them are available in standard textbooks, and one may refer to them.

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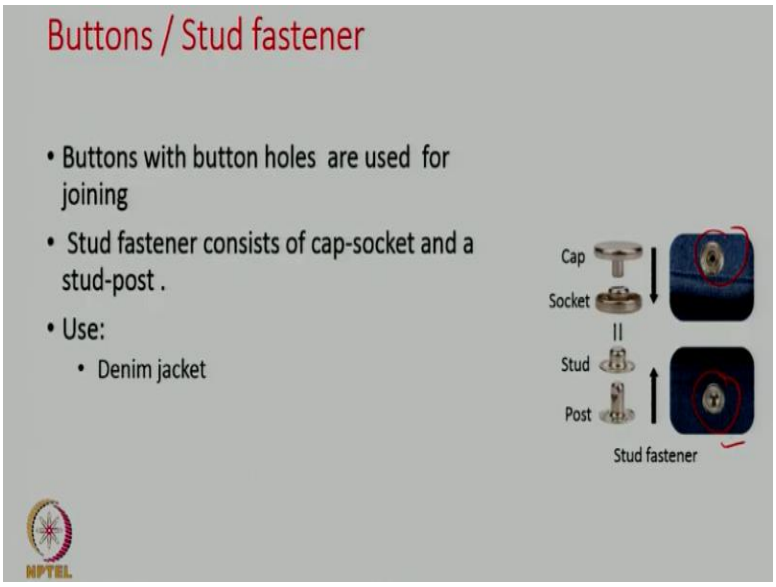

Buttons and stud fasteners: as discussed, with buttons and buttonholes, we can join two pieces of fabrics, which we found in most of the shorts that we wear. The stud fasteners consist of a cap socket and stud post, as shown in the diagram. They are used in denim jackets and in many other places. If we push the stud into the socket, there is a click sound, and it fits there. We need to apply force to take them out again.

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Stitch and seam: it is also a very old technique. Stitching has existed with us for a long time to join fabric pieces to make a product.

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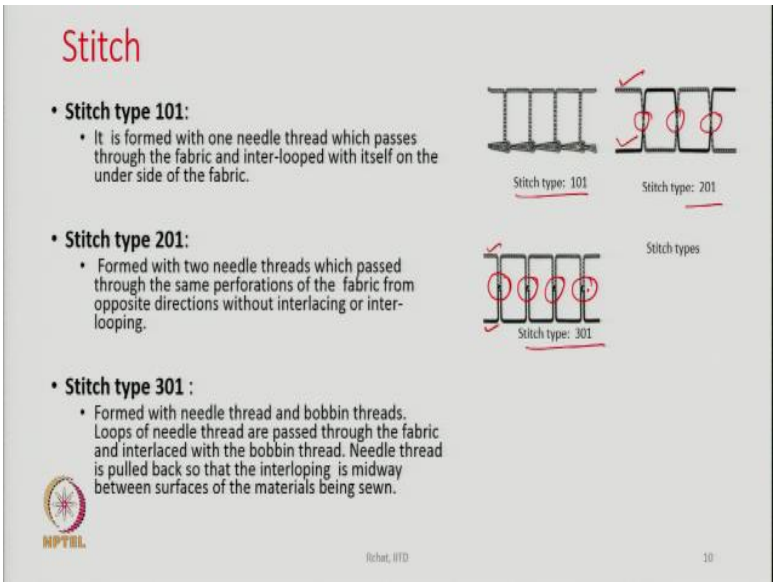

Stitch: there are different types of stitches are shown in the slide. They are stitch type 101, stitch type 201, stitch type 301, etc.; Stitch type 101 is formed with one needle thread, which passes through the fabric and inter-looped with itself on the other side of the fabric, as shown in the figure. So, the needle thread is inter-looping with itself only.

Stitch type 201: formed with two needle threads, which pass through the same perforations of the fabric from opposite directions without interlacing or inter-looping. Here, there is no inter-looping, or there is no interlacing, and it just passes through the perforations.

Stitch type 301: formed with needle thread and bobbin threads. Loops of needle thread are passed through the fabric and interlaced with the bobbin thread. So, the needle thread is pulled back so that the inter-looping is midway between the surfaces of the materials being sewn. The ideal placement of the loop is in the middle. If there is a variation in tension either in the bobbin thread or in the needle thread, the placement of this loop may either go towards the surface, or it can go towards the bottom part of the fabric.

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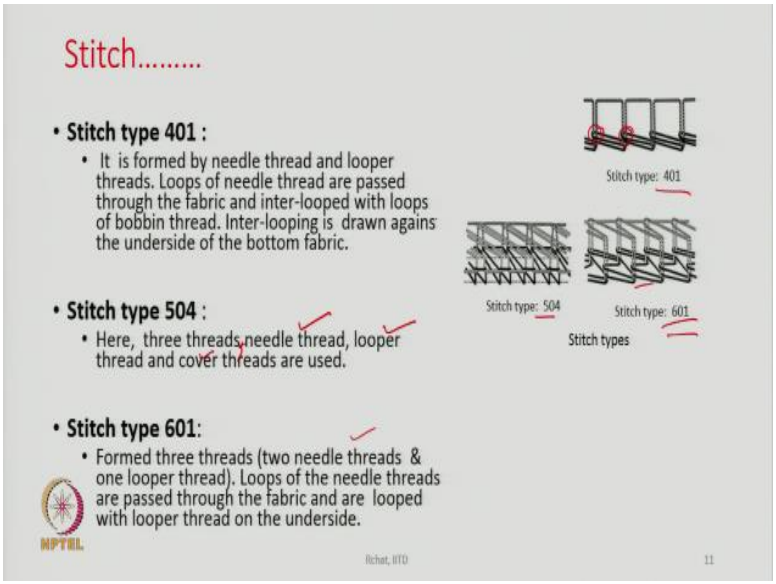

Stitch type 401: it is formed by needle thread and looper threads. Loops of needle threads are passed through the fabric and inter-looped with loops of the bobbin thread. Inter-looping is drawn against the underside of the bottom of the fabric. So here, the inter-looping part is very close to the bottom part of the fabric, so that is how these stitches are made.

Stitch type 504: three threads; needle thread, looper thread and cover threads are used. The combinations of all three types of threads are used to produce a loop.

Stitch type 601: formed by three threads (two needle threads & one looper thread). Loops of the needle threads are passed through the fabric and are looped with the looper thread on the underside. Anyway, there are different ways of inter-looping the threads, which are part of them are visible on the top side of the fabric, and the rest is visible on the bottom side of the fabric.

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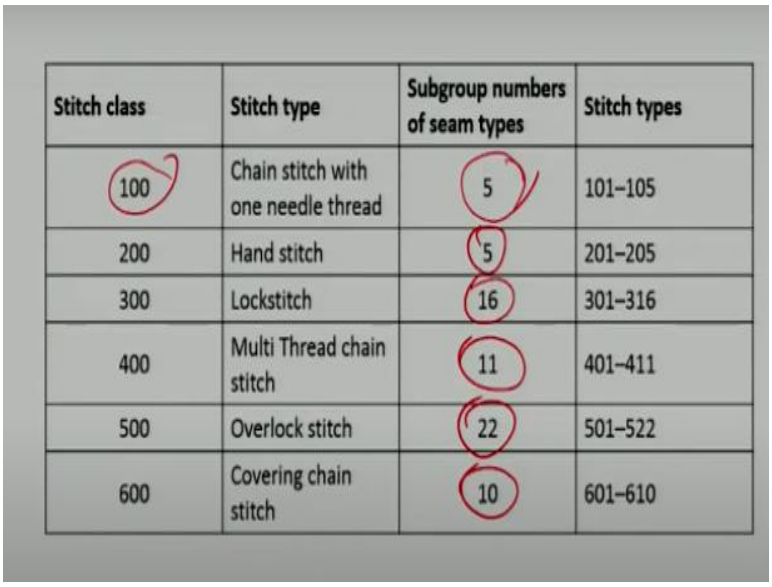

Stitch class	Stitch type	Subgroup numbers of seam types	Stitch types
100	Chain stitch with one needle thread	5	101–105
200	Hand stitch	5	201–205
300	Lockstitch	16	301–316
400	Multi Thread chain stitch	11	401–411
500	Overlock stitch	22	501–522
600	Covering chain stitch	10	601–610

The table provided in this slide gives an idea about the different stitch class and their subgroup. In stitch class 100, which is a chain stitch with one needle thread, have five subgroups, and their numbers are 101 to 105. Then, stitch class 200, which is a hand stitch, has subgroups within it. The details of these stitch classes are also available in the standard textbooks.

