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Fundamentals of production technology

Strategic project of UTB in Zlin, No. CZ.02.2.69/0.0/0.0/16_015/0002204

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1. Basic technological processes



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Most used technologies of leather production

- Separation
- Coupling
- Shaping of deformations
- Forming
- Chip machining
- Adjustment of physical properties
- Surface finish



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Separation

- This designation defines technological operations in which a part of the material is separated from a larger unit
- Separation: gradual and one-ordinate



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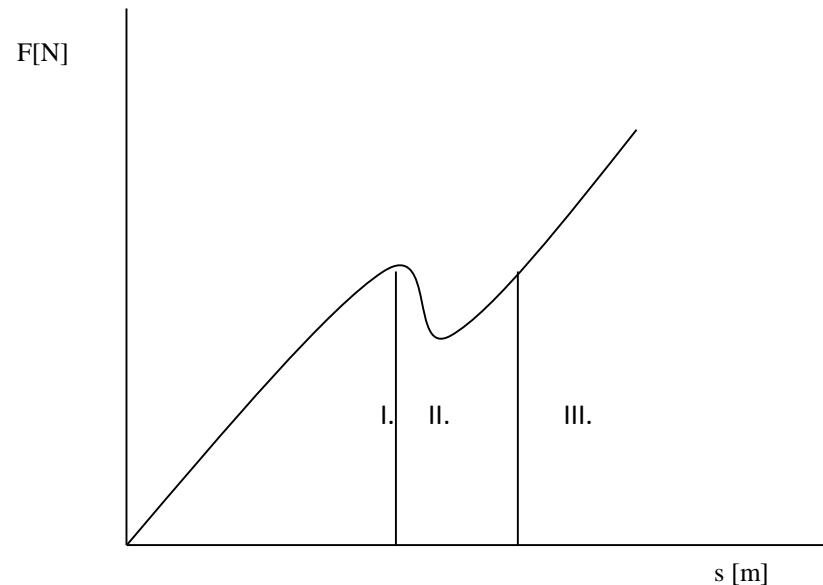


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Cutting out (Hluchý, 1998)



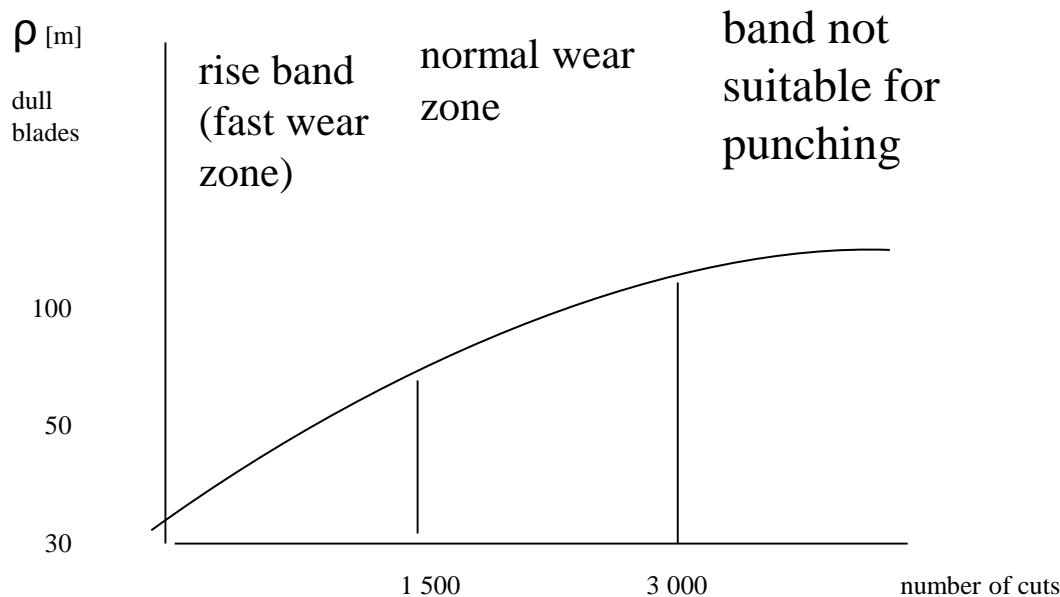
- I. Deformation of the material
- II. Cutting material
- III. Lock into the washer

The course of the punching force





Cutting out (Kalpakjian, 2014)



The process of dulling the knife





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Cutting knives

- With a one-sided blade
- With a double-sided blade
- Hot-produced
- Cold-produced
- Individual - stems with rubber extractors
- Combined – passage and non - passing



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Cutting pads

- Wooden for undercut handling
- Cardboard (made from strips of shoemaking cardboard or fibrous leather)
- drawn bolts through wooden cutters for cutting the textiles



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Separating the oscillating knife

- Gerber – USA, Investronica – Spain, Lectra – France
- The entire system is controlled by a powerful, easy-to-use computer
- The folding method is programmed, and the number of layers and devices will be performed automatically by the entire stacking process directly on the cutting table



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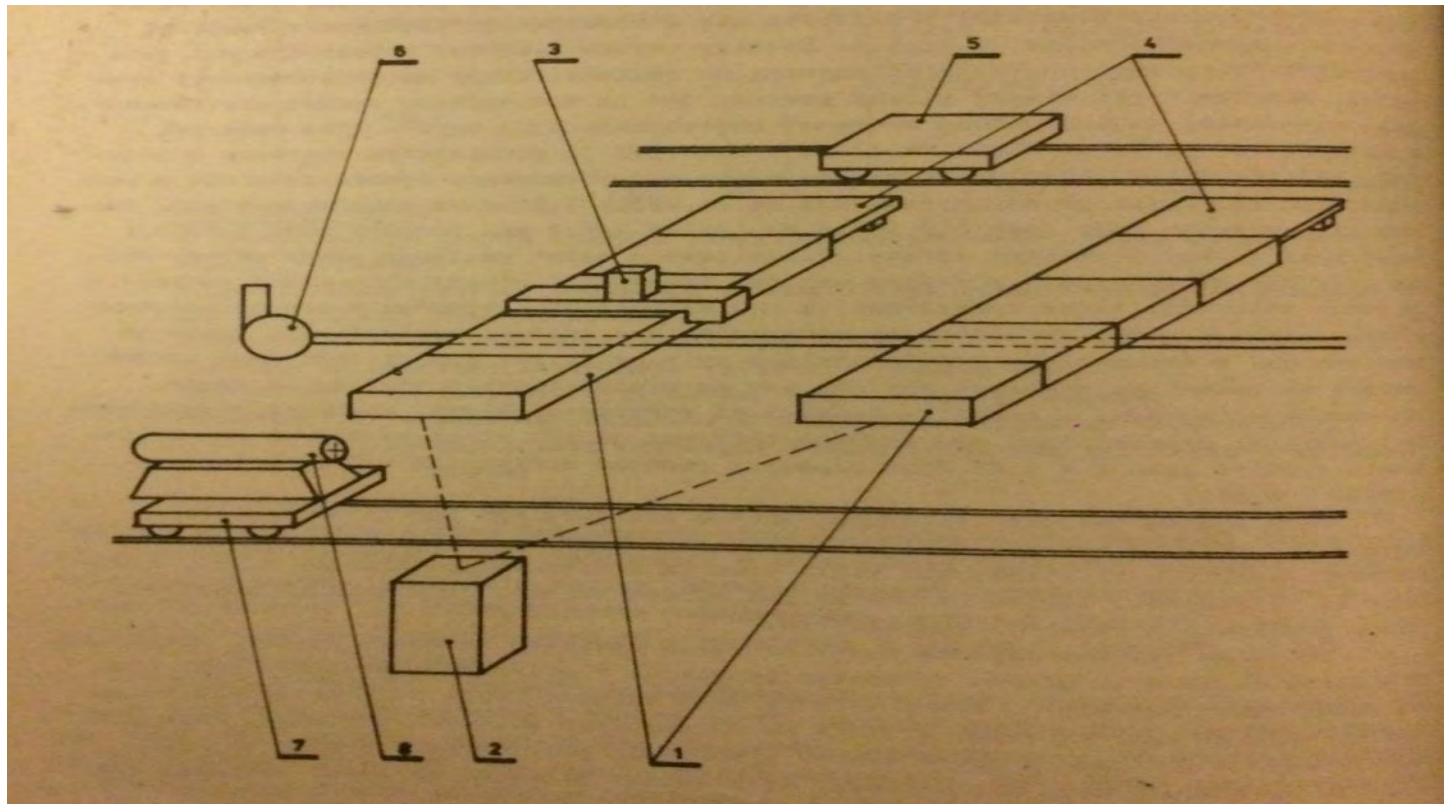


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Schematic diagram of one of the possible configurations of the cutting device based on the oscillating knife principle(Goonetilleke,2012)





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Description of the figure above:

1. Cutting tables
2. Control unit
3. Cutting head
4. Extension module
5. A transport cart
6. A vacuum generator
7. Transport trolley for folding device
8. Folding device





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Liquid jet separation

- Relatively new technologies
- Separating the material with a very narrow beam of highly compressed fluid medium
- This system is mainly applied to the materials used for production of footwear parts



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The automatic separation of materials by the liquid jet method can be further divided according to the high-pressure liquid used:

- A. Equipment using water as a cutting medium
- B. Apparatus using a mixture of water and polymer as a cutting medium
- C. Apparatus utilizing a mixture of water and abrasive as a cutting medium





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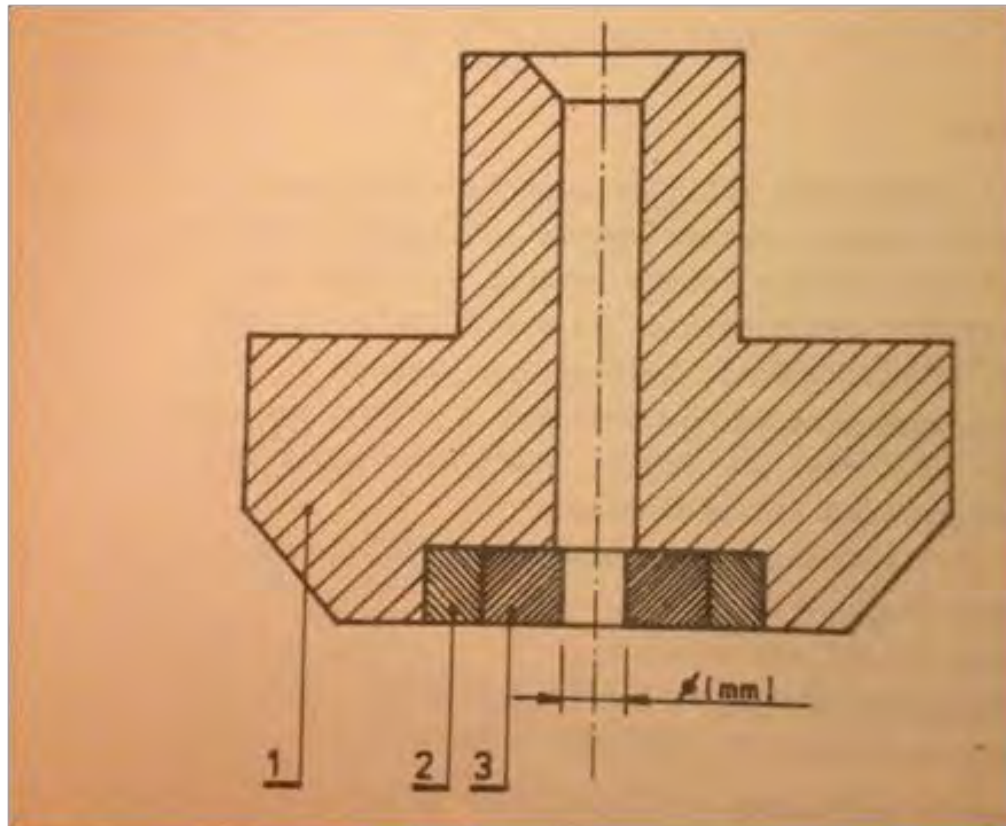
Water jet cutting device

- Consists of the following basic parts:
 - Filtration device ensuring cleanliness of the cutting medium
 - Compressor and pressure multiplier (provide high energy water jet)
 - Static or coordinate cutter table with trap
 - Cutting head with sapphire nozzle.





Sapphire nozzle scheme (Leinweber, 2003)



Description:

1. Steel holder
2. Centring seal
3. Sapphire
4. $\varnothing = 0,03 - 0,25 \text{ mm}$





The device utilizing a mixture of water and polymer

- the cutting fluid is in this case formed by filtered demineralized water with an admixture of 0.3% of the polymer
- the advantage of using this medium is that it forms a longer coherent jet beyond the nozzle, which is suitable for cutting thicker or multilayer materials.





Apparatus employing a mixture of water and abrasive

= PASER (Particle Stream Erosion)

- is the name of a device using cut water (demineralised, distilled or at least filtered) to which the abrasive material is mixed
- the most commonly used abrasive materials include siliceous sand





Radiation separation (laser)

- The laser beam was one of the first cutting tools of the new generation
- The disadvantage: there are considerable demands on the adjustment and maintenance of the equipment, there is also an increased risk of material burning and dangerous gases are released during cutting





Coupling – sewing

- of the oldest and most widely used techniques
- Initially, the hand sewing process
- in the middle of the 19th century by machine sewing
- the second half of the 20th century, sewing machines came into sewing workshops.
- The seam is the place of the union of two or more of the same or of various materials by sewing and gluing, welding, etc.