Lockstitch: it has sixteen subgroups and 301-316 stitch types. Then, stitch class 400 is a multithread chain stitch with eleven subgroups and 401-411 stitch types. Next, stitch class 500 is the overlock stitch with twenty-two subgroups and 501-522 stitch types. Stitch class 600 covering chain stitch with ten different subgroups and 601-610 stitch types.

So, each of them has different varieties also. So, there are six different classes, each containing a subgroup. There are different types of seams that are available and used for different purposes.

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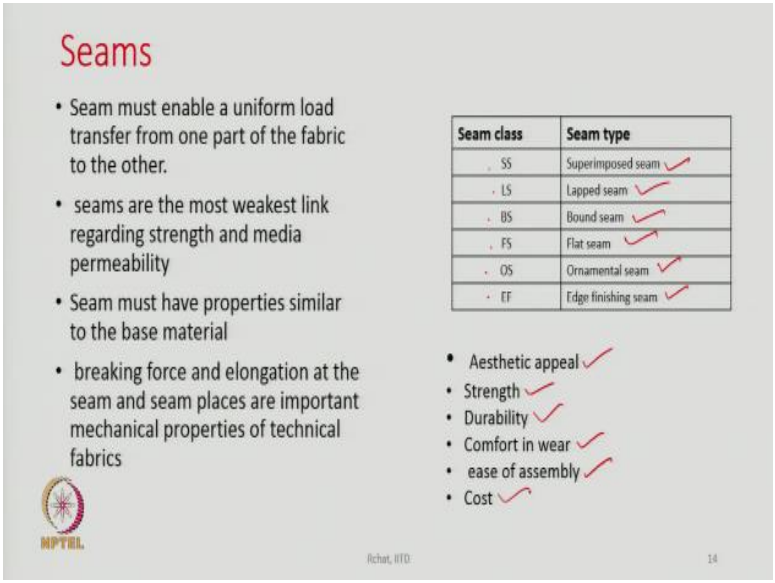

Seams: The seam must enable a uniform load transfer from one part of the fabric to the other. Seams are the weakest link regarding strength and media permeability because there is a chance of perforations during stitching; there is a chance of hole formations. Stitching can also lead to damage to the fabrics. If the stitching is not done properly, it leads to high chances of seam puckering. Anyway, we bring the two fabrics together to stitch them.

How do the two fabrics get joined? How to bring them together? How to place them? To answer these questions, the study of the seam is very important. There are different ways of placing the fabrics together during seaming, and we will study that. Seam material must have properties like the base material; breaking force and elongation at the seam and the seam places are important mechanical properties of the technical fabrics.

So, whenever we try to sew the fabrics together, perforations are created in the joined fabric and are a source of weakness. So, generally, the strength of the seams is expected to be less than the strength of the fabrics, and this becomes more important in the case of technical fabrics. We must join the technical fabrics because we need a large size of fabrics. As we cannot weave such large pieces on the loom due to the width limitations of looms, the seaming of technical fabric is very significant.

How to join the technical fabrics without compromising the strength of the fabric at the seam portion? The joining area is a source of weakness as far as strength is concerned, and therefore, a lot of research has been done in this aspect, i.e., the breaking force and elongations of the

seams, and how much it differs from the base fabric. The different types of seams are listed in the table. The very first one, 'SS', stands for superimposing seam.

The other class of seams are lapped seam, bound seam, flat seam, ornamental seam and edge finishing seam. So, in total, six different types of seams are available. The aesthetic appeal of the seam is very important because the buying decision of the garment is based on its aesthetic appeal. Therefore, the aesthetic should not be disturbed by the defects in the seam. Further, the aesthetic appeal of the seam can also enhance the aesthetic appeal of a garment. Because of the stitching line and the colour of the chosen thread, these can enhance the aesthetic appeal.

As discussed, the strength is very important, and the durability of the seam is also equally important. Comfort in wear: the seam should not lead to any discomfort, especially for the garments which are used next-to-skin, i.e., it should not abrade with the skin and create a rashes sensation to the wearer. The seam portion should not be too stiff, as it creates discomfort to the wearer. The ease of assembly is another important thing, and ultimately, the cost part is also an important consideration.

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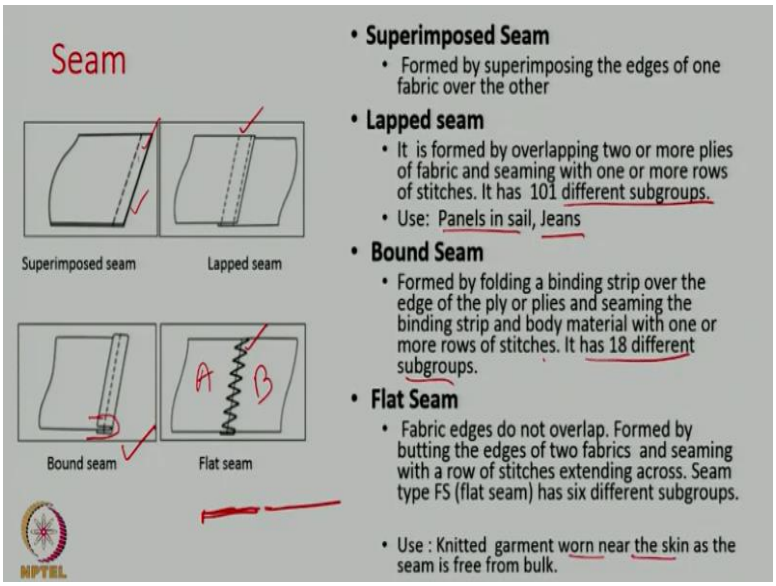

Seam types: superimposed seams are formed by superimposing the edges of one fabric over the other. As shown in the figure, two fabrics are placed, one on top of the other, and they are sewn together, which is known as superimposing; it is a very simple type of seam. Lapped seam: it is formed by overlapping two or more plies of fabric and seaming with one or more

rows of stitches. But there are more rows of stitches in this type of seam. It has 101 different subgroups within it. They are mostly used in panels in sail and jeans.

Bound seam: it is formed by folding a binding strip. As shown in the figure, a strip is bent like a U-shaped fold. It covers the edges of the fabric and sewing it. So, the edge of the fabric is not visible because it is covered by the other edge which is taking a U shape. As stated, it is formed by folding a binding strip over the edge of the ply or the plies; here, ply means fabric and seaming the binding strip and the body material with one or more rows of stitches. It has 18 different types of subgroups.

Flat seam: in the flat seam, fabric edges do not overlap. The two fabrics are broad, and the edges of the two fabrics are in the same plane. We join them by a row of stitches as shown in the figure. In the previous cases, when one fabric is placed on top of the other, the thickness of the seam area increases. Thickness may become double at the seam region when two fabric pieces are joined together. In some seam types, the thickness may be triple. So, the seam area is very thick and very hard as well.

There are products which do not need any bulk and stiffness. As shown in the figure, fabric ‘A’ and fabric ‘B’ are placed side by side without any overlap between them. The edges are brought very close to each other and are joined together by these zigzag seams. These are mostly used in knitted garments worn near the skin as the seam is free from bulk and the seam is not very stiff in nature.

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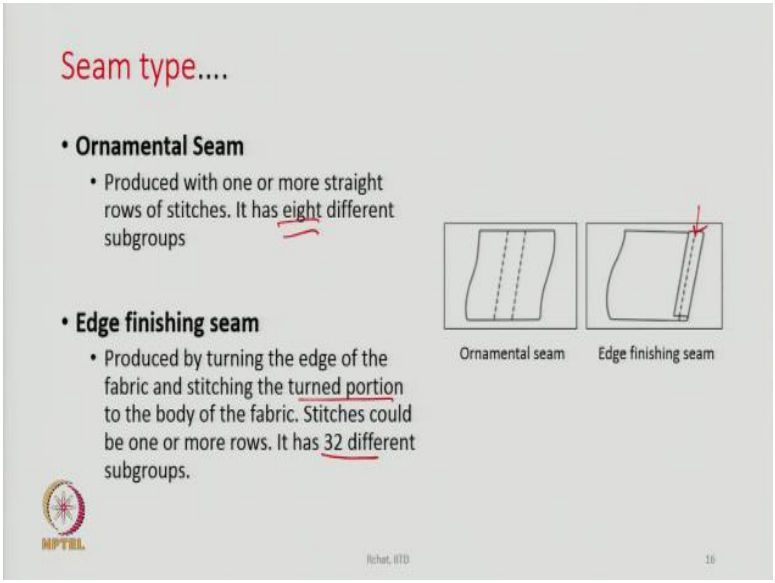

Ornamental seam: they are produced with one or more straight rows of stitches. It has eight different subgroups. Edge finishing seam: if the edges are not properly seamed, the threads may be fraying. So, to avoid such a problem, edge finishing seams are used. It is produced by turning the edge of the fabric and stitching the turn portion as it is shown in the figure. The dotted line indicates the stitch line.

The threads present at the edges could not come out due to the seam. It has 32 different subgroups. The above discussed seams are the six different types of seams. So, stitching and seams together are important for stitching. Then, we need sewing thread also. So, different types of stitching techniques are available. We can use different types of thread for sewing, and we have different types of seams as well.

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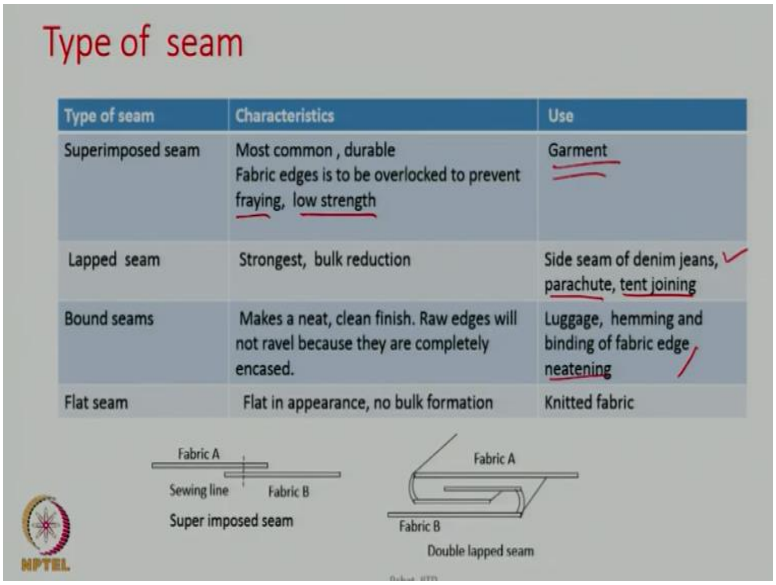

The designer must choose the right kind of seam for specific end-use. The characteristics of superimposed seams are they are most common and durable, fabric edges are to be overlocked to prevent fraying, and they have low strength. They are mostly used in garments.

Lapped seams are the strongest seams, and they are used as side seams of denim jeans. Because denim is a very tough material, and very thick fabrics are used in denim. It can be used for parachute fabrics. Lapped seams are preferred for tent joining because for sewing the tent fabrics, we need strong seams and obviously very strong threads as well. We may have one or multiple sewing lines depending upon what is the end use of that material. We must also remember that the more punctures we create, the possibility of damage is also there.

Bound seams: it makes a very neat and clean finish; raw edges do not ravel because they are completely encased. They are used in luggage, hemming and binding of fabric edges, and neatening. Flat seams: it is used mostly for knitted fabrics. Flat in appearance and with no bulk formations, they are generally soft also.

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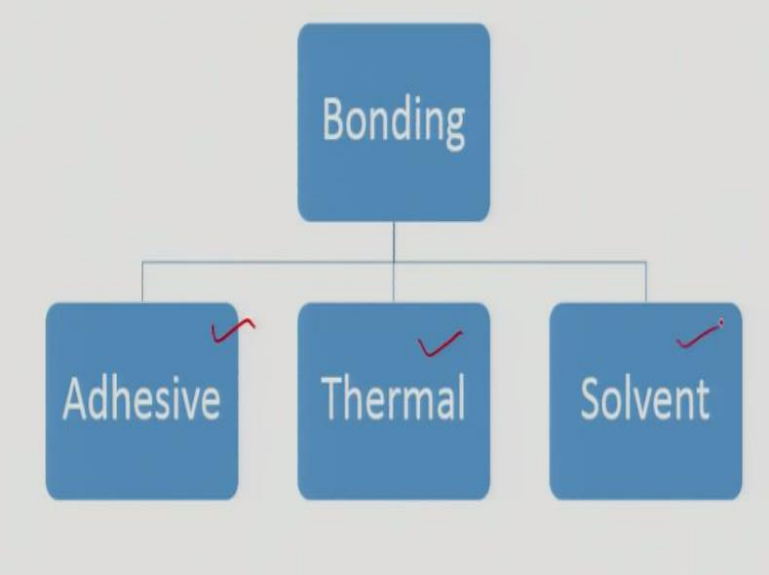

Bonding techniques: three types of bonding principles are available. For bonding, we can use adhesives, thermal energy, or solvent.

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Theories of adhesion: adsorptions and wetting, diffusion, mechanical interlocking and chemical bonding.

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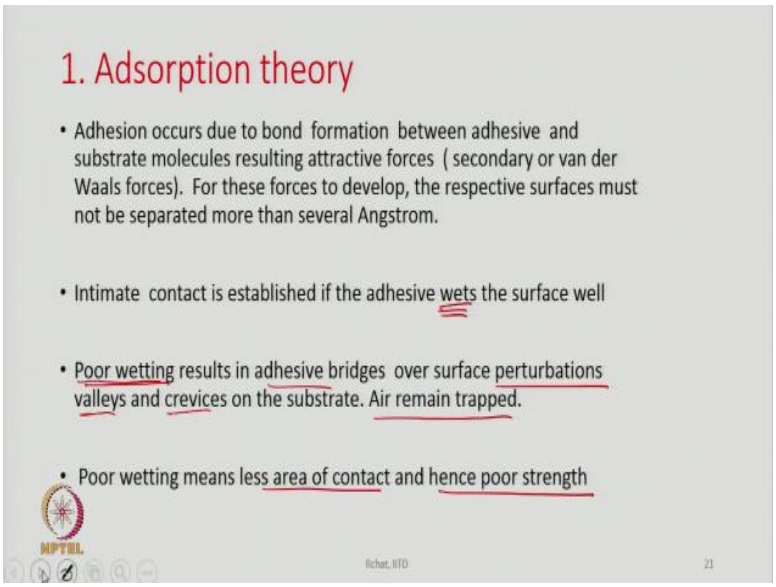

Adhesion by adhesive itself is a big field of study. In this lecture, only the surface level of information and very basics will be discussed. Adsorption theory: adhesion occurs due to bond formations between the adhesive and the substrate molecules, resulting in attractive forces (secondary or van der Waals forces). For secondary forces to develop, the respective surfaces must not be separated by more than several angstroms.

So, the adhesion occurs at the molecular level. Intimate contact is established if the adhesive wets the surface well. Poor wetting results in adhesive bridges; the adhesive does not flow properly over the substrate, and the flow property of the adhesive depends on the surface tension or the viscosity of the adhesive and the surface energy of the substrate. As discussed, poor wetting results in adhesive bridges over the surface perturbations, if the surface is rough. In that case, adhesive bridges may form on the valleys and crevices on the substrate, and there the air may remain trapped. Therefore, the adhesion is not good.

The wetting properties of the substrate can be evaluated based on contact angle measurements. The point is that it must be completely wet the surface so that the adhesive flows every nook and corner of the fabric. Many times, the fabric that we wish to join is not necessarily very smooth. There could be roughness on the fabric surface depending upon the count of yarn used, the type of weave, the roughness of the yarn, etc.

Many factors decide the surface roughness of the fabric; the yarn properties play a significant role, as the ends and pick density of the fabric and the construction parameter of the fabric. Poor wetting leads to less area of contact, and hence poor strength.

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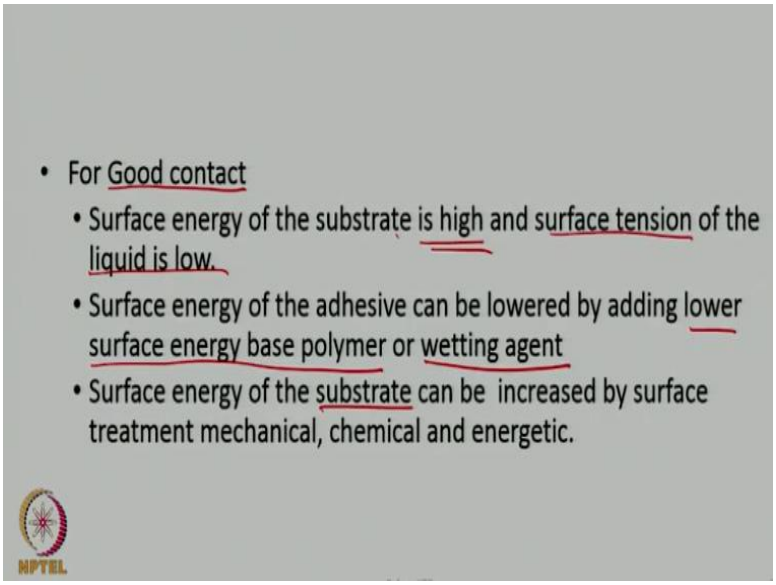

What should we do for good contact? The Surface energy of the substrate is to be high, and the surface tension of the liquid must be low; so, we need to choose the substrate and adhesive which fulfils this condition. How to bring down the surface tension of the adhesive? The surface

energy of the adhesive can be lowered by adding a lower surface energy-based polymer or by adding a wetting agent.