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Sewing up shoes(Goonetilleke,2012)



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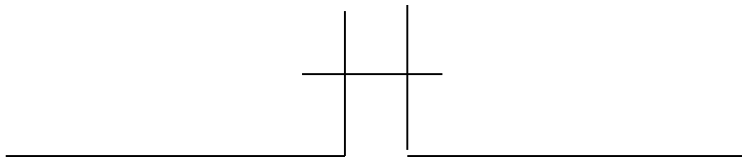


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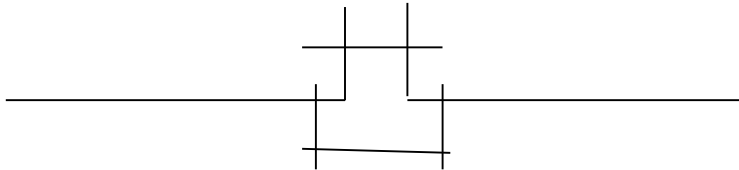


Joining - sewing(Goonetilleke,2012)

Spine seam



Spine seam overlapped



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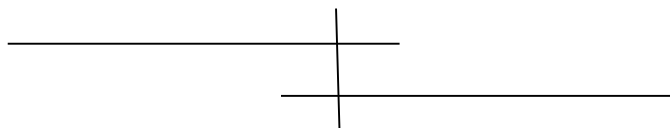




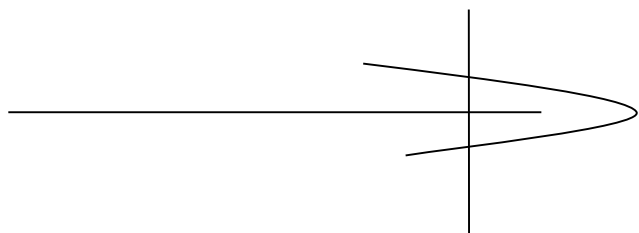
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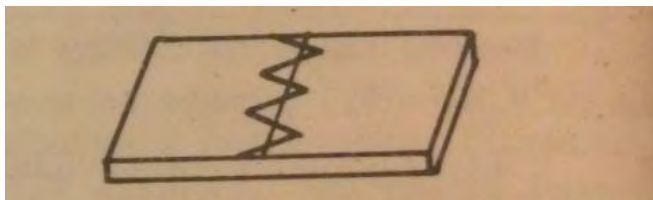
Overlapped seam



Lining seam



Touch seam



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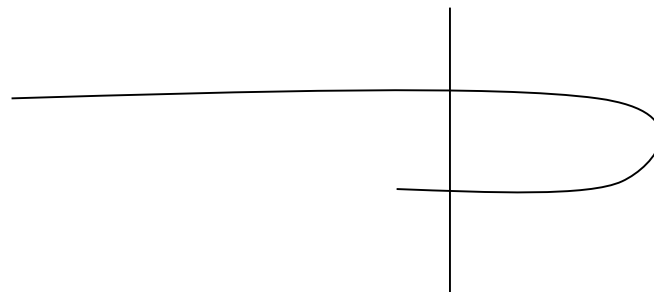
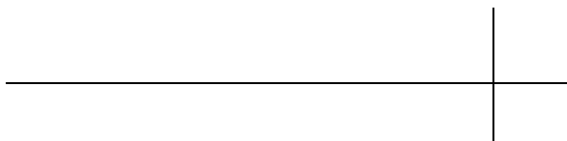




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Decorative seams



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Coupling - sewing

- the stitch is a planar or spatial formation formed by a group of sewing material in the seamed material.
- Repeating the stitch creates a stitch line



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The bonded stitch(Goonetilleke,2012)

-Much stronger, it is created by interconnecting the upper thread (from a high-capacity coil) with the lower thread (small coil - frequent replacement)

- It is difficult to match; in practice, its use is predominant.

The bound stitch is formed by the interconnection of the upper and lower threads

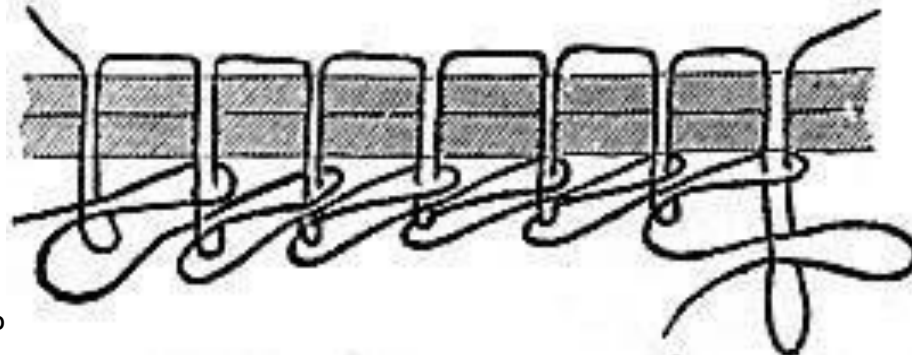




The chain stitch(Goonetilleke,2012)

- when sewing, it is flexible, but it is sensitive to damage, easily malleable.
- Usage limited.
- The advantage is the extraction of yarn from large-capacity coils.

The chain stitch is made up of a single thread





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- The needle and the connecting material (thread) are mainly involved in the sewing.
- The strength of the seam joint is a function of the sewing method and mechanical properties of the materials bonded.
- Loop creation occurs when the needle is back (2.5 - 3 mm) above the lower dead center





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Threads

- Types of threads are judged by their fineness, origin, direction of twist and surface treatment
- Threads marking: Metric numbering, ČSN 80 2151
- Two or more threads are connected together in an operation called scanned
- The thread is a product of one or more fibers





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Rigid connectors

- The nails
- The staples
- Wooden pins
- we include zip fasteners with metal or plastic (PA, PE) fasteners, plastic loops (PA), embedded in some types of sport shoes and velcro fasteners.



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The nails

- The nails are best applied when stretching the heel of the shoe, the hoof must be flocked so that the nails are flushed
- The nails are used for production of the frame footwear or tensioning of the front part respectively.





The staples

- Staples are used when stretching the bookmark most often in the crotch part (securing a bonded joint) or stretching itself (for example, frame boots).
- Staples are also applied when attaching thighs to the hoof.
- Metal rings and hooks are used to thread the lace while reinforcing the punched hole.





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Wooden pins

- Used exceptionally
- Rivets are mainly used in haberdashery for reinforcing joints in the production of tapes
- In shoemaking, these are used to fix the skates to skating shoes



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Gluing

- Natural adhesives (resins, starches, sugars)
- Glue is a substance that connects the given surfaces of adhesion and cohesion
- Adhesion – force acting on the phase tearing of two surfaces
- A mechanical theory
- A specific adhesion theory
- A theory of electronics
- Cohesion - it is the formation of attractive forces between homogeneous molecules, in our case, adhesives.





Gluing is essentially about how the glue in the form of a solvent (solution) is converted into a gel.

Several ways of transformation:

- a) Evaporation of water - starches, dextrans, glues, latexes**
- b) Evaporation of the solvent - PVAc, rubber**
- c) By changing the temperature – it the viscosity of the adhesive is reduced by heating, so that the gel is easier to cool**
- d) Pressure - Some adhesives are pressure-sensitive (e.g. ,rubber)**
- e) Initiation - by means of catalysts or initiators**
- f) Activation - Solvents, Heat (RF Heat, Ultrasonic).**





Halogenations

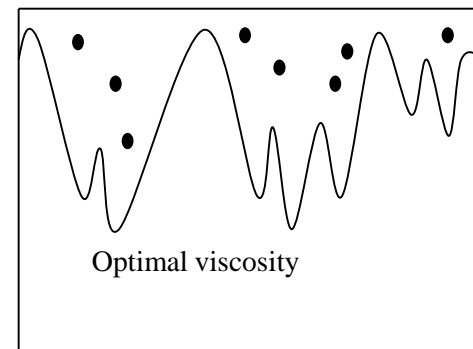
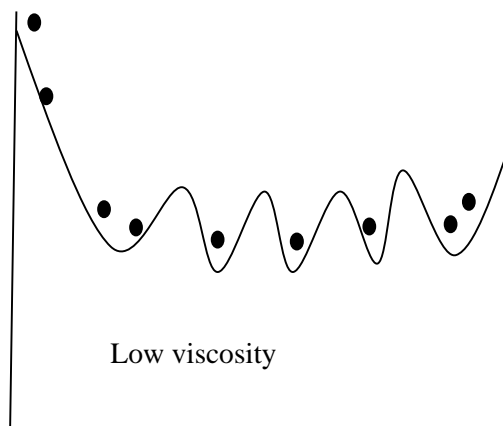
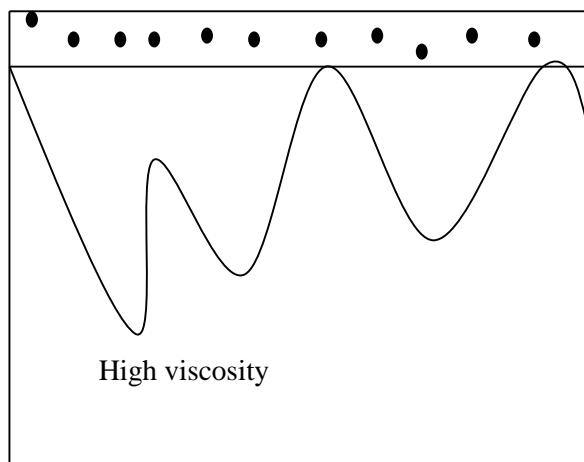
= a special type of treatment of glued surfaces prior to bonding

Factors affecting the bond strength: size of the active surface and surface tension of the adhesive, effects of interfering interlayers (fat, dust, ...), i.e. surface treatment, viscosity of the adhesive, thickness of adhesive application, drying time, bonding technology, type of bonded joint



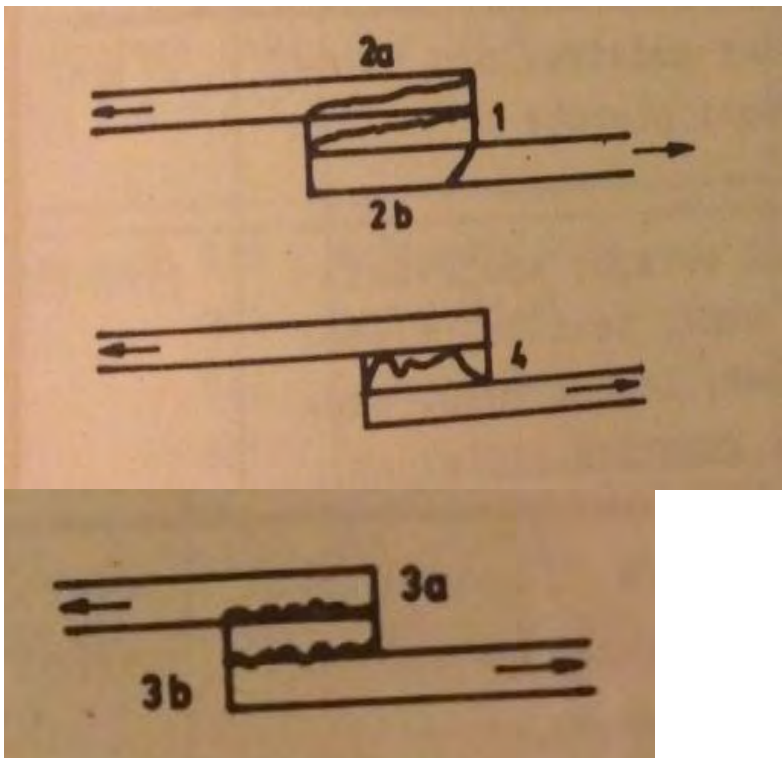


Viscosity (internal friction) (Ebnesajjad,2014)





The strength of the glued joint(Snížek, 2015)



1. low cohesion strength of adhesive

2a, 2b. low cohesive strength of adherends

3a, 3b. low adhesion strength between adherend and adhesive

4. poor cohesion of the adhesive and adhesion between adhesive and adherend





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Solvent adhesives

Adhesive components of the adhesives are organic solvents (gasoline, methanol, acetone, toluene ...), which form a health-hazardous environment at work. The effort is to gradually remove these adhesives from production, even if they have excellent bonding capabilities.



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Melt adhesives

- Melt adhesives are substances that melt at elevated temperatures and can be used as adhesives.
- They have a solid content of 100%, they do not contain either water or solvent, and allow for a good bond strength in a few seconds.
- Hot melt adhesives usually consist of a base polymer, resin, extenders, fillers, pigment, softener and antioxidant.





A dry glue

- a) Adhesive tapes are also referred to as permanent (still sticky) adhesives.

We know them in the form of self-adhesive tapes, tags, or stickers.

This is the sticky adhesive applied on the mat (paper, textile).

Their applications are growing more and more (reinforcements).





b) Powder glue, films are not commonly used yet, but they seem to have a great perspective.

The viscoelastic state is indicated immediately before application or, directly in the joining process, e.g. in a high-frequency way.

Adhesive powder coatings are in the electrostatic field.

Dry adhesives are characterized by health, non-waste technology, relatively rigid bonding.





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A welding

- High Frequency Welding (RF Heat)
- Welding conductive
- Ultrasonic welding



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High Frequency Welding (RF Heat)

- In addition to the welding of non-conductive materials, the use of VF heating also when activating adhesives and drainage of sheet flats, was found practical
- The heat of heating is based on the fact that heat is produced inside the materials due to so-called dielectric losses.





A welding conductive

- is a simpler technology, replacing usually ancillary bonding
- It is used in the overlapped joint, where a heated wedge is formed from the side of the slot and remains at the time of the contact. After the wedge has been pushed out, the contact points are pressed together to connect together.
- Conducting welding is thus welding by touching hot objects.





An ultrasonic welding

- offers the possibility of welding materials and even thicker ones
- The principle consists in spreading of the sound in a rigid body, which causes the elastic oscillation deformation of its individual parts.
- Unlike high-frequency heating (UV), ultrasonic welding does not depend on the dielectric properties of material nor on its degree of purity.