The adhesive is the liquid which flows and wets the substrate surface so that the surface energy of the substrate is equally important. Sometimes, it is not necessary that fabric must be joined with the fabric itself. Fabric can be joined with leather, or artificial leather or with plastic material. So, it all depends on the type of materials that we need to join. Anyway, the surface energy of the substrate can be increased by surface treatments, which can be mechanical, chemical treatments or by some energy.

Detailed discussions of surface treatments are available in standard textbooks, which helps to understand the methods to change the surface energy of the substrate. Plasma treatment is one of the techniques, and there are other techniques also by which the surface energy of the substrate can be changed. The surface can be modified by chemical treatment also; there are some chemicals that change the surface energy of a fibre or a fabric.

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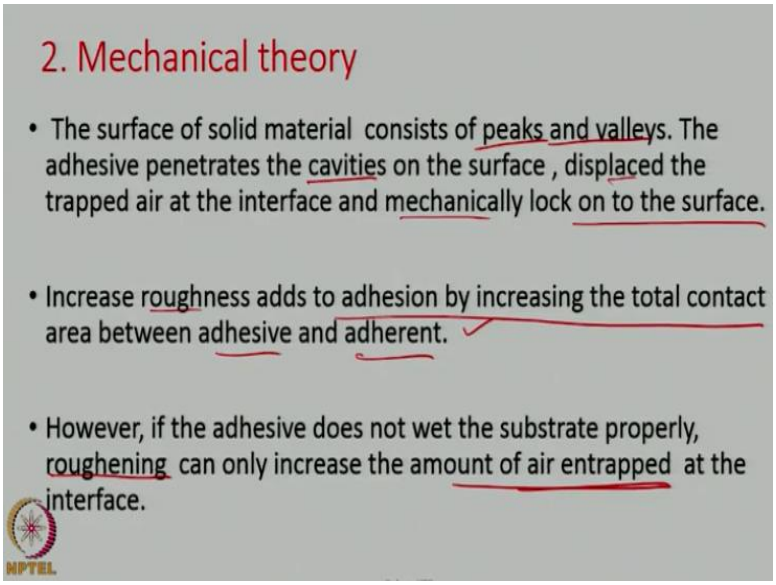

The mechanical theory is based on the fact that the surface of a solid material consists of peaks and valleys. We know that the fabric surface is rough, unlike glass, which is very smooth. It has a lot of peaks and valleys. There is always undulation, and the adhesive penetrates the cavities on the surface, displays the trapped air at the interface, and mechanically locks onto the surface. So, an increase in roughness benefits adhesion by increasing the total contact area

between adhesives and the substrate. However, we must be very careful so that the air should not remain trapped.

If the adhesive does not wet the substrate properly, roughening can increase the amount of air trapped. Due to the air entrapment, sometimes we may not get the expected strength from the adhesive joint. So, roughening may lead to this kind of problem, i.e., the trapping of the air. There could be micro pockets of air, and those air pockets are a source of weakness. Therefore, it reduces the interfacial strength. There are certain technical products where the strength of the joint is very important, and one such product is aerostat products.

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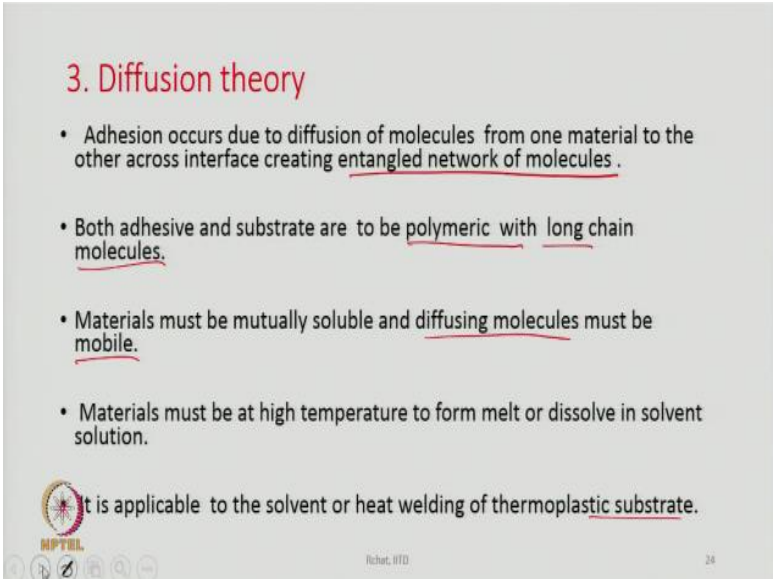

Diffusion theory is based on the adhesion that occurs due to the diffusion of the molecules from one material to the other across the interface, creating an entangled network of molecules. So, the diffusion of the molecules creates an entanglement at the molecular level. Earlier, we discussed the entanglement between fibres to join the two ends of broken spun yarn which creates entanglement through splicing techniques. Here, we are dealing with molecular-level entanglement because of the diffusion process.

For the diffusion process, both adhesive and substrate are to be polymeric in nature with long-chain molecules. It cannot be the joining of metal with polymer or any other similar combinations which restricts the diffusion process. So, both must be polymeric in nature, and materials must be mutually soluble, diffusing molecules must be mobile.

The material must be at a very high temperature to form a melt or dissolve in solvent solution so that we can use a solvent which melts both the polymers at the interface and creates the molecules to diffuse into each other, forming an entangled network of molecules. On the other hand, we can melt the material at the interface, and the molten polymer molecules become mobile and try to diffuse into each other to form a very entangled network of molecules.

The diffusion theory is applicable to solvent or heat welding of thermoplastic substrates. Thermoplastic substrates are polymeric materials which soften upon heating and harden upon cooling.

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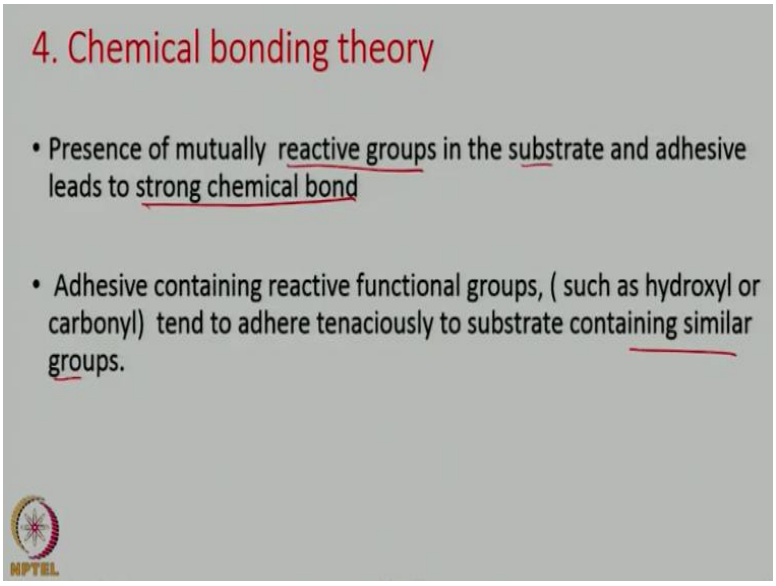

Chemical bonding theory based on the presence of mutually reactive groups in the substrate and the adhesive leads to strong chemical bonds. So, adhesives containing reactive functional groups, such as hydroxyl groups or carbonyl groups, tend to adhere to substrates containing similar groups. So, there is a chemical bond formation between the adhesive and substrate. It is similar to the chemistry of dyeing where the dye molecules are attached to the fibres by chemical bonds.

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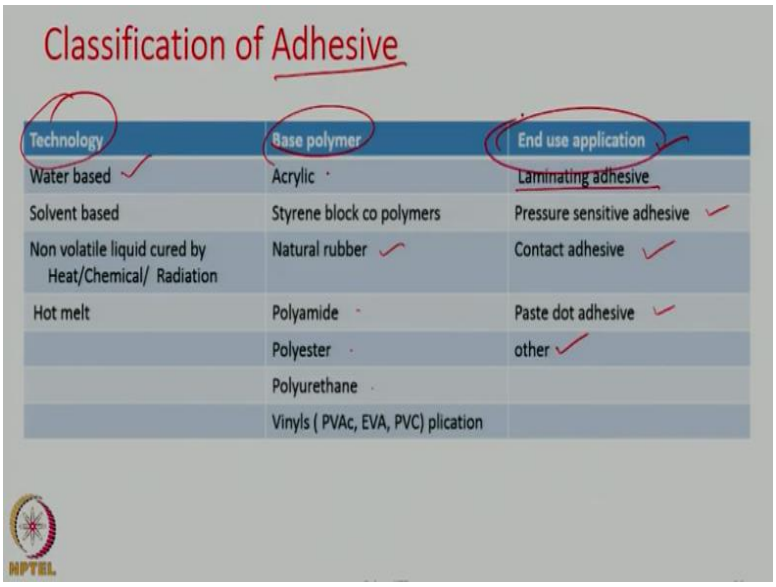

Classification of adhesive: it can be classified based on technology, polymer, and end-use application. Under the technology-wise classification, the adhesives could be water-based, solvent-based, non-volatile or hot melt-based. The base polymer-wise could be acrylic, styrene block copolymers, natural rubber, polyamide, polyester, polyurethane, or vinyls. The applications are laminating adhesives or pressure-sensitive adhesives, contact adhesives, paste dot adhesives and others.

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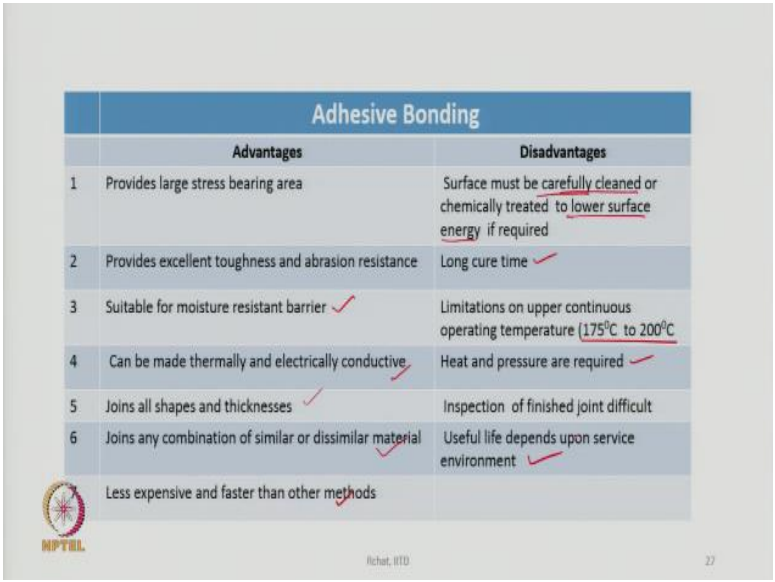

Adhesive bonding: the advantages and disadvantages are listed in the table. The advantages are providing a large stress-bearing area, excellent toughness and abrasion resistance, suitable for moisture resistance barrier, can be made thermally and electrically conductive, joins of all

shapes and thicknesses, joins any combination of similar or dissimilar material, i.e., fabric with plastic or with metal pieces or maybe with foam, less expensive and faster than the other methods.

Disadvantages are that the surface must be carefully cleaned as there should not be an air trap, and chemically treated to lower surface energy if required. Many times, we reduce the surface energy of the substrate through chemical treatment (for example, the polyester fibre must make a good bond with the rubber in the case of tyres). In that case, the surface of the polyester fibre is treated chemically to create a strong bond with the tyre material, so generally, a long curing time could be there.

Next is the limitation on upper continuous operating temperatures of 175 to 200 ℃; heat and pressure are required, an inspection of finished joints is difficult, and useful life depends upon the service environment.

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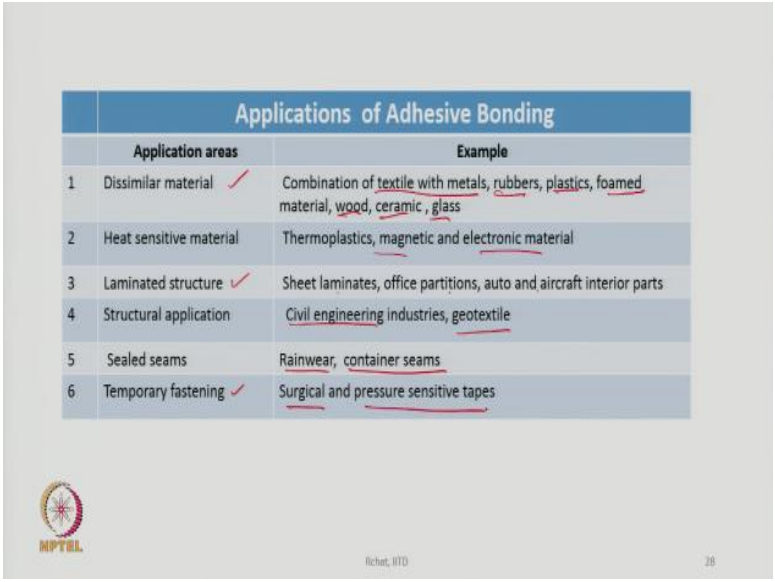

Applications of adhesive bonding: dissimilar materials like textiles with metals, rubbers, plastics, foamed materials, wood, ceramic, and glass can be used. When textiles must be joined with them, then adhesive bonding is preferred. We cannot sew very hard materials, so adhesive bonding is preferred in such cases. It is primarily used to join heat-sensitive materials such as thermoplastics, magnetic, and electrical materials. For laminated structures such as sheet laminates, office partitions, auto and aircraft interior parts.

Next is the structural application in civil engineering industries and geotextiles. Sealed seams: rainwear and container seams. So, for the rainwear, the sealed seams are preferred because the puncture hole should be completely sealed by some adhesive so that there is no chance of water penetrating through those puncture holes. Nowadays, we can put adhesive tape also. Temporary fastening: surgical and pressure-sensitive tapes are available.

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Common Adhesive Applications

Application areas	Example	Common substrate	Requirements in Adhesive
Apparel accessories	Lamination in clothing and fashion accessories	Fabric to fabric Fabric to foam Fabric to metalized film	Wash and dry cleaning resistance, Soft hand Good elongation
Upholstery	Home, office and automotive interior parts	Woven to non woven fabric Fabric to foam	Resistance to dry cleaning solvent / steam cleaning, elongation
Home furnishing	Table cover, shower curtain, draperies	Fabric to fabric Fabric to foam Fabric to film	Wash and dry cleaning resistance,
Tarpaulins, covers, industrial blanket	chemically treated fabric	Fabric to film Film to fabric to film	High shear strength, weather ability, heat, cold , chemical resistance
Pressure sensitive applications	Shoe construction tapes,	Fabric, fibre glass	High peel strength, resistant to the end use environment

The application areas of adhesive bonded products are very vast. Some of the common adhesive applications are stated in the table. Application areas like apparel accessories, lamination in clothing and fashion accessories. Common substrate of fabric to fabric, fabric to foam or fabric to metallized film. The requirements in adhesives are they must be washable and dry cleanable. Resistance is very important because these accessories which are there in apparel are subjected to washing and dry cleaning.

The adhesives should give a soft hand, and they must provide good elongation because they must adhere to the clothing material fabric, which already possesses certain elongation. The adhesive joint should not stiffen. Upholstery is another application area; home furnishing, tarpaulin covers, and industrial blankets are technical textile areas and pressure-sensitive applications. Only a few of the examples are stated. As stated, the application range is very vast. The adhesive type must be chosen based on the substrate and end-use application.

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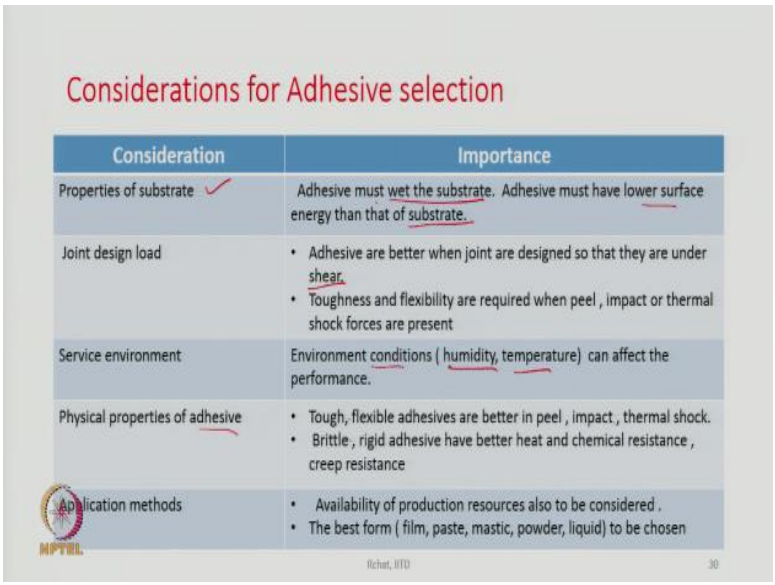

What are the considerations for adhesive selection? The first one is the properties of the substrate because the adhesive must wet the substrate. The substrate could be a cotton fabric, polyester/cotton fabric, 100 % polyester or nylon, etc. The adhesive must have a lower surface energy than the substrate. Most of the soft luggage is made from either polypropylene or nylons, and there, the adhesive may be used.