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Shaping

A deformation:

- by bending
- by pressure
- by pulling



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A machining

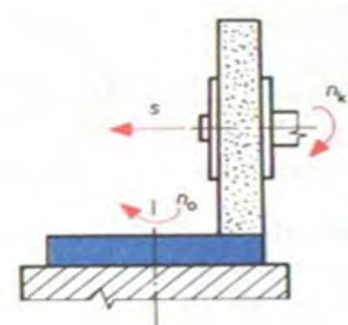
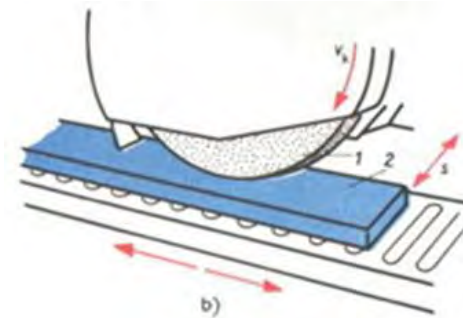
= Machining is defined as a process that produces the desired geometric shape of the work piece in prescribed dimensions and surface quality by a chip removal.

- A tingling
- A mowing
- A milling work
- A grind
- A cracking





Sharpening the blades of the blades and planes with the circumference of the blade(Hluchý,1998)

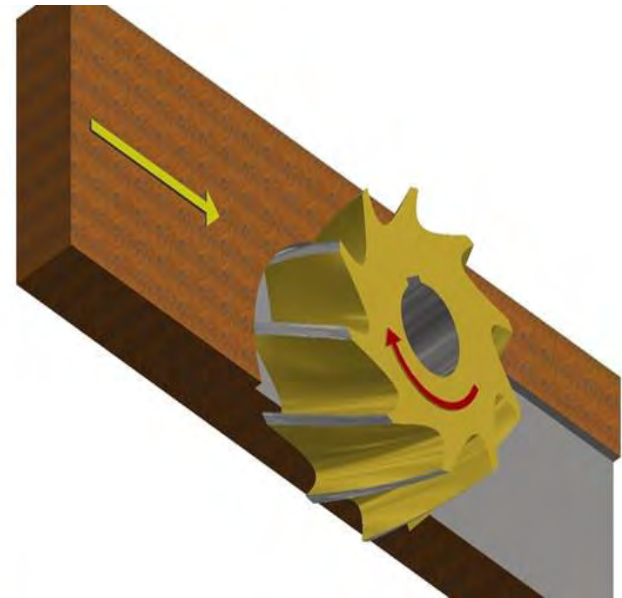




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MS
MT
MINISTERSTVO ŠKOLSTVÍ,
MLÁDEŽE A TĚLOVÝCHOVY

A milling work (Hluchý,1998)



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A lacerate machine(Goonetilleke,2012)



Suspended upper before crawling(Goonetilleke,2012)



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2. BASIC PLASTIC TECHNOLOGY



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The polymer

the polymer, is formed by joining the low-molecular substances - monomers through three types of basic reactions:

- Polymerization
- Polycondensation
- Polyaddition



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The properties of the polymer material and the final product influence mainly:

- a) The structure and character of the polymer chain**
- b) The super molecular structure (e.g., crystal)**
- c) Polymer product manufacturing technology**
- d) The nature and content of ingredients**
- e) Method of processing.**

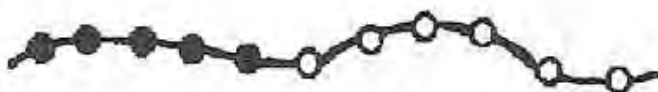




Different types of copolymer(Dvořák, 2008)



Statistical



Blocked



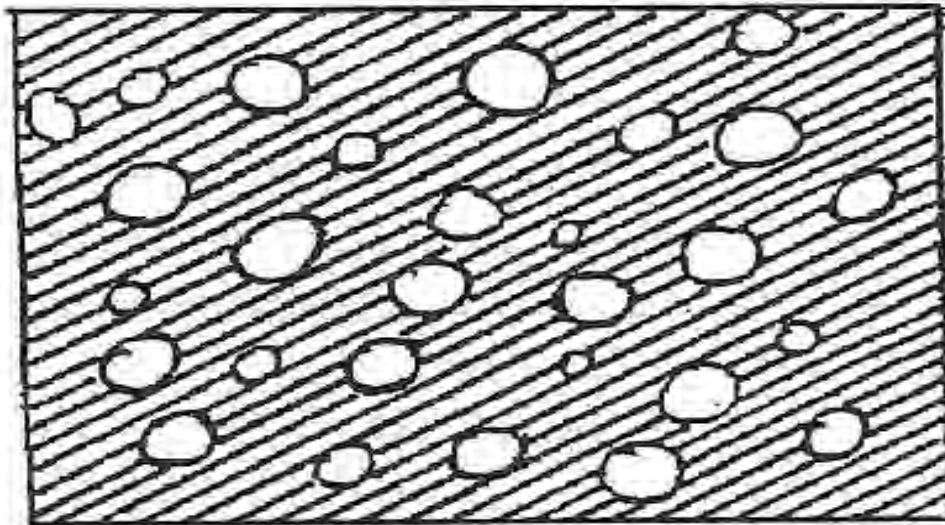
Grafted





Tough PS can be prepared by adding about 4% of SBR powder. The rubber here acts as a filler (Stoklasa,2007) .

The structure of tough PS (glass phase) with SBR filler (rubber)



Caoutchouc SBR

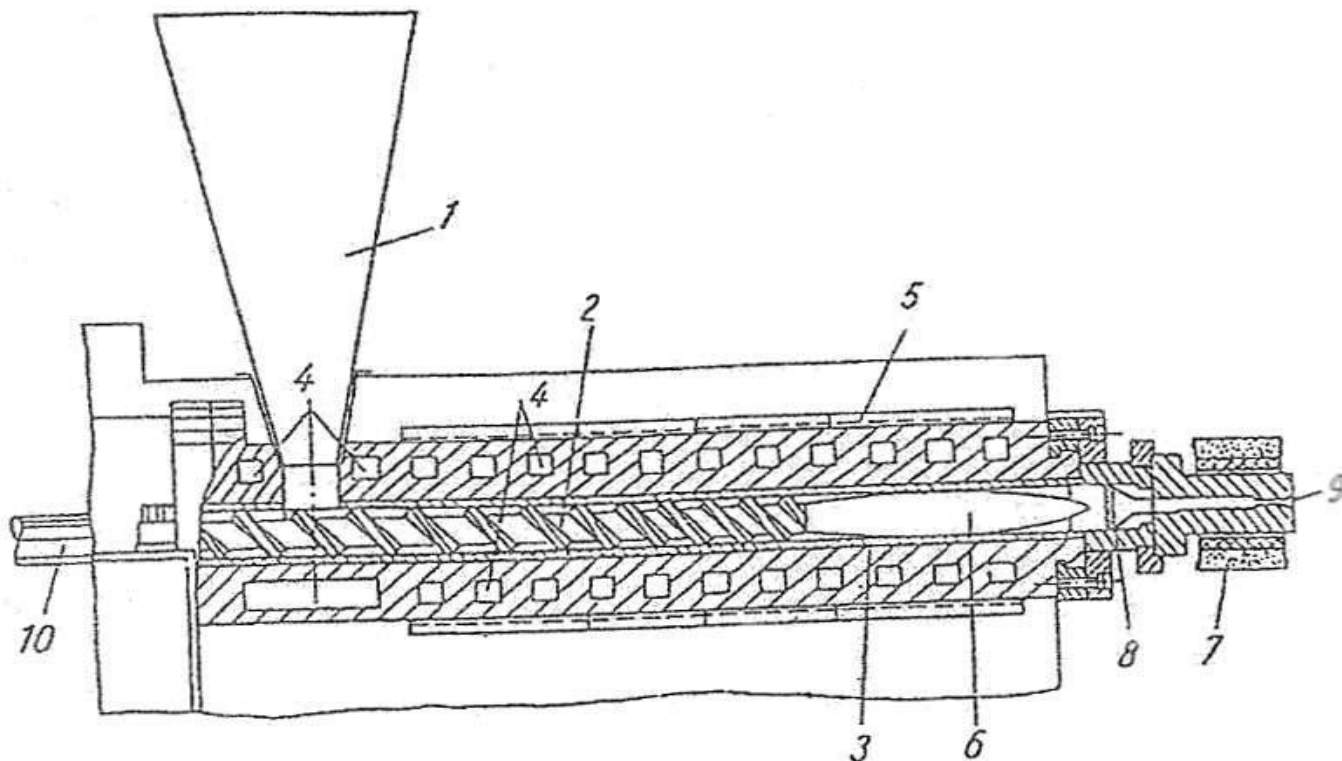


Glass phase PS





Worm Extruder(Dvořák, 2008)





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- 1 – hopper
- 2 – auger
- 3 - worm sleeve (cylinder)
- 4 - cooling,
- 5 – heating
- 6 – torpedo
- 7 – nozzle
- 8 – axis
- 9 - longitudinal slot of the nozzle
- 10 - drive axis



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Individual plastics and their applications

- The most common types include polyolefins.
- Nejjednodušším plastem daného typu jsou polyetylény (PE), které mají obecně dobré elektrické a chemické vlastnosti.
- Polyolefin polypropylene has similar properties to PE. The high crystalline content makes it a high quality material for production of fibers or foils.
- Polyisobutylene (PIB) known more as butyl rubber. It has a low gas permeability, so it serves, among other things, to produce an inner tube.





Individual plastics and their applications

- Polystyrene (PS) - it is an amorphous solid-chain polymer
- Polyvinyl chloride (PVC) is the most well-known halogen-containing polymer. It has a wide range of applications
- Polyvinylidene chloride (PVCl) mainly used in packaging
- Polytetrafluoroethylene (PTFE) - known as teflon
- These highly crystalline polymers have high strength, high elastic modulus and good dimensional stability, allowing them to compete for some products with metals such as aluminium or zinc.





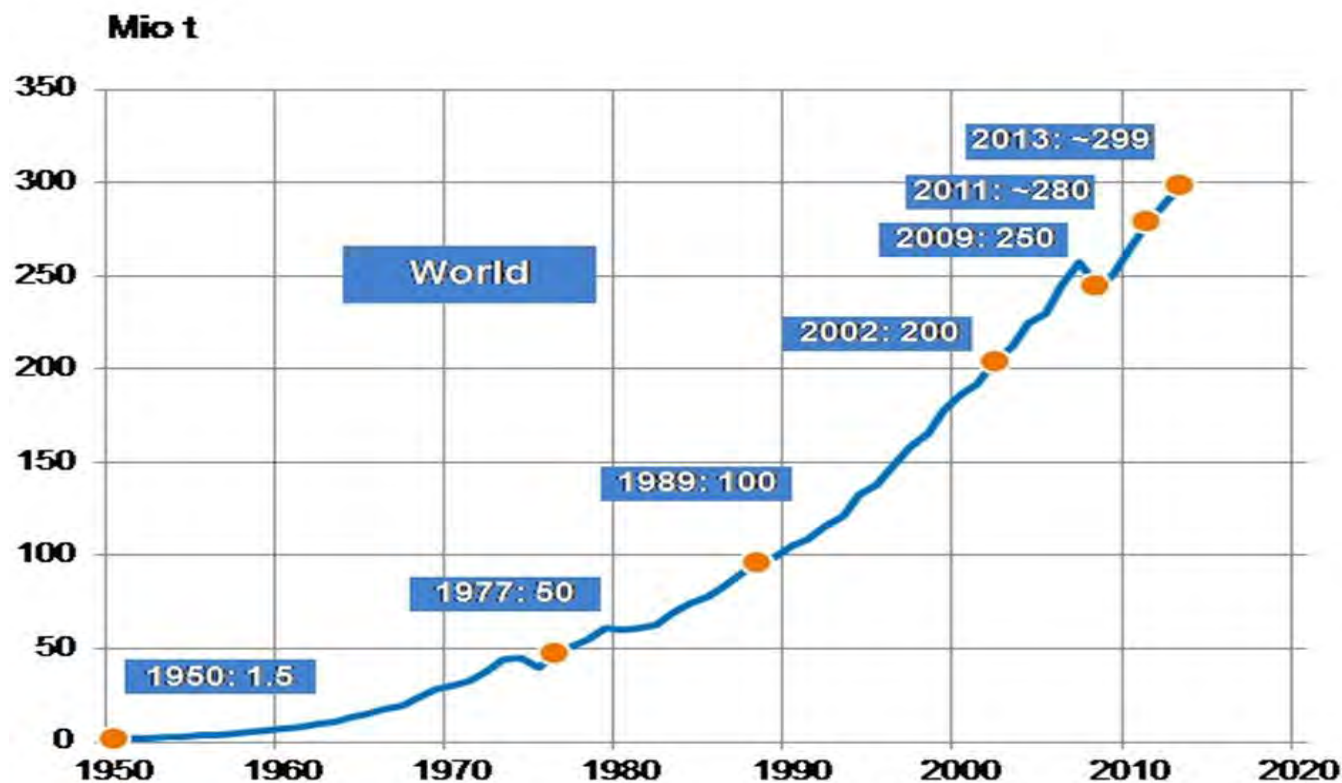
Individual plastics and their applications

- Polyesters (PES) are known on the market in two variants, such as thermoplastics or thermosetting resins
- Polycarbonate (PC). They are characterized by high toughness (including notched toughness) even at low temperatures
- The oldest elastomer that was expediently used by humans is natural rubber (NR).





Development in plastics production(Baird 2014)





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MŠMT
MINISTERSTVO ŠKOLSTVÍ,
MLÁDEŽE A TĚLOVÝCHOVY

Plastic granules for the production of plastic products(Stoklasa,2007)



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Univerzita Tomáše Bati ve Zlíně
Fakulta humanitních studií





Summary

1. Separation
2. Coupling
3. Shaping of deformations
4. Forming
5. Chip machining
6. Adjusting the physical properties
7. Surface treatments

which are mainly focused on mechanical technologies and the basics of plastic technologies that represent chemical technologies.





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Summary

Fundamentals of plastics technologies that represent chemical technologies.

Polymerization

Polycondensation

Polyadice



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Thank you for your attention



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Fundamentals of production technology

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2019

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INTRODUCTION

Technology is a technical field which deals with the application of natural sciences – especially physical and chemical - knowledge in the implementation, improvement, utilization of production processes, that is, in the acquisition and processing of starting materials (raw materials) for intermediates or final products. It is closely related to the development of knowledge, science and technology and engineering in a wide variety of disciplines.

Technology therefore deals with ways of converting work articles into finished products. For a given manufacturing process, technology determines the use of existing production techniques, i.e. it provides not only the summary of machines, tools, apparatus and equipment used, but also determines the way they work. However it also sets the sequence of their use, i.e. a technological process.

A technological process deals with the technical aspect of a production process, is binding for the production process and is determined by the relevant technological standard. The right technological procedure showed guarantees the economy of the production process, i.e. the lowest consumption of raw materials, materials, energy and time.

Depending on the nature of the changes that occur in the processed work piece, we can divide technology into mechanical and chemical technology.

Mechanical technology is characterized by the fact that it only changes the shape, size and position of the work item, but there is no change in its chemical composition. (Fischer, 2004) An example of mechanical technology is the production of yarns, fabrics, woodworking for furniture, etc.

Chemical technology is characterized by a change in a chemical composition of the work piece, and the change in shape or size is only a concomitant phenomenon. Chemical technologies include, for example, the production of iron ore, the production of polymer materials, etc.

In addition to this basic division of technology, there is a breakdown of technology by the sciences that it deals with - for example, organic technology, inorganic technology, glass technology, etc.





Primary production deals with the extraction and processing of raw materials, second-generation production is typical for production of products for a specific use of the consumer or the downstream production. In the present teaching materials, the basic mechanical technologies are presented based on examples of leathery generic production. Chemical technologies are represented by plasticizing technologies only due to the limited range of support.



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1 BASIC TECHNOLOGICAL PROCESSES

In this chapter, we will deal only with the basic, most used technologies, which are coincidentally largely used in the course of leather production.

1. Separation:
 - a. Gradual separation: cutting (blade, saw, radiation, liquid jet) or cutting (straight knives or disc knives)
 - b. Separation of single-cut (straight knives or shaped knives)
2. Coupling:
 - a. Mechanical bonding: stiff connectors or sewing
 - b. Physical-chemical bonding: gluing
 - c. Thermal bonding: welding
3. Shaping of deformations:
 - a. Shaping by pulling (in one direction by lonely force or in multiple directions by a group of forces)
 - b. Pressurizing - pressing
 - c. Bending shaping - folding
 - d. Shaping of combined.
4. Forming:
 - a. Cyclical forming
 - Rigid forming - pressing, injection molding
 - Forming of liquid systems - casting of dipping
 - b. Continuous forming, forming rigid systems - rolling, extrusion
5. Chip machining:
 - a. Cracking
 - b. Milling
 - c. Grinding
 - d. Mowing
 - e. Splitting
6. Adjustment of physical properties:
 - a. Softening (mechanical, chemical, physical)





- b. Drying
 - c. Claims (chemical, physical, mechanical)
 - d. Stabilization.
7. Surface finish:
- a. Mechanical
 - b. Chemical
 - c. Physical
 - d. Applying layers (coating, deposits, spraying, dipping)

1.1 Separation

This designation defines technological operations in which a part of the material is separated from a larger unit. As can be seen from the above-mentioned "spider", we divide the separation into two basic groups - namely the gradual separation and separation of the one-ordinate. From the historical point of view, was of great importance at the beginning the gradual separation (knife), which was then pushed out by the one-off separation. At present, there is a clear return to the gradual separation, but of a new generation - with the application of vibrating knife, liquid beam and radiation, with one-off separation still playing a dominant role in natural leather processing for its specific qualities.

1.1.1 Cutting out

This equation expresses the balance of forces in the x-axis as a condition to prevent deformation of the blade when cutting and to ensure the same shape of all die cuts.

The punching force F [N] is defined as the force required to punch the part, which can be calculated by means of the specific punching resistance p [Pa] - a tabulated value indicating the force required to cut the unit length (1 cm) of the specified material of defined thickness in one or more layers. (Hluchý, 1998)

$$F = p * l * k \text{ [N]}$$

K = a constant including the effect of knife dulling, cutting speed and factors

l = the length of the cut line



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From the experimental measurement, it was found out that the cutting force F increases with the angle of the blade b , with the increase of the blade dulling, with the length of the cutting path, with the thickness, respectively number of layers. Also, the mechanical properties of a die cut material and a kind of the pad affect this power. The F increase is relatively small when increasing the cutting speed.

See is a snapshot of the cutting action below, which has three parts:

- I. Deformation of the material
- II. Cutting material
- III. Lock into the washer

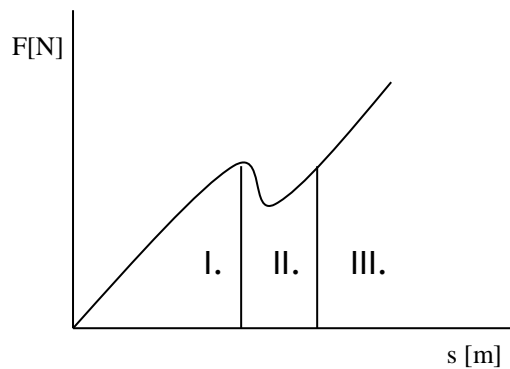


Figure 1. The course of the punching force

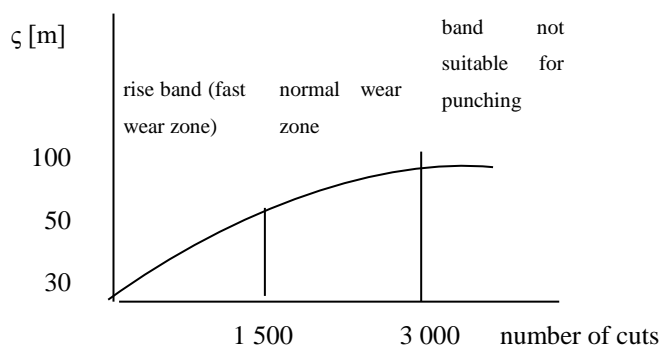


Figure 2. The process of dulling the knife

Cutting knives

- With a one-sided blade (left and right half for hair, one half for textile, poromer)



- With a double-sided blade (soft metal shoulder support, risk of injuries during handling, economy)
- Hot products (heavy knives - undercuts - fittings)
- Cold-produced (lightweight knives - tapered steel)
- Individual - stems with rubber extractors (accuracy)
- Combined - passage (pot - one - off multiple cuts) and non - passing (equipped with various attachments - reinforcement, spikes) (Kalpakjian, 2014)

Cutting knives are made according to sheet metal templates, all of them marked on the outer side (size group, pattern number, variation, hoop number, perimeter group, size number, and also with molded inserts in the blade edge (sharp tooth, half- round tooth,), indicating the size and circumference group. The height of the light knives is 19 mm of the heavy ones 51 mm + extension -> 140 mm (pot knives) or 19 + extension = 140 mm (shank knives).

Cutting pads

Wooden (oak, beech) for undercut handling, cardboard (made from strips of shoemaking cardboard or fibrous leather), drawn bolts through wooden cutters for cutting the textiles, poromers. High-grade PVC washers (93-95 Sh) are the most used for cutting out top hides, or others plastics (PA, PP). The plane is restored in the first two cases by milling. In the case of plastics, it is over-molding.

Generally speaking, hard supports are more suitable for cutting solid materials and vice versa. (Leinweber, 2003)

Mechanical punching machines transfer force (noisy) to the punching knife, while hydraulic die-cutting machines are hydraulically pressurized. Further, we distinguish between two (textile) and one-armed.

A gradual separation agent is a vibrating knife and a liquid beam. In these processes, the perimeter of the component determines the time required to separate the component. This is a significant difference compared to a conventional technology of one time separation, when the time is little dependent on the perimeter of the component.



1.1.2 Separating the oscillating knife

Pioneers in this area are three companies engaged in the production of a cutting machine operating on the principle of a numerically controlled oscillating knife (Gerber - USA, Investronica - Spain, Lectra - France).

The Gerber Cutter system with the S 91 marker achieves the best parameters. The basic unit of this system is a cutting table with a shifting head that can be used for multiple cutting tables. The cutting table consists of modules with a length of 3.6 m. The most commonly used cutting table length is 10.80 m at a width of 1.86 m. The cutting table has a dense bristle surface that allows a deep penetration of the cutter and thus contributes to having a precise cutting of the top and bottom panels in the layer. Bristles (height 2.45 cm, diameter 0.6 mm) are made of polypropylene. They are attached to a polyurethane-based base. The bristles form a smooth flat surface, which is a reliable support for all types of material of which specific weight does not exceed 83.3 kg / m². Through material in the multi-layer load, the PE foil is inserted and the material is pressed against the surface of the table by a vacuum system to ensure precise cutting. The system allows for more substrates to cut accurately up to 7.5 cm in a compressed state. The cutter blade dimensions are 2.2 x 7.6 mm, length 245 mm. The dimensions of the blade allow cutting of narrow notches and inner cut outs. "Knife Intelligence" allow you to capture the resistance of the material and tilt changes during trimming to ensure precise cutting of the material in all layers. During cutting, the knife is automatically cut at pre-set intervals according to the carved materials. A knife of automatically adjustable speed is used to reduce the heat generated. Cutting corners or narrow strips slows the stroke rate to minimize heat, remove melting and reduce wear on the cutting head. The feed rate of the blade is 0.085 m / s; the available time of one device is 480 minutes per shift. At the time utilization coefficient $K = 0.85$, the capacity of one device is $s = 2081 \text{ m}$ ($0.085 * 28.800 * 0.85$).

The entire system is controlled by a powerful, easy-to-use computer. The complex is also equipped with an automatic folding device, material for cutting table material, drilling device for marking of parts, paper perforation (put under each load), material edge trimmer and vacuum generator.





Work on the system begins with perforating such amount of paper that covers the entire bristle surface of the cutting table. In the preparation area, one edge of the material will be cut, which will then be folded. This material roll is scraped through a mechanical hand and stored on the automatic folding device. The folding method is programmed, and the number of layers and devices will be performed automatically by the entire stacking process directly on the cutting table. Upon completion of folding, the folding device will land the landing gear and the work will be commended for securing the material at the second cutting table. On the first cutter table at this time, the cutting head starts and cuts, including marking of the parts (this is usually done separately before cutting - automatically triggering the same head). After cutting, the cutter head is moved over the second cutter table where a further charge of material should be prepared at this time. On the first table after finishing the carving, the carved pieces will be selected and their removed to the sorting area, the waste from the cutting table as well. By means of an industrial vacuum cleaner, the textile residues one removed from the bristle surface. Then, preparation cycle of the new charge follows. The cutting times are combined with the



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folding and cleaning times so that the cutting head does not have a downtime, and the only unused time will be the time of crossing the cutting head from one table to another.

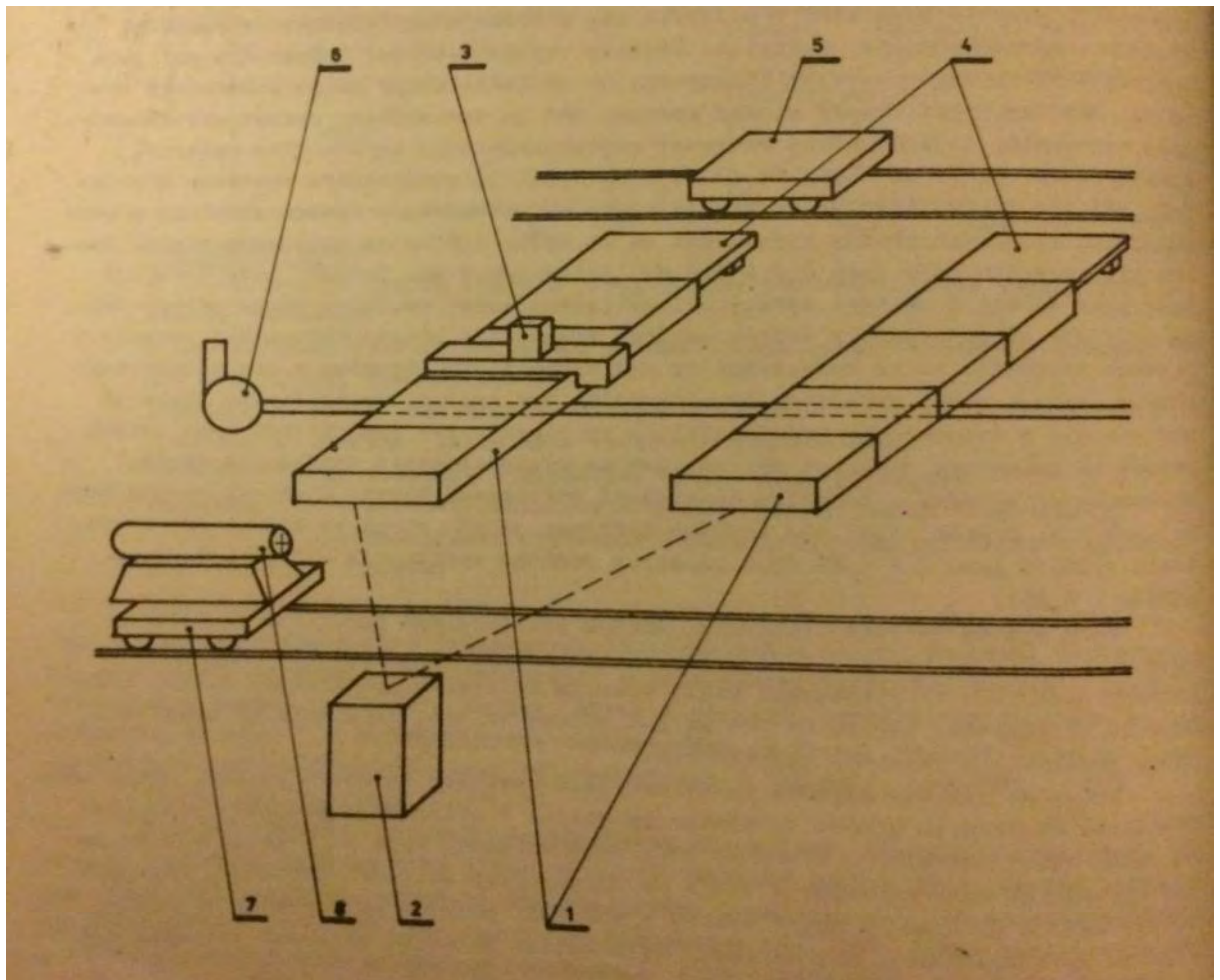


Figure 3. Schematic diagram of one of the possible configurations of the cutting device based on the oscillating knife principle

Description of the figure above:

1. Cutting tables
2. Control unit
3. Cutting head
4. Extension module
5. A transport cart
6. A vacuum generator
7. Transport trolley for folding device

8. Folding device

Automatic sharpening knife cutting is primarily intended for cutting soft materials (even great thicknesses) produced in rolls. Materials suitable for cutting by the oscillating knife can be divided into top, lining and stiffening ones. The common feature of these materials is their synthetic character, which ensures homogeneity both in the extent as well as thickness, which is a prerequisite for their separation in multiple layers. Only on the basis of cutting tests can we determine the optimal number of layers of one or more of the sheet material. Czech footwear manufacturers tested the following set of sheet materials and recommended separating them with a vibrating blade in the following layers.