Joint design load: adhesives are better when joints are designed so that they heat under shear. On shear, adhesives are much better. Surface environment: the environmental conditions, especially humidity and temperature, are very important as they affect the performance of the adhesive. Physical properties of adhesive: toughness, flexibility, impact resistance, thermal shock, brittleness, etc, are very important considerations for the adhesive.

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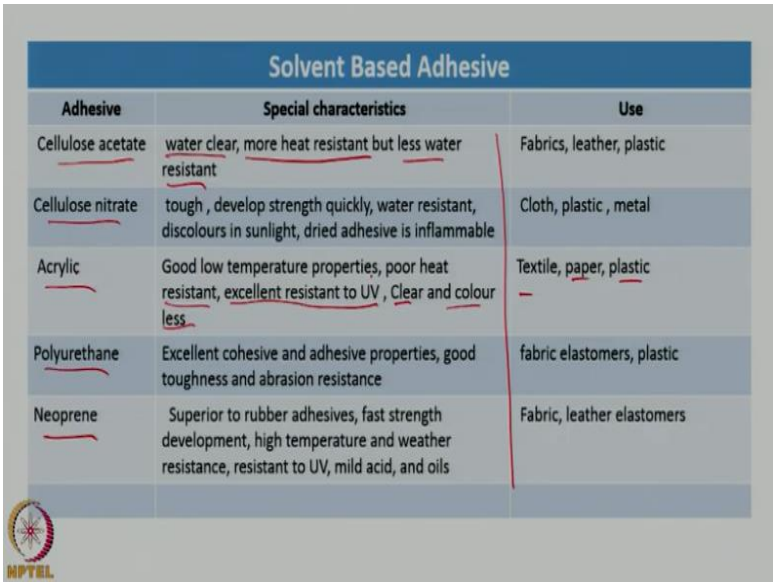

Solvent-based adhesives are stated in the table. Cellulose acetate, cellulose nitrate, acrylic, polyurethane, and neoprene are solvent-based adhesives. Special characteristics: the special characteristics of cellulose acetate are water clear, more heat resistant but less water resistant. For cellulose nitrate also, the special characteristics are stated in the table along with uses. Acrylic: good low-temperature properties, poor heat resistance, excellent resistance to UV. The acrylic adhesive is colourless. So, it does not affect the colour of the base fabric, the original colour will be visible. It is used in textiles, papers and plastics. The other adhesives' special characteristics and uses are also given in the table, which is self-explanatory.

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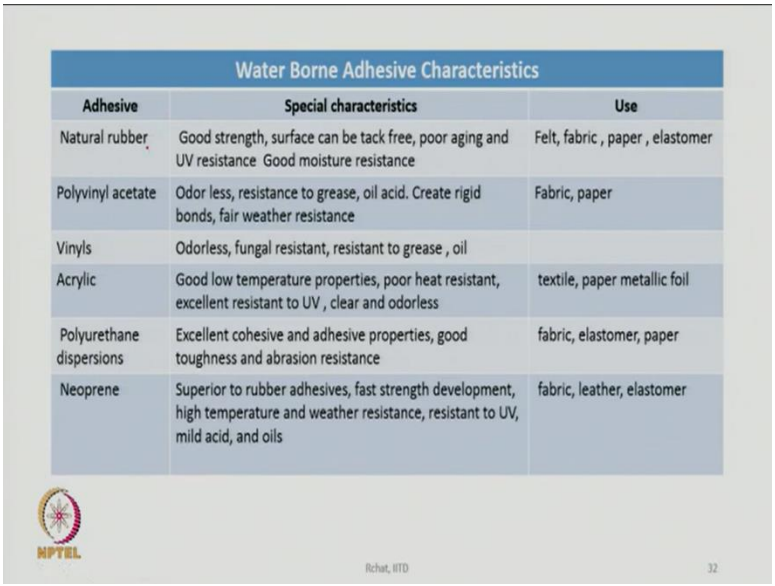

Similarly, water-borne adhesive characteristics and uses are also given in the table. The adhesive types are natural rubber, polyvinyl acetate, vinyls, acrylics, and so on.

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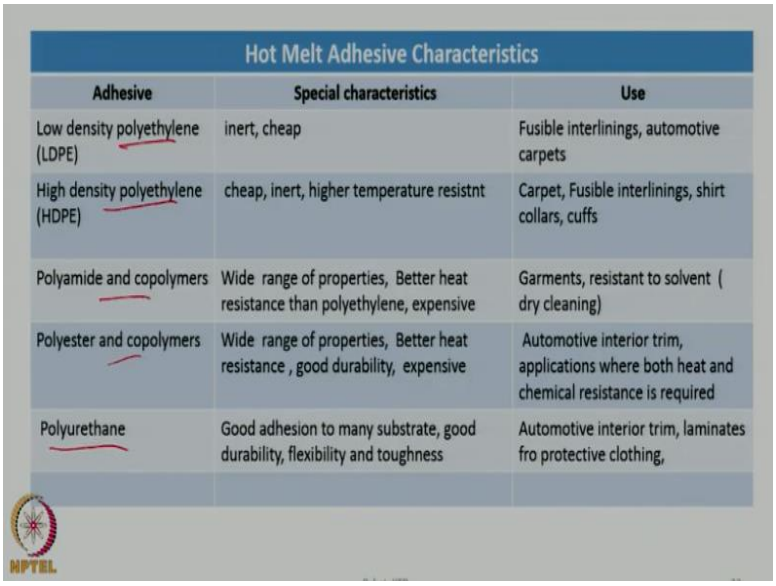

Hot melt adhesive characteristics and uses are stated in the table. The adhesives are low-density polyethylene, high-density polyethylene, polyamide, polyester, polyurethane, etc. There is no need to remember all the characteristics as these types of data banks are available with the designer. Based on these tables, the designer can make a preliminary selection. If one wants to know more about it, obviously, it is advised to refer to the standard textbooks where much more details are available about adhesives.

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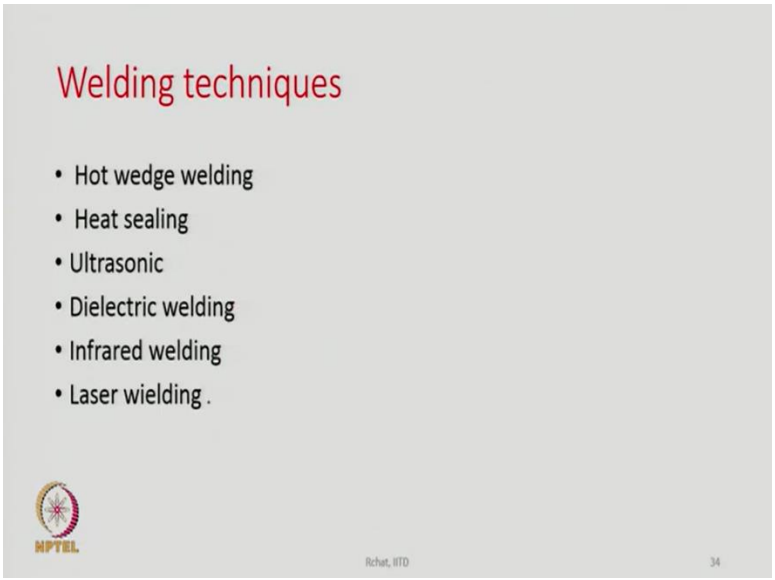

The next discussion is about welding techniques. The types are hot wedge welding, heat sealing, ultrasonic, dielectric welding, infrared welding and laser welding. So, these are the different welding techniques where the textile materials are welded together.