Material	Width	Number of layers
Jacquard knitted Oswan knitted	80 cm	20
OPOMAT II.	140 cm	50
Wellington knitted fabric	140 cm	40
Kepr Ravlis fixed	140 cm	52

The estimated economic effect when implementating of the above-mentioned configuration is saving of workforce 34, saving of material 5%, annual saving of own costs 4, 170, 000 CZK, return on investment of 3.13 years.

1.1.3 Liquid jet separation

Relatively new technologies also include industrial applications of a liquid jet - separating the material with a very narrow beam of highly compressed fluid medium. According to literary sources, this system is mainly applied to the materials used for production of footwear parts. These can be both leather as well as various types of cardboard, fibrous leather, lightened and non-lightened rubber materials, and various salary materials used on the midsole. From a technological point of view, this technology cannot be applied to cutting of textile materials due to the intertwining of fibers in a bundle of wearing parts.





The automatic separation of materials by the liquid jet method can be further divided according to the high-pressure liquid used:

- A. Equipment using water as a cutting medium
- B. Apparatus using a mixture of water and polymer as a cutting medium
- C. Apparatus utilizing a mixture of water and abrasive as a cutting medium

Ad B/ The device utilizing a mixture of water and polymer - the cutting fluid is in this case formed by filtered demineralized water with an admixture of 0.3% of the polymer. As the polymer, acrylate copolymers are used which are supplied in powder or as an aqueous emulsion. The mixing process requires strict adherence to the technological conditions, which ensures the automatic preparation and mixing equipment connected directly to the cutter. The advantage of using this medium is that it forms a longer coherent jet beyond the nozzle, which is suitable for cutting thicker or multilayer materials.

Ad C/ Apparatus employing a mixture of water and abrasive - also PASER - (Particle Stream Erosion) is the name of a device using cut water (demineralised, distilled or at least, filtered) to which the abrasive material is mixed. The most commonly used abrasive materials include siliceous sand with a roughness of up to 0.25 mm. This is added to the water in the cutter head. Paser is mainly used for cutting hard materials such as metals, chalks, porcelain, etc. The consumption of abrasive material is about 0.2 kg / min.

ad A/ Water jet cutting device - consists of the following basic parts:

- Filtration device ensuring cleanliness of the cutting medium
- Compressor and pressure multiplier (provide high energy water jet)
- Static or coordinate cutter table with trap
- Cutting head with sapphire nozzle.

Water is fed through the pump into a pressure tank with a constant pressure of 0.6 MPa. A toothed hydraulic pump is connected to the tank to achieve the water pressure of 20 MPa. A further increase in water pressure (20x) is achieved by the piston talc multiplier, which is the essence of the system. A pneumatic valve is positioned in the cutter head to control the beam



passing through the sapphire nozzle sealed with a rubber seal in the steel case. When cutting the distance between the cutting head and the nozzle over the carved material is adjusted as needed. The cutting speed for shoe materials ranges from 0.04 m / s (2 mm stiffened board thickness of 2 mm) to 0.34 m / s (11 mm thick in 2 layers).

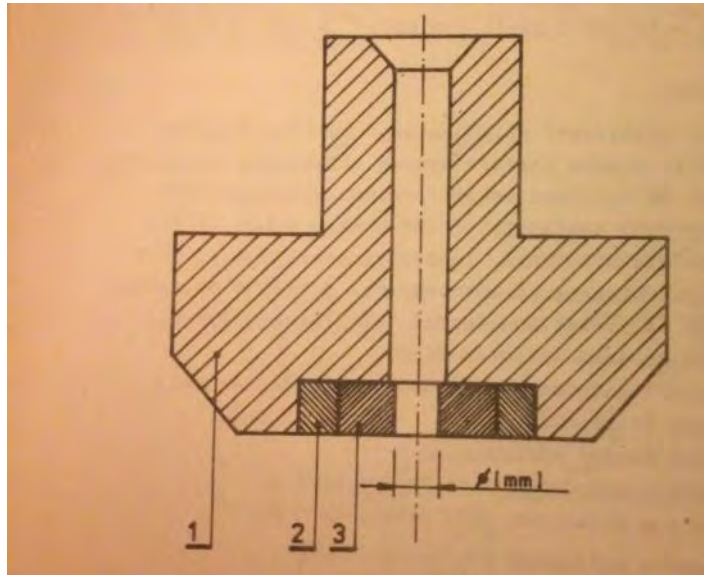


Figure 4. Sapphire nozzle scheme

Description of Figure 4:

1. Steel holder
2. Centring seal
3. Sapphire
4. $\varnothing = 0,03 - 0,25 \text{ mm}$

Radiation separation (laser)

The laser beam was one of the first cutting tools of the new generation that began in the 1970s in the footwear industry. The disadvantage of using this splitting method is that there are considerable demands on the adjustment and maintenance of the equipment. There is also an increased risk of material burning and dangerous gases are released during cutting.

For laminated materials, the edges of the carved bundle are severed, thereby reducing performance when sorting cuts. Despite all these unfavourable features, the laser has retained



its position. It is used for cutting cardboard, rubber, fibrous leather, plastics, but has found the greatest use in the preparation of shoe patterns.

The nature of the laser

LASER LIGHT AMPLIFICATION BY STIMULATED EMISSION OF RADIATION – means the amplification of light by stimulated (forced) radiation emission in Czech. External energy quantum's equal to the difference in energy levels ($hf = E_2 - E_1$) affect the atom that is in the state (E_1 = the energy level of the base, the electron is in the basic state, E_2 = the external energy level, excited) condition.

As a result of the external stimulus, the electron returns to its original state by emitting (releasing) a new quantum of the same energy hf and at the same frequency as the preceding quantum. As a result, the light strengthens.

In the forced emission process, one radiation blade that has the appropriate energy releases a new bounty when it collides with the enriched atom. Thus, instead of one quantum entering the system, we have two equal quanta on its output, which means amplification of the radiation.

The consistency of prevention, phase and direction of forced radiation with the external (stimulant) radiation results in the output of so-called "coherent" radiation.

In practice, this phenomenon occurs in a liquid, gaseous or solid environment. The light source phenomena are driven in one direction and are highly concentrated. The beam of light does not disperse even over long distances (spatial coherence). Optical focus lenses are precisely defined. The material that absorbs such energy decomposes, coming from the solid state to the gas (sublimation). When moving the focus point, the material can be separated. The SATRA English Institute began publishing the first results of laser application in the footwear industry when cutting leather. Until today, however, the laser is not commonly used to cut the leather (great difficulty with the inhomogeneity of the leather). He founds the application in carving both cardboard and metal templates in CAD / CAM technology. ERAM cuts in four to six layers of PUR and PVC materials. The basis of an industrial laser device is an active medium - a solid, liquid or gaseous substance adapted to contain more excited particles than non-excited particles. In addition, the excitation mechanism - the main



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driver is light radiation, but also with light reaction, heat heating, etc. According to the character of the active environment, we recognize the CO₂ laser (active environment CO₂, N₂, He) with the power of 50 - 1000 W, which is the most common from the category of gas lasers, there is a semiconductor laser (the active medium is a semiconductor) and the youngest is a liquid laser (the liquid forms organic compounds - chelates).

1.2 Coupling

1.2.1 Sewing

Sewing is one of the oldest and most widely used techniques. Initially, the hand sewing process was replaced in the middle of the 19th century by machine sewing. In the second half of the 20th century, sewing machines came into sewing workshops. They are now part of the CAD / CAM systems. The seam is the place of the union of two or more of the same or of various materials by sewing and gluing, welding, etc. According to the ČSN Standard, the seams are divided into spines, overlapping, edging, touching, decorative and clearing.

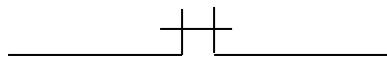


Figure 5. Spine seam

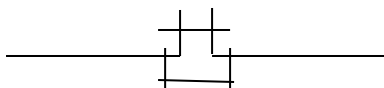


Figure 6. Spine seam overlapped

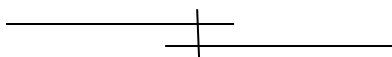


Figure 7. Overlapped seam

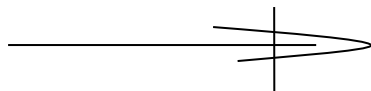


Figure 8. Lining seam

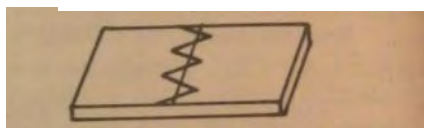


Figure 9. Touch seam (Goonetilleke,2012)

The ornamental seam has stitches made on the material either in a straight line, curve, or in patterns for decorative purposes. The sealing seam is formed such that the edge of the material bends or stitches through several rows of stitches.



Figure 10. Decorative seams

The stitch is a planar or spatial formation formed by a group of sewing material in the seamed material. Repeating the stitch creates a stitch line. The basic and most used stitches are tied and chained.

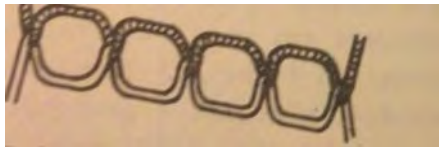


Figure 11. The bound stitch is formed by the interconnection of the upper and lower threads

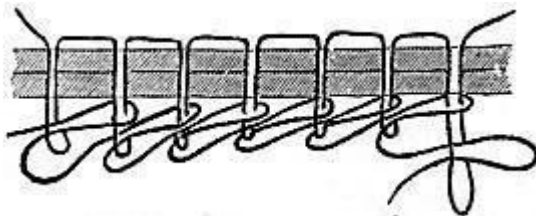


Figure 12. The chain stitch is made up of a single thread

The needle and the connecting material (thread) are mainly involved in the sewing. The strength of the seam joint is a function of the sewing method and mechanical properties of the materials bonded.

Loop creation occurs when the needle is back (2.5 - 3 mm) above the lower dead center. At this point, yarn is intertwined by a functional member of the loop trap. The upper thread is either intertwined with the bottom yarn (for double stitches) or is intertwined with the adjacent loop of the upper thread (one-stitch stitches). The loop is formed such that a thread is strung into a long groove on the sleeve side.



On the hook side, the thread to the needle is pushed by force. The friction forces that cause looping occur at the points of contact.

Chain stitch - when sewing, it is flexible, but it is sensitive to damage, easily malleable. Usage limited. The advantage is the extraction of yarn from large-capacity coils.

Bonded stitch - is much stronger, it is created by interconnecting the upper thread (from a high-capacity coil) with the lower thread (small coil - frequent replacement). It is difficult to match; in practice, its use is predominant. The stitch length is 1 cm (stitch, material) when sewing. The most common one is the sewing of 5 - 7 stitches up to 1 cm.

Threads

Types of threads are judged by their fineness, origin, direction of twist and surface treatment. The yarn fineness is characterized by:

- a) $\text{TEX} = \text{number of grams weighing } 1,000 \text{ m yarn}$ $1 \text{ tex} = 1 \text{ g} / 1,000 \text{ m}$.
- b) Metric number = number indicating yarn counts after 1,000 m to 1 kg.

In practice, the use of yarns from Ba, PES, PA is predominant.

Threads marking: Metric numbering, ČSN 80 2151

Example: Threads marking:

Cotton 17/3 17= Metric number/ Thread of 3 yarns

Synthetic 265/2x3

265 fiber thickness in thousandths mm / 2 number of fibers in 3 yarns

The thread thickness of natural fibers is denoted by a fraction where the numerator is the metric number of the single yarn of the yarn and denominator the number of simple yarns from which the yarn is slashed.

In the designation of synthetic fiber yarns, the numerator denotes the thickness of a single filament in thousandths of a millimetre, the denominator number of threads from which single yarns are plunged, the number of these simple yarns from which the yarn is cut. Depending on the method of treatment, we divide cotton sewing threads into polished and matt (non-polished) ones.



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Two or more threads are connected together in an operation called scanned. In multiple scrolling, the sense of twists (twist with left-hand helix, twist from right-handed helix) is alternated.

Note: The yarn is a single or multiple fiber length fabric (nomenclature inconsistency).

The thread is (as well as the yarn) a product of one or more fibers. While the yarn is a generic and wider concept for this fabric, the thread always represents a single piece of yarn only. However, this definition is not generally valid, so the yarn and yarn concept is confused not only by laymen, but also often among textile experts.

Thread modulation: Most of the silicone emulsion on a thread to improve the negative effects (heating the needle), PA and PES threads often burn in the needle. The temperature at stitching speed of about 2 000 rpm. / minute reaches up to 300 ° C in the needle. It is usually not used for stitching at such high speeds due to short stitches on the upper part.

The structural strength of the sewn material is often reduced by stitching. With each needle puncture, the material loses some of its original strength. The degree of decrease in strength is determined by the number of stitches per cm, the needle thickness and the shape of its spike. The strength of the material after stitching is called residual. The edges of the sewn material are also affected by the bond strength.

Hand sewing is used where there is a difficult access to machine sewing. Sewing is done with one needle or two needles simultaneously. In the first case, the stitch is halved, the second stitch is continuous.

Sewing ability: When inserting new needles, yarns, when searching for an optimal needle, needle diameter, material thickness, etc., it is necessary to perform the tests and objectively evaluate them. The number of breaks over a certain period or an average sewing time between two breaks is evaluated most often. To ensure the reproducibility of the tests, some conditions are defined - sewing speed, material, sewing time or number of breaks.

1.2.2 Rigid connectors

Mechanical bonding also includes joining with rigid connectors. The nails are best applied when stretching the heel of the shoe, the hoof must be flocked so that the nails are flushed.



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Otherwise there is a danger of foot injury. The nails are used for production of the frame footwear or tensioning of the front part respectively. Two half-sharpened nails on each side into the rib of the insole serve to fix the wire by which the toe is manually tightened. The nails are most used when attaching the heels, from the inside or from the outside.

Staples are used when stretching the bookmark most often in the crotch part (securing a bonded joint) or stretching itself (for example, frame boots). Snapshots are also applied when attaching thighs to the hoof. Metal rings and hooks are used to thread the lace while reinforcing the punched hole.

Wooden pins are used exceptionally. Rivets are mainly used in haberdashery for reinforcing joints in the production of tapes. In shoemaking, these are used to fix the skates to skating shoes. Furthermore, we include zip fasteners with metal or plastic (PA, PE) fasteners, plastic loops (PA), embedded in some types of sport shoes and velcro fasteners.

1.2.3 Gluing

Another way of bonding materials in leather production is gluing. The use of natural adhesives has been known for several millennia (resins, starches, sugars). For gluing the soles, the AGO KITT adhesive based on nitrocellulose was first used (rigid joint, 30 minutes drying). In the 1930s, solid adhesives based on synthetic elastomers appeared. When polychloroprene adhesives allowed rational production of footwear. In recent years, PUR adhesives have joined them.

Glue is a substance that connects the given surfaces of adhesion and cohesion. ADHESION - the force acting on the phase tearing of two surfaces. Perfect adhesion has adhesives that wet the surfaces of materials. The wet ability changes with a marginal angle and is expressed quantitatively by the relation: $A = \gamma_{1,3} (1 + \cos \varphi)$

In summary, the necessary condition for satisfactory bond strength is the perfect wetting of the surface with glue. The formation of a rigid joint between the adhesive film and the leaky material (substrate) depends on reaching a large area of intermolecular contact.

So far, there is no theory that would clearly clarify the nature of bonding - the origin of adhesion forces. This fact shows that the entire complex of influences that can occur gradually



and depending on the specific conditions of the bonding is applied during bonding. There are two main theories - mechanical and specific.

Mechanical theory states that adhesion explains the formation of a bonded bond based on the mechanical anchoring of the adhesive layer in a porous, fibrous or irregular surface. The leakage agent penetrates the pores of the bonded material and forms a firm connection after drying. (Ebnesajjad, 2014)

A specific adhesion theory explains the formation of a bond with intermolecular attractive forces. Impacts of adsorption, diffusion, surface tension, effects of chemical and electrical bonds are expected.

For example, the theory of electronics states that the electron transfer from functional groups of the substrate-adhesive occurs in the contact zone, an electrical double layer is formed, one of the materials acting as a donor and the other as an electron acceptor.

Good bonding results are achieved in those cases where functional groups of the adhesive and bonded material are within a sufficient distance from each other in the donor-acceptor line.

For example, when bonding the leather with VUKOLEP (polychloroprene glue), good bonding is achieved because the functional groups of leather (NH_2 , OH) and functional groups of adhesive (halogens- Cl) are sufficiently distant. The excellent bonding can be achieved by VUKOPLAST (butadiene acrylonitrile copolymer with CN groups) because the distance of functional groups of the adhesive leather - VUKOPLAST is maximal for this combination.

Cohesion - it is the formation of attractive forces between homogeneous molecules, in our case, adhesives.

In addition to a number of other properties, cohesion and adhesion determine tackiness of the adhesive. Good adhesive films must adhere well to the material that we bond, i.e. it must be characterized by adhesive strength and resistance to rupture. This means that it must also be characterized by cohesive strength.

Adhesives with a high cohesion and adhesion are highly sticky. The external feature of stickiness is the ductility of the adhesive, its fiber length. This is done by pulling it with





fingers. If the fibers are pulled out, the adhesive is long and usually good. Conversely, the feeling of grease between the fingers is a symptom of the fact that the glue is short and the material sticks little or not at all.

Chemical theory assumes the formation of specific primary bonds at the interface (covalent and ionic bond). These links are rarely created. Thermodynamic conditions do not allow chemical bonds to form.

Induction theory claims that forces are generated by the action of a molecule with a permanent dipole on another molecule, causing deformation of the electron shell and the induction of the induced dipole of the second molecule. The induced effect causes the interaction between the permanent dipole and the r^{-6} step (r = distance between the atoms).

The dipole theory explains stickiness as a result of the forces occurring between permanent dipoles. The dipoles on the phase interface act by trying to orient each other because the discontinuous ends of the dipole are attracted to and consistently repelled. The resulting interaction strength decreases with r^{-3} and depends on the nature of the dipoles. It can, therefore, be both attractive and repulsive. Basically, it may be noted that in order to obtain the necessary strength of the glued joint, it is necessary to bond polar with polar and non-polar with non-polar substances.

Factors influencing the bonding process:

Gluing is essentially about how the glue in the form of a solvent (solution) is converted into a gel.

We know several ways of transformation:

- a) Evaporation of water - starches, dextrans, glues, latexes
- b) Evaporation of the solvent - PVAc, rubber
- c) By changing the temperature – if the viscosity of the adhesive is reduced by heating, so that the gel is easier to cool - the evaporation of water and solvents is accelerated and the polymerization of the thermoactive adhesives is initiated and accelerated
- d) Pressure - Some adhesives are pressure-sensitive (e.g. ,rubber)
- e) Initiation - by means of catalysts or initiators





f) Activation - Solvents, Heat (RF Heat, Ultrasonic).

The following technological factors are important in real bonding conditions:

Preparation of surfaces for bonding.

Surface of the bonded material must be thoroughly cleaned in advance as the bond strength is reduced by substances absorbed on the surface of the bonded materials (dust, grease, residues of adhesives used before, etc.).

It is known from practice that smooth surfaces of porous materials are roughened prior to bonding. This is to increase the contact area and thereby increase the mechanical adhesion.

By cracking, some skin fibers are released and then form some over-construction of the microstructure - the pico structure on a roughened surface.

The amount of loose skin fibers is different for different types of leather. In those cases where the skin is thinner, it is possible to achieve a better formation of the pico structure. The technique of cracking (type of tool, speed of cracking, direction of movement of the tool and others) is also affected by its origin.

The thickness of adhesive application is as narrow as possible, since different conditions are created between the individual layers of adhesive than directly between the adhesive and the surface of the bonded material.

The optimum thickness for rubber adhesives ranges from 0.15 to 0.20 mm, and this thickness also corresponds to the best bond ability of the glued joint to deformations.

Principles of working with rubber adhesives - rubber adhesives are mostly glues on both sides, that is, the adhesive is applied to both glued surfaces. If we apply more coats, the preceding ones should always be dry.

Another condition for obtaining a good joint quality is to extract the solvent from the deposited film. The bonded adhesive surface is exposed to atmospheric conditions for a certain period of time. During this time, part of the solvent is evaporated and part is absorbed in the material. The bonded surfaces are attached to each other only after partial drying and



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thickening of the layer. A drying time depends on the type of solvent, working environment, and relative humidity.

The ambient temperature must be such that the solvents evaporate evenly. At a too high temperature, the evaporation rate of the surface layers (especially for thick deposits) is higher than the evaporation rate from the middle layers of adhesives. This then results in a substantially faster thickening of the surface layer, which later makes diffusion of the solvent out of the middle layers difficult and the adhesive layer produces stress that weakens the strength of the joint.

Pressure action - mild pressure is always beneficial for bonding and it contributes to an even distribution of adhesive across the surface and removal of air bubbles. High pressures break the forces between the molecules on the phase interface and are therefore inappropriate.

Depending on the nature of the adhesive used, pressure is in the range 30 to 50 N / cm².

Glue acidity - Inappropriate pH of the adhesive due to bonded materials may cause a reduction in bond strength or even blinding.

An example may be gluing of textiles with chloroprene rubbers. Released hydrogen chloride damages cellulosic fiber to the point of disintegration.

Activation of adhesives - some types of adhesive have the feature that the deposition can be re-energized after a certain period of time, i.e. to activate. This technique is especially interesting because it allows for the central application of adhesives and additional activation in the workshop and reduction of the harmful environment when working with solution adhesives at a single workplace. The number of workers thus exposed to toxic effects is minimal. The adhesive strength can be recovered as needed for several hours or days after the application. The pre-formed deposition is activated by a short-term heating to a specific temperature, the degree of which depends on the type of thermoactive adhesive. Other forms of energy, particularly ultrasonic, may be used to activate, which provides other advantages in a generally unattainable manner.

Activation is the most commonly used adhesive in the leather industry, i.e. one-component adhesive made of polychloroprene rubber (VUKOLEPS), where the activation temperature ranges between 60-80 ° C and glutting glues. When activated by heat, they are suitable for



joining such surfaces, at least one of which is porous. Using ultrasonic activation, these adhesives will also incorporate non-porous materials. Additionally, there are some types of PVAc-based adhesives for which thermal activation is used when PVC foils are laid. The most preferred glues for activation are melts, for example, a grid coating of melt glue on the lining is used in practice.

Ultrasound activation allows not only to revive the coating of the adhesive that has been made over a certain period of time but also affects the strength of the connection itself.

Generally speaking, if the thermoplastic or solution glue is suitable for bonded materials by traditional methods, the bond strength is increased by the use of ultrasound.

Ultrasound activation has the following advantages:

- The heat required for activation develops almost instantly, and only in the contact area where it is most needed, in the case of normal thermal activation, the heat is exposed to the whole of the temperature,
- High-speed mechanical vibrations cause the adhesive to penetrate through porous materials, the contact surface increases, and thus the strength of joint increases, porous materials such as leather, wood, textiles can be associated with such materials which would otherwise require special types of adhesives ,
- The surface cleanliness is not as critical as ultrasonic activation results in severe surface wiping.

Halogenations

Halogenations is a special type of treatment of glued surfaces prior to bonding. It is made of TPE, PVC, rubber and PUR adhesive. It is actually the application (by dipping, coating) of chlorine-containing substances.(Ebnesajjad,2014)

Upon the contact, a surface layer with an altered polarity is formed. The halogenations agent has a limited activity (max 3 weeks). The halogenations effect can be reached after 10-15 minutes (after evaporation of solvents).

Factors affecting the bond strength:

1. Size of the active surface and surface tension of the adhesive



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2. Effects of interfering interlayers (fat, dust, ...), i.e. surface treatment
3. Viscosity of the adhesive
4. Thickness of adhesive application
5. Drying time
6. Bonding technology, type of bonded joint

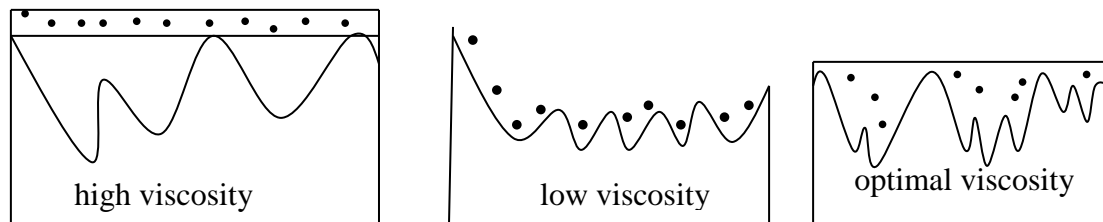
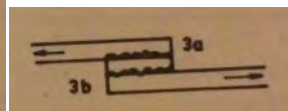
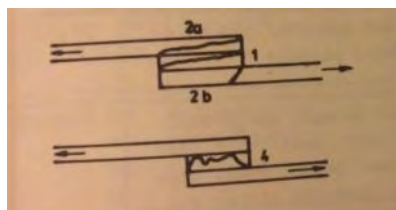


Figure 13. Viscosity (internal friction)



- 1 ... low cohesion strength of adhesive
- 2a, 2b ... low cohesive strength of adherends
- 3a, 3b ... low adhesion strength between adherend and adhesive
- 4 ... poor cohesion of the adhesive and adhesion between adhesive and adherend

Figure 14. The strength of the glued joint

Solvent adhesives - adhesive components of the adhesives are organic solvents (gasoline, methanol, acetone, toluene ...), which form a health-hazardous environment at work. The effort is to gradually remove these adhesives from production, even if they have excellent bonding capabilities. (Snižek, 2015)

Melt adhesives are substances that melt at elevated temperatures and can be used as adhesives. They have a solid content of 100%, they do not contain either water or solvent, and allow for a good bond strength in a few seconds. Hot melt adhesives usually consist of a base polymer, resin, extenders, fillers, pigment, softener and antioxidant.

Dry glue:

- a) Adhesive tapes are also referred to as permanent (still sticky) adhesives. We know them in the form of self-adhesive tapes, tags, or stickers. This is the sticky adhesive applied on the mat (paper, textile). Their applications are growing more and more (reinforcements).
- b) Powder glue, films are not commonly used yet, but they seem to have a great perspective. The viscoelastic state is indicated immediately before application or, directly in the joining process, e.g. in a high-frequency way. Adhesive powder coatings are in the electrostatic field.

Dry adhesives are characterized by health, non-waste technology, relatively rigid bonding.

1.2.4 Welding

In the shoe and other haberdashery industries, other bonding techniques are used – high - frequency welding (or high-frequency heating), conductive welding and ultrasonic welding.

High Frequency Welding (RF Heat)

Siemens discovered heating by dielectric losses in 1864. This company worked in industrial production in the 20's and 30's in the US, in the shoemaking and haberdashery industry much later. In addition to the welding of non-conductive materials, the use of VF heating also when activating adhesives and drainage of sheet flats, was found practical.