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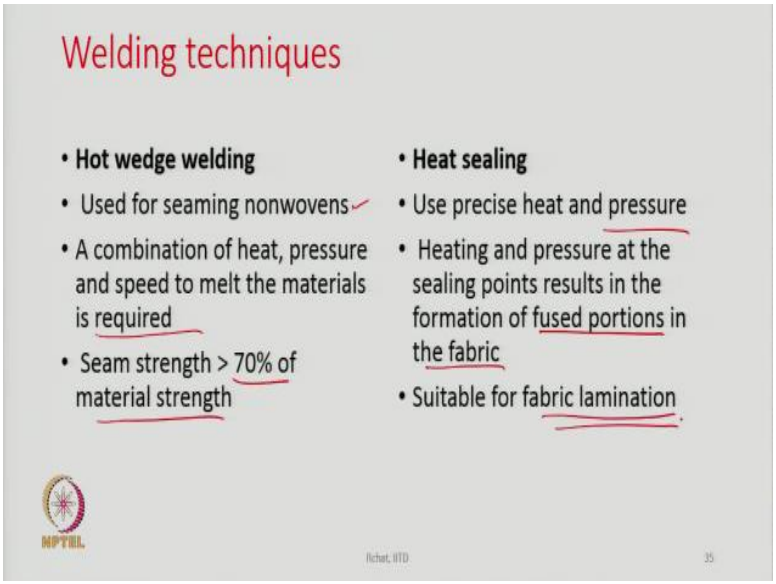

The hot wedge welding technique is usually employed for seaming nonwovens. A combination of heat, pressure and speed to melt the material is required for seaming. Obviously, we cool them to create a joint between the fibres. The seam strength becomes 70% of the material strength in this technique.

The heat sealing uses precise heat and pressure. Heat and pressure at the sealing point results in the formation of fused portions. The heat is applied to a level so that the polymer melts. Once it melts, then, we must cool it down for the formation of fused ends. and that would be a bonding between the two materials. Heat sealing and hot wedge welding techniques are suitable for fabric laminations.

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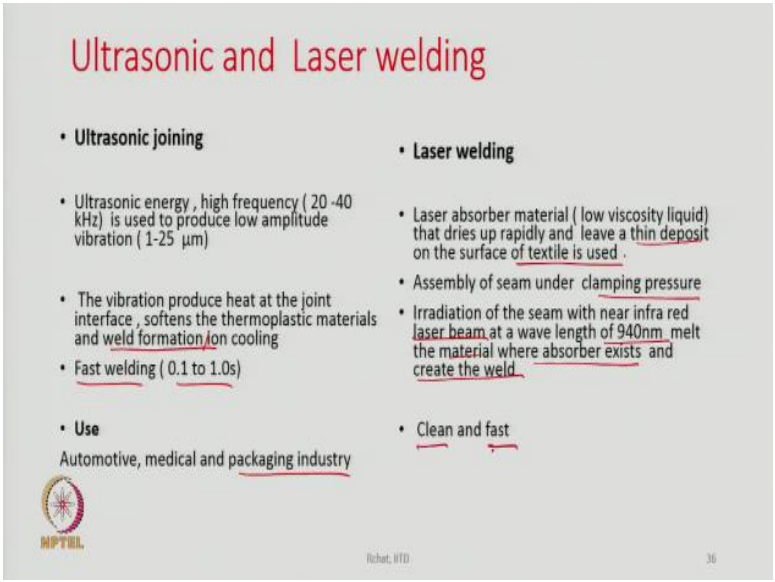

Ultrasonic and laser welding: in ultrasonic joining, ultrasonic energy, which is high frequency, is used to produce low amplitude vibration. The vibration produces heat at the point, i.e., at the interface. So, the advantage is that at the interface, the heat will be generated; it is not the heat that has to be supplied from the top or from the bottom. The generated heat softens the thermoplastic material and welds formations on cooling. Fast welding takes 0.1 to 1.0 s. The uses are in the automotive, medical and packaging industries.

Laser welding: the source of heat is the laser. Laser absorber material (low viscosity liquid) that dries up rapidly and leaves a thin deposit on the surface of the textile is used. So, laser-absorbing material must be used here. Then, assembly of seam under clamping pressure. The irradiation of the seam with a near-infrared laser beam at a wavelength of 940 nm melts the

material where the absorber exists and creates the weld. So, the absorber present at the interface creates a melt with the substrate. In laser welding, only the targeted area gets melted, which is the biggest advantage. It is clean and very fast technology.

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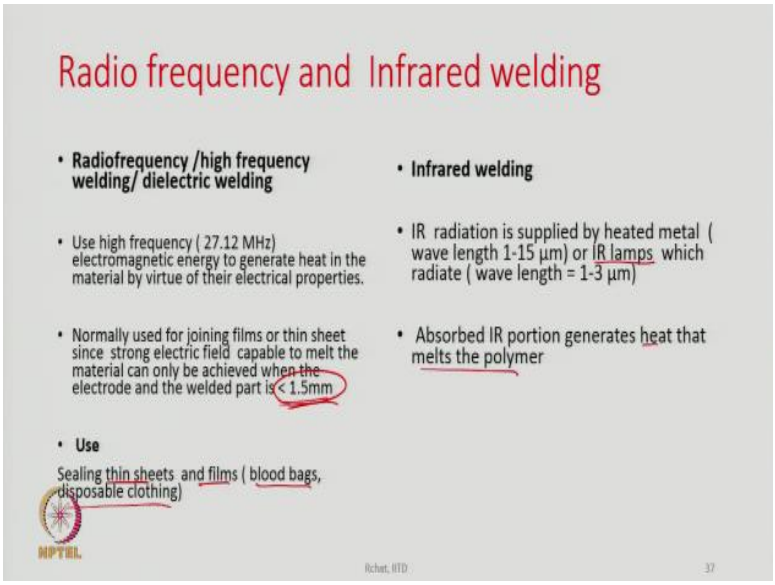

Radiofrequency and infrared welding: radio frequency welding technology uses high-frequency electromagnetic energy to generate heat in the material by virtue of their electrical properties. Normally, it is used for joining films or thin sheets since a strong electric field capable of melting the material can only be achieved when the electrode and the welded part are less than 1.5 mm.

So, very thin fabrics can only be used with a thickness of less than 1.5 mm. If it is too thick fabrics, then radio frequency welding devices cannot be used. The uses are sealing thin sheets, and films like blood bags, disposable clothing, etc.

Infrared radiation welding: IR radiation is supplied by heated metal or IR lamps. The absorbed IR portion generates heat that melts the polymer.

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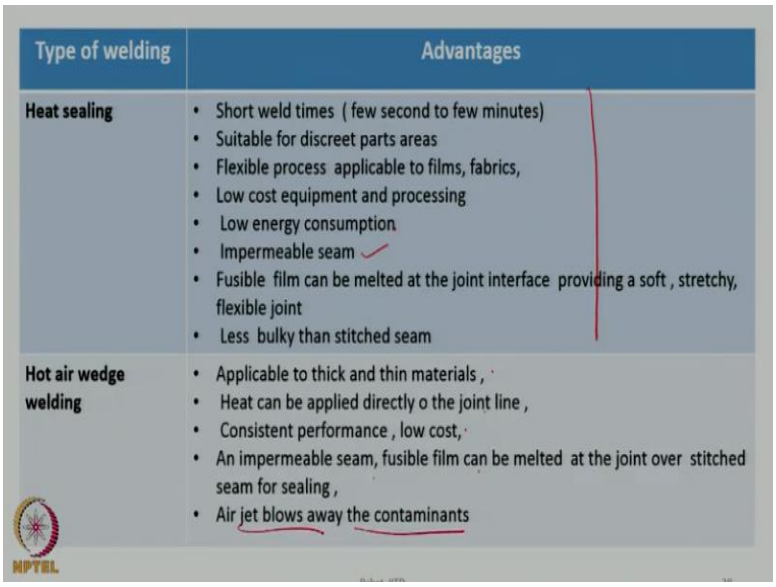

Type of welding	Advantages
Heat sealing	• Short weld times (few second to few minutes) • Suitable for discreet parts areas • Flexible process applicable to films, fabrics, • Low cost equipment and processing • Low energy consumption • Impermeable seam • Fusible film can be melted at the joint interface providing a soft , stretchy, flexible joint • Less bulky than stitched seam
Hot air wedge welding	• Applicable to thick and thin materials , • Heat can be applied directly o the joint line , • Consistent performance , low cost, • An impermeable seam, fusible film can be melted at the joint over stitched seam for sealing , • Air jet blows away the contaminants

Different welding techniques and their advantages are stated in the table. Heat sealing: the advantages are short weld times, suitability for discrete parts areas, flexible process, low-cost equipment, low energy consumption, and impermeable seam, and these are the advantages.