The heat of heating is based on the fact that heat is produced inside the materials due to so-called dielectric losses. Dipoles that occur between the capacitor plates (due to the voltage transferred to the plates) are rotated from one position to another (due to alternating current). A quick heat-up of the dipoles generates heat. We include polar plastics between dielectrics (insulators). The biggest use has so far been made with PVC, which has high dielectric losses, for example from PE or PS, which cannot be welded. However, it is also possible to weld these materials (even leather) by placing plastics with the preferred dielectric properties between the bonded materials. It then sinks between uneven surfaces and ensures a solid joint after solidification.

The magnitude of dielectric losses in the material is the loss factor ($\tan \delta$ = the tangent of the loss angle) and the relative dielectric constant (ϵ). ϵ indicates how many times more energy



absorbs the capacitor with a dielectric than the same capacitor with a vacuum. In other words, it is a current indicator that can pass through a capacitor.

ϵ is related to the polarization of material. The more the dipole substance will be, the greater the disturbing effect is. If you connect an alternating voltage to the ideal capacitor terminal, alternating charging and discharging occurs. From the electronics we know that I is overtaking U o $\pi / 2$, ie $1/4$ period \rightarrow at U_{\max} , there is no current flowing through the capacitor and at minimum voltage $I = \text{maximum}$.

Since the vectors are temporally shifted by $\pi / 2$ with the ideal capacitor, their product is zero and, therefore, the power is zero, we call it reactive. The ideal capacitor does not lose energy.

In the case of the dielectric application, the time span I to U is less than the loss angle δ . The capacitive stream has then an active ingredient and a reactive component. The active ingredient is in the phase with a voltage. The active ingredient causes some of the energy supplied to the condenser to change to heat, and the power of the actual capacitor will be:

$$P = U * I_{\epsilon} = U * I_j * \operatorname{tg} \delta$$

$\operatorname{tg} \delta$ a ϵ therefore give an idea of how the substance will behave in the HF field. Both variables are not constants (they change with temperature, frequency, and humidity).

By breaking the voltage into the electrodes, the polarization of the molecules is also cancelled. The time taken to return the dipole to the equilibrium position is called relaxation time. This time depends on the internal friction of the molecules / viscosity of the material and changes with the temperature. The low temperature makes dipoles frozen, scarcely mobile. The temperature increase increases $\operatorname{tg} \delta$. Upon further temperature rise, the viscosity drops considerably, friction of the dipoles changes, and $\operatorname{tg} \delta$ decreases again. The resulting thermal effect will depend on how the machine's frequency is in line with the relaxation time of the dipole of the welded material.

At a low frequency, between dipole movements of pause-lag periods, for which the dipoles remain for a certain period of time, the heat effect will be small, just as in the case of excessive frequency when the dipoles are not enough to track the HF field changes. The greatest losses will only be achieved if the relaxation time is equal to the frequency period.



An effective heating occurs for the value $\varepsilon \cdot \tan \delta$ (loss number) 0.05-0.5. The frequencies used are in the radio frequency range and are always fixed (industrial frequency). The Czech Republic uses 27.12 MHz.

For the calculation of performance, the formula $P = 0,556 \cdot f \cdot U^2 \cdot \varepsilon \cdot \tan \delta$ is used. It implies that it is viable by voltage, frequency and material. Voltage cannot be increased voluntarily because at some value, a breakthrough (breakthrough strength of the substance) will occur. Frequency is fixed. In order to achieve a maximum weld strength (% strength $P = P_s / P_m \cdot 10$; P_s - weld strength, P_m - material strength), a precise pressure setting, welding time and cooling time, choosing a suitable profile and electrode width are needed.

In the HF field, thermoplastic fibers (PA, PES, PAN, PVC) can be melted in addition to the foils. Very good results can be achieved. In addition, traditional textiles and leather can be welded – but with much more difficulty (because of the inhomogeneity of the fabric). These materials deal with the problem of joining with the so-called auxiliary interlayer welding means. This results in melt penetration into the structure of the bonded materials and after it is solidified to a mechanical bond. The auxiliary interlayer may be a powder, an emulsion, a paste or a foil. The most common PVC and PVAc are used.

Welding conductive

is a simpler technology, replacing usually ancillary bonding. It is used in the overlapped joint, where a heated wedge is formed from the side of the slot and remains at the time of the contact. After the wedge has been pushed out, the contact points are pressed together to connect together. The entire process can be carried out continuously with the help of machine. The foils to be bonded are connected to the surface of an electrically heated lock and the rollers are connected at the desired location. Conducting welding is thus welding by touching hot objects. The transition temperature of the PVC film into the melt is 160-180 °C.

Ultrasonic welding

offers the possibility of welding materials and even thicker ones. The principle consists in spreading of the sound in a rigid body, which causes the elastic oscillation deformation of its individual parts. In the body, oscillation energy changes into heat. If the ultrasound





vibrations pass through the parts pressed together, the parts with the heat and mechanical action of vibrations are welded. UZ oscillations have a frequency higher than 20,000 Hz (human ear does not perceive) -(human ear - 16 Hz - 20 kHz).

Unlike high-frequency heating (UV), ultrasonic welding does not depend on the dielectric properties of material nor on its degree of purity.

The frequency converter converts 50 Hz from the grid to 20 - 25 KHz. This high frequency is converted to a conversion element that transforms it into mechanical vibrations. Mechanical vibrations are centred on the tip of the instrument (sonotrode). The counterpart of the sonotrode is an anvil.

In practice, in addition to welding of thermoplastic materials (better welding of harder materials), UZ is also used in shaping (forming the relief on plastic cloth).

Riveting (attachment of plastic ornaments to uppers). Pushing metal objects into plastics (e.g. metal beads in plastic heels to prevent cracks due to the strength of material - very strong connection - exchange of the stand by ultrasound only = disadvantage).

Other applications of UZ include glue activation. The main advantages of UZ are that almost all plastics can be combined, the welding time is short, the shape of the weld (stitch) is unlimited, the material is not mechanically disturbed. The bond strength is almost 100% relative to the welded material.

1.3 Shaping

Shaping is one of the basic technologies of leather-grade generics. Deformation can be done by bending, pressure or pulling, usually all three components with the predominance of one (common stress) are common in practice. Shaping can be defined as a process in which the original shape of material changes by external forces without substantial rearrangement of a part of the mass. The most typical case of molding in the leather production is molding of the upper on the hoof with its simultaneous connection with the supporting part (insole, sole).

The external forces acting on the upper cause, in addition to a partial relocation of the upper, mainly causes changes. Force tension causes material tension. The effect of tension on the



material and its resistance against it is manifested by a change of shape (deformation), permanent (plastic) or reversible (elastic).

The processing conditions and the technological mode of shaping are usually influenced so that the resulting proportion of plastic deformations is in the predominance. Deformation is controlled by the force (size, direction, position) and shape of the form (hooves) in the shaping process, which regulates deformation changes. The complex process of shaping the shoe upper is related to the whole set of activities that we summarize into the following phases:

- a) Preparation of the upper for shaping
- b) Custom shaping
- c) Attachment of the upper to the carrier
- d) Modification and stabilization of the shape of the upper.

Preparation of the upper for shaping = conditioning, i.e. adaptation of material to the processing requirements. Conditioning can be divided into dampening, tempering, mechanical rolling and mechanical machining.

Moisture - moisture of stored leather (14%) must be increased to the optimum value for molding (20-25%). The method of dampening depends on the nature and surface treatment of skin (direct dampening - soaking or applying the damping agent) - then applying the foil - penetrating the moisture into the centre; indirect humidification - absorption of moisture from a saturated environment - combining with temperature and splashing hot water.

Tempering – a short-term heat treatment on the shoe upper shortly before shaping. This method is particularly effective for synthetic material uppers = partial plasticization of the thermoplastic component of material.

Mechanical softening - folding and folding material in two perpendicular directions or dragging materials across the edge of a softening tool.

Mechanical machining – a minor trimming of the upper - usually reducing the thickness of material in a tensioning tab of the front of the upper by mowing, cutting the peripheral edges = ease of tensioning.



The actual stretching of the shoe upper itself generally takes place in several stages:

- a) Three-phase shaping - tensioning of the toe, crotch part and heel
- b) Two-phase shaping - tip + diaphragm and heel, front and partial crotch part + heel part with the remaining crotch part, front and bottom part + crotch part
- c) Single-phase shaping - in one operation, the upper is shaped in the whole range.

The tipping process is a classic way. The foot forming process is more advantageous when using the knobs that are shaped simultaneously with the upper (the foot part is refined with a special part). Bonding the upper with the bottom panel is done by gluing, stiff connectors (cloves, skeins) and sewing.

Stabilization (fixation) means processes that ensure the shape stability of the shoe upper within the limits required.

From the graphical trend of strain and deformation, it is evident that there is no internal stress and no deformation in the preparation of the upper for molding in material. In the section of shaping, deformation of the maximum values is achieved. In other sections, i.e. fixation of the upper over the entire tensioning ring, the tension decreases with the relaxation tension, but the deformation does not change, it is manifested on the entire upper part.

After the kicks of the hooves, the tension on the upper material disappears and the deformation changes qualitatively. Elastic deformation disappears with tension, but flow (viscoelastic) exponentially changes - decreases. After a certain period of time, it stabilizes, no longer changing. The resulting deformation is called plastic or permanent.

Note: Elastic deformation (elastic deformation is not a function of time and is perfectly ported, with the extinction of external force elastic deformation); plastic deformation (must be permanent after cancellation of the external force, the body acquires new dimensions - deformation is irreversible) and viscoelastic deformation (typical for plastics, characterizes their flow properties, the influence of external force changes a relative position of macromolecules from one to another, and is inhibited by the interaction group of atoms. This type of deformation has a time dependence, so that the shoes are well stabilized. The stabilization value must be in the range of 75% - 90% - the stabilization value is given by the so-called stabilization degree



$$S_t = \frac{\varepsilon_{pl}}{\varepsilon_{max}} = 75 \div 90\%$$

Stabilization is mainly influenced by the time of molding on the hoof, temperature and humidity of environment, which also affects the top after the shaping process, as well as conditioning of the upper before shaping.

The stabilization process speeds up the heat (from 60 ° C). In practice, it is carried out with warm air (flow) and infrared radiators (radiation). Drying is a physical process in which the volatile component content of the dried material is reduced by temperature. The volatile component is usually water. Drying of material and stabilization of the shape of the upper, which has been achieved during shaping, generally has the same course.

Moisturization and drying processes, which in fact promote faster and better molding of the hoop hooves and which are related to the process of stabilization, have the disadvantage of increasing production costs (equipment, energy, labour). On the other hand, they speed up production, allow you to make a smaller book allowance (stretch material is more drawn) when constructing the upper, thus saving material and increasing production speed.

1.4 Machining

Machining is defined as a process that produces the desired geometric shape of the work piece in prescribed dimensions and surface quality by a chip removal. In the case of mechanical machining, the tool blade penetrates into the machined material and, in the relative movement between the tool and the work piece, separates the chip particles from it. The required moves call the tool or work piece, or both at the same time.

1.4.1 Tingling

Splitting means chip-cutting (or chipping of material) when the material is moved in line of its surface at a constant speed against the blade of the fixed or movable blade. The hard knife is applied where there are no high demands on the quality of the work surface and where material is too stiff (cutting of rubber plates). The moving knife improves the quality of the machined surface, reduces the cutting resistance and increases the splitting speed. Movement of the knife can be linear smooth, oscillating in the direction and perpendicular to the edge of the knife blade and rotary.





The cutting angle of the cutting angle - cutting wedges may be bent on either side or on both sides, with a flat or hollow grinded face. The cutting wedge angle is $15 - 25^\circ$ (soft materials have a smaller angle).

Speed and movement of the tool, the split material and their relative positioning at work have an effect on creating a real, technological angle of the β_s cutting wedge.

Movement can be performed by material (v_1) or a knife (v_2), or both:

- a) Material movement perpendicular to the edge of the blade $v_1, \beta = \beta_s, v_2 = 0$
- b) Moving the material obliquely to the edge of the blade $v_1, v_2 = 0$
- c) The material moves perpendicular to the edge of the blade $v_1, v_2 \neq 0 = \text{constant}, K = (v_2) / v_1$

If K increases, β_s intensity decreases.

The application of splitting in practice: processing of skins, rubber planks, machining of top and bottom parts (thickness equalization).

1.4.2 Mowing

Stitching refers to a local attenuation of the circumferential or internal parts of the panels in the required thicknesses and widths for later connection, nesting and folding. This method of treatment is especially characteristic for leather. It is also good to skin plastic leather without a textile backing. Furthermore, milling of cardboard and cardboard of similar materials is carried out. The principle of mowing is similar to splitting; the knife is movable in this case and the material to be machined is fed by a carborundum roller against the blade of the rotating knife and held by the foot from the top. The adjusting screw, located on the top of the pressure mechanism, controls the foot pressure. High pressure means bending the material, low pressure causes a little grubbing or none at all. In addition to a pressing function, the foot has a technological function as it tends to determine the method of mowing.

This mowing is characteristic of haberdashery and production of footwear for top panels. For rigid materials, undercut mowing machines are used where a top feed roller is used instead of the upper foot.





In addition to the above-mentioned types of mowing, we distinguish so-called mowing in a negative form, namely mowing and mowing profiled. The operations are performed on splitting machines.

Template mowing is based on the principle of a shape template (form) into which cavities are pressed and those parts of the part that are not to be mowed. The remaining parts, beyond the edges of the template, will be cut off. In the normal splitting process, only a split piece is inserted into the splitting machine, while template mowing is included with the slicing mowing. The shape of the template is the same as the shape of the part. The inner part of the template (cavity) is opposite to this. In other words, where the piece is to be thinned, the template is thick, and vice versa. The top roller is a feeder (feeding), the lower pressure roller is generally articulated. The piece together with the template is placed between the two rollers so that the profile sections of the template are directed toward the facing side of the gathered material. The mowing process can be combined in one splitting operation.