Hot air wedge welding: applicable to thick and thin materials, heat can be applied directly to the joint line, consistent performance, lower cost, an impermeable seam, fusible film can be melted, and air jet blows away the contaminants. In the case of hot air, because the air is blowing, the contaminants will be flying away, which will not be there in the case of heat sealing, where there is no air.

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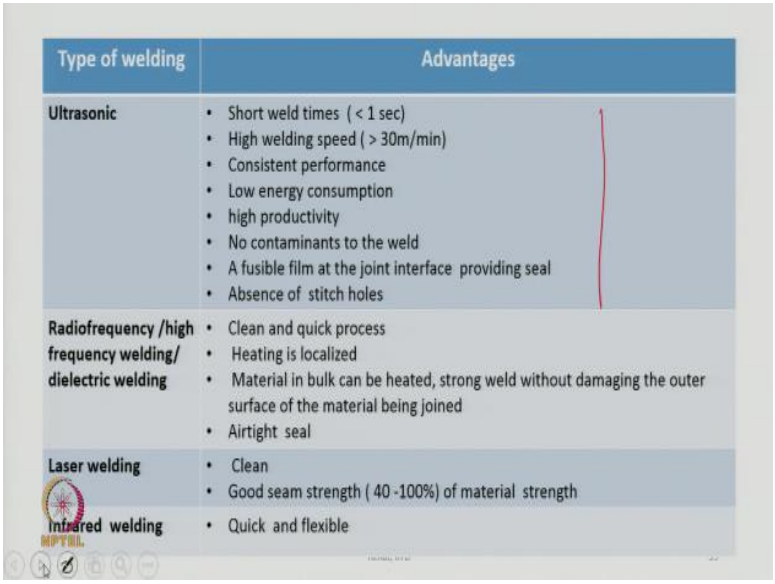

Type of welding	Advantages
Ultrasonic	• Short weld times (< 1 sec) • High welding speed (> 30m/min) • Consistent performance • Low energy consumption • high productivity • No contaminants to the weld • A fusible film at the joint interface providing seal • Absence of stitch holes
Radiofrequency /high frequency welding/ dielectric welding	• Clean and quick process • Heating is localized • Material in bulk can be heated, strong weld without damaging the outer surface of the material being joined • Airtight seal
Laser welding	• Clean • Good seam strength (40 -100%) of material strength
Infrared welding	• Quick and flexible

Ultrasonic advantages are stated: short weld time and high welding speed. The advantages of other welding techniques are self-explanatory. So, depending upon the advantages, the cost, the material to be processed, and the productivity, the designer can choose any welding technique.

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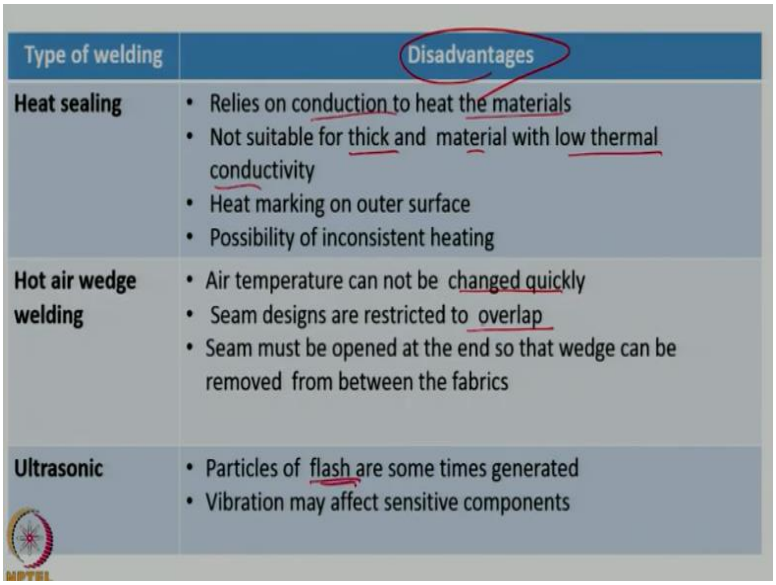

The disadvantages of each welding technique are also stated in the table. When deciding on the welding technology, the disadvantages also must be considered. The heat sealing technology relies on conduction to heat the material. So, the conductivity of the material is important. The material, which is highly insulative in nature, obviously takes more time for welding. It is not suitable for thick material, and material with low thermal conductivity.

Hot air wedge welding: air temperature cannot be changed quickly, and seam designs are restricted to overlap, etc. Ultrasonic welding: the particles of flash are sometimes generated, and the vibration may affect sensitive components which are around.

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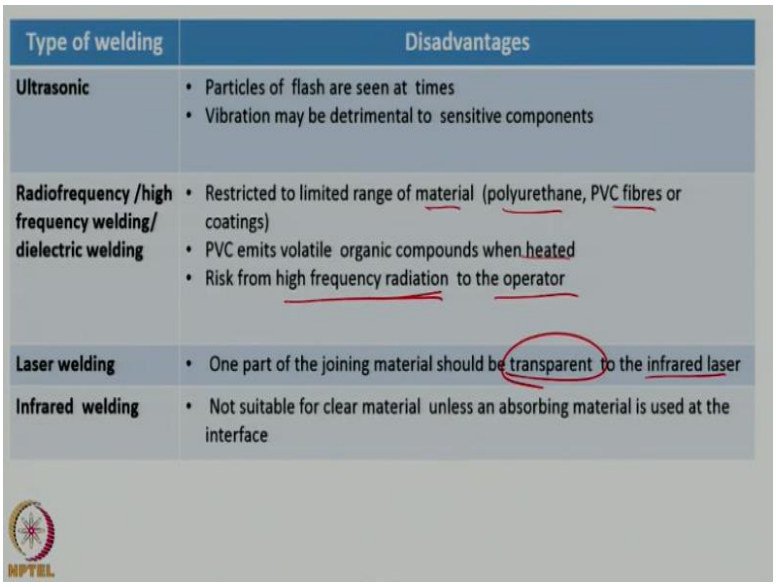

Radiofrequency welding: it is restricted to a limited range of materials (polyurethane, PVC fibres or coating). PVC emits volatile organic compounds when heated, causing risk from high-frequency radiations to the operator. Laser welding: one part of the joining material should be transparent to the infrared laser.

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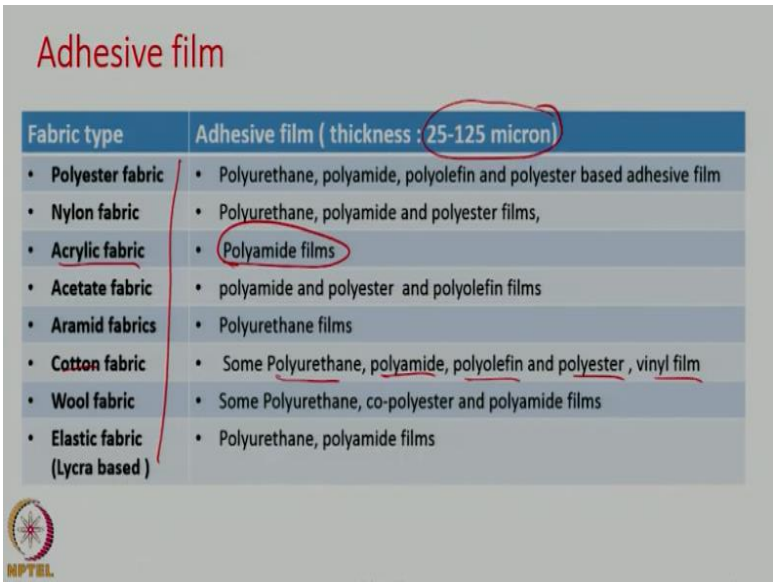

Adhesive film: the fabric types and their suitable adhesive films are stated in the table. The textile fabrics could be polyester, nylon, acrylic, acetate, aramid, cotton, wool, or elastic fabric (lycra-based fabrics). The adhesive films are very thin; 25 to 125 microns. Let us say, if the fabric is acrylic fabric, we can use polyamide films for the joining purpose.

For cotton, we have many choices: polyurethane, polyamide, polyolefin, polyester, and vinyl film. Through the adhesive film also, we can join the fabrics or seal the seams depending upon the requirement. So, as a designer, we must have an idea of the various options that we have. Based on the applications, the type of material being used, and the user environment in which the product could be used, the cost, the expected service life, and the suitable joining technique must be chosen based on all the above factors.

Sometimes we may have multiple options suitable for joining. In that case, depending upon the cost of the technology and the availability of technology with that company, one should select. So, it is not that all the technologies are available in any industry. With this, we conclude, thank you.