Profiled mowing is based on a similar principle, with a desired mowing method being achieved by a top profiled cylinder consisting of rollers of different widths and different diameters. It is also done with mowing and equalization.

1.4.3 Milling work

The shoe industry includes milling for important machining of leather, rubber, micro-porous rubber, cardboard and other materials replacing the leather. The mantle and heel circuits for mens, women's and children's shoes, gluing outsole, hoop cubes, etc. are milling.

The material is drawn in the form of chips changing its cross-section from a minimum to maximum or vice versa by rotating, most often with a wedge tool, a milling cutter. The rotary movement of a milling cutter is the main movement, the secondary movement is performed by the machined material. A relative sliding motion of the material is either tangential (milling circumferential) or radial (when milling the front).

In the shoe industry, tangential - cylindrical milling is the most used, which is suitable for copying contour shapes of the machined parts such as soles and underpants. In this milling, relative work piece displacement relative to the tool axis can be in two senses. If the blade is against the feed direction, we are talking about a non-sharpened milling. For a sharpened





milling, the work piece feed is consistent with the direction of rotation of the milling cutter. Consequently, milling is not used here because the material is picked out when machining the soft materials and the quality of the machined surface deteriorates to such an extent that it does not meet the requirements.

1.4.4 Grind

Grinding is one of the oldest machining methods. The original natural material - sandstone was used in the earliest times to sharpen weapons, tools, etc. Grinding is machining with a multi-prong tool (brush) which performs the main rotary movement. The work piece then moves side by side. Grinding is used for machining planar, cylindrical and profile surfaces. The brush is made of abrasive grains, which are bonded to the blade (grains are SiC - carborundum - silicon carbide artificial or Al₂O₃ - corundum - natural). As for a binder, is most commonly used the ceramic binder. The second alternative to the sanding tool is a cylinder to which the sanding paper or abrasive cloth is mechanically attached. These materials are formed by adhering abrasive grains to a flexible substrate with cement and binder. In the latter case, it is easy to change the size of chips to be picked up by changing the sandpaper with a different grain size. The partial roughness is given by a number indicating the number of holes in a 1-inch (2, 54 cm) mesh. The size of the hole corresponds to the size of the grain.

In the leather industry, grinding of the leather and the bottom parts is carried out. The sanding machines are used with sanding screens of 100-150 grain size. They are gently soaked with a grain size of 400. Binders use synthetic resins, grains of SiC or Al₂O₃. Abrasive blades and abrasive papers (canvas) are used for machining the bottom parts. New types of base materials contain various abrasive fillers that enable a faster milling wear. For machining the soles of the Styropor, Obolite and other types of rubber, PVC and other substrates, grinding may be used in some cases. Based on a number of tests and experience from operations, some advantages and disadvantages of grinding with regard to milling can be noted.

- a) Grinding wheels are cheaper than milling cutters
- b) No special treatment is required





- c) A better surface finish is achieved
- d) The shape accuracy of the periphery of the sole is better
- e) There is no a complicated profile of the sole
- f) Less material is used
- g) Smoke occurs when material is picked up

1.4.5 Cracking

A technological operation for the preparation of surfaces to be bonded (by mechanical or chemical means).

Chemical cracking is not widespread (etching of the required part of chemicals).

Mechanical cracking involves mechanical machining in a chip-like manner, which is based on disruption of the surface (papillary) layer by a grinding wheel (rubber disc) in which hairpin-shaped wires of 0.35 mm diameter are vulcanized. Wires are ground on a grinding wheel. The whole area of the bookmark is drawn to a distance of 1 mm from the edge. After cracking, the tension tab is cleaned of dust and various scraps of cheeks on a disc brush that is part of a ripper. Roughing will rupture the structure of the surface to be glued. Inequalities and depressions increase the required bonding surface. You can also see and check at the same time the correct crawling by seeing the color of a crawling area. It is a gray-green color for the chrome-skinned skin, the brown skin looks like a light brown.

In addition to the rim blades, steel discs are used (the wires are fixed in a steel case).

At present, hand crawling still prevails. However, a number of slot machines (USM, ISM, FORTUNA, etc.) have been developed. Punching is 0.1 - 0.2 mm for thin materials, 0.2 - 0.4 mm for thick materials.

Wire life is increased by the fact that the working wire is formed by stranding three thinner wires. For weak materials, grinding (leather, etc.) can be used with success, instead of braking.



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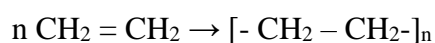


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2 BASIC PLASTIC TECHNOLOGY

An important group of useful substances made from the products obtained by mostly treating caustobiolites are plastics (Baird 2014). It is a wide group of macromolecular substances composed of basic building units called merry, nowadays, monomers. The macromolecule, i.e. the polymer, is formed by joining the low-molecular substances - monomers through three types of basic reactions:

a) polymerization - monomer contains a double bond, which is converted to a single bond to form a polymer



ethylene

polyethylene

b) polycondensation - substances containing two so-called functional groups enter into the reaction. Its reaction results in the cleavage of the low molecular weight product to form a polymer. Different functional groups may be linked to two different molecules.

c) polyaddition - similar to polycondensation, but does not cleave the low-molecular substance.

The described reactions result in linear polymers, which are mostly thermoplastic, i.e., the heat softens or melts and reversibly shapes the heat. If the monomer unit contains more functional groups or more double bonds, a spatial structure (cross-linked polymer) may be formed. The shape of the product in this case must be achieved during the crosslinking reaction. A cured polymer is thermally resistant - thermosetting. If the space is relatively sparse and the base chain flexible, the product may exhibit a high degree of reversible elastic (rubber) deformation. Such products are called elastomers.

Note: There are also groups of polymers that are characterized by rubber deformation and thermoplastic so-called thermoplastic elastomers. Spatial chain interconnection is provided either by heat-reversible chemical bonding or crosslinking is carried out in a physical manner (e.g., multiple strings are bound in one crystallinity or alternating a rigid and flexible sequence in a macromolecule) - thermoplastic rubbers (e.g. SBR - styrenebutadiene rubber).





The properties of the polymer material and the final product influence mainly:

- a) The structure and character of the polymer chain
- b) The super molecular structure (e.g., crystal)
- c) Polymer product manufacturing technology
- d) The nature and content of ingredients

e) Method of processing.

Ad. a) The basic structure of the polymer chain is determined by a chemical structure of its base unit, i.e. the monomer. If the polymer structure is a long aliphatic chain (e.g., a chain consisting of - CH₂ - groups), the polymer obtained (e.g., polyethylene) is soft and flexible. The aromatic core in the chain provides for its stiffening. If it is attached to the side branches, it increases the brittleness of the polymer (polystyrene). The content of polar groups (e.g. NHCO) increases the ability of macromolecules to interconnect with each other by means of polar bonds. In practice, this means that by using a suitable monomer, the behavior of a polymer substance composed of one type of the so-called homopolymer can be determined.

Capabilities of individual molecules are able to influence the properties of the macromolecule, leading to the synthesis of macromolecules containing two types of measure, copolymers such as ethylene vinylacetate or even more types of so-called terpolymers, such as ABS - acrylonitrile butadiene styrene. These molecules may be randomly distributed in the macromolecule (static copolymers) or in the form of longer chains composed of one type of block (block copolymers) or, optionally, the backbone macromolecules (graft copolymers).

Statistical

Blocked

Grabbed

Figure 15. Different types of copolymer

To obtain specific properties of the polymeric material, additional chemical treatments of the finished polymer are also used. Insoluble polyvinyl acetate is converted by hydrolysis to a water-soluble polyvinyl alcohol (used in the food industry, textile industry, etc.). This can be converted to acetyls which are widely used as a construction material. Chlorosulfonation of polyethylene enhances its mechanical properties and elasticity, and other possibilities of chemical modification of the chain.

Note: Chemical interference on the polymer chain can also include the formation of cross-links between chains, for example vulcanization of rubber, crosslinking of polyethylene or the creation of a spatial network in classic thermosets (phenol plastics, urea plastics, etc.) where after the final pressing the whole product can essentially form one huge macromolecule.

A very important feature of the polymeric chain is the polymerization stage, i.e. how many molecules contain the polymeric, polymeric chain in diameter. The required physical and mechanical properties (strength, toughness, etc.) can only be achieved with polymeric material with a certain degree of polymerisation (this is different for different types of polymers). With linear polymers with increasing polymerization degrees, the viscosity of the melt increases, which can subsequently affect the workability of the polymeric material.

In practice, the molecular weight, which is the polymerization degree multiplied by the molecular weight of the meter, is very often used instead of the polymerization stage. The reason is its simple determination using physicochemical methods.





Other parameters include the degree of branching of the linear chain, proportional representation of macromolecules of different lengths in a particular material (molecular weight distribution), and so on.

Ad.b) Over molecular structure In most cases, the properties of a polymeric material, such as mechanical strength, affect not only the structure of the polymer chain but also the way the chains are interconnected - the over molecular structure. If we neglect the chemical bonding of cross linked polymers, chain linking is ensured by secondary (van der Waals) bonds that are orderly weaker than primary chemical bonds. The weakest secondary bond provides the so-called dispersion forces that are spatially bound by non-polar strings. Polymers whose chains are only bound by dispersion forces often exhibit low mechanical properties (e.g., atactic polyethylene).

Note: However, the polymer molecule cannot be considered as a rigid stick. The flexibility of the chain causes most macromolecules to have more or less flexible "threads". These "yarns" can be interlocking with each other, and for their separation, for example, by mechanical stress; we need to use more energy than if they were bound only by dispersion forces (friction between threads is attached to the dispersion forces). If the string contains large and rigid substituents, the yarn can be reworked as if the yarn was provided with "hooks" that are capable of transferring the imposed stress on its own polymer string. These phenomena increase the strength of the polymer.

Ad. c) Polymer production technology may affect the structure of the polymer chain (e.g. in the form of side branches in PE), its length, the amount of foreign matter in the polymer material, the crystalline of the polymer obtained, etc., or characteristics that may affect the way the material is processed further into the performance or product or final properties of the product. Generally, manufacturing technology can be classified as:

- Method of reaction
- Influence of external factors (temperature, pressure, concentration of monomers, etc.)
- The catalysts and initiators used



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As far as the actual process of reactions is concerned, the origin of polymer formation is in most cases associated with the liquid phase, i.e. a liquid monomer or mixture of monomers or a solution thereof.

Note: In technical practice, gas phase polymerisation (typical example of LDPE production) is performed and solid phase reactions (radiation-initiated polymerization of acrylamide) are also described.

When the liquid phase forms a liquid monomer or a monomer mixture with catalysts or initiators, the resulting product is a melt in the case of polycondensation and, in the case of polymerization, a solid block polymer (block polymerization). For polyaddition reactions, both the melt and the solid can be obtained.

The solid polymer can form a solid block in the form of a finished blank or article which no longer needs to be subjected to further processing operations. These are, for example, sheets with polymethyl methacrylate (plexiglass) or cogwheels made of alkali polyamide or polyformaldehyde.

Note: In the first approach, polyurethane products, based on integral foam such as soles, rests and car dashboards, etc. can also be included here.

The acquisition of solid polymer in a block is in practice associated with technical difficulties (difficult homogenization of the viscous mixture and mainly heat removal and temperature regulation). Therefore, polymerization is often carried out on a monomer which is dispersed in water as a dispersion or emulsion. The solid polymer powder is obtained by evaporation of water (dispersion or emulsion polymerisation).

Note: In some cases, especially emulsion polymerization products, the water does not evaporate and the final product is a "latex", more correctly a polymer dispersion. This is used, for example, to impregnate fabrics, make adhesives, etc.

If the liquid phase forms a monomer solution in a solvent, two situations may occur:

- The polymer (i) is soluble in the solvent used, in which case it is advantageous to use this technology to produce a product which is further processed as a polymer solution, e.g. for the preparation of solution coatings, etc. As for production of a solid polymer (which can be



obtained by evaporation of the solvent or precipitation of a polymer by means of a non-solvent), this technology is only used rarely in practice.

- The polymer is insoluble in the solvent used (monomer is soluble), i.e. precipitates from the solution as a precipitate. This type of polymerization technology is used considerably more. For example, polyacrylonitrile (PAN) is obtained from an aqueous solution of acrylonitrile, aliphatic solvents (heptane, hexane) are monomer carriers in stereospecific polymerizations of polyethylene or polypropylene, etc. In both cases, a polymer precipitate is formed, which is filtered off.

Note: A specific technology using solvents is polycarbonate production. This is a polycondensation where one monomer component (glycol, usually dian) is dissolved in water and the second monomer component (phosgene) in an organic solvent which does not mix with water (benzene or toluene). The solid polymer is formed at the interface between the phase (withdrawn from it) and the low molecular weight product (HCl) dissolves in water. A pure polymer of relatively high molecular weight is obtained.

Technologies for polymerization of the desired properties include chemical modifications of the already existing polymer chain. The polymers obtained by treating the cellulose chain (obtained from wood) are among the oldest man-made plastics. Nitrocellulose obtained by the action of nitric acid (or nitration mixture) on cellulose can be used according to the scope (NO₂) both for production of gypsum powder and production of foils, binders for paints, etc. (its first use was for production of billiard balls). This material was, in the case of consumer products, due to its negative properties in the form of easy flammability mostly replaced by other types of modified celluloses, mainly cellulose esters. These are formed by the action of an organic acid anhydride on cellulose. The widespread use also includes cellulose ethers formed by the action of organic halogen compounds on cellulose sodium salts.

Conversion of polyvinyl acetate to polyvinyl alcohol, respectively to polyvinyl acetals, was mentioned earlier.

Other polymers include, but are not limited to, methoxylated polyamide having rubber properties, soluble in conventional solvents, producing highly abrasion-resistant film and therefore used for the surface treatment of various polymers.





Most reactions which are designed to produce a high quality polymer are very sensitive to the careful setting of external conditions. These conditions are mostly specific for each type of monomer to be treated. For example, polymerization of butene is preferably carried out at low temperatures of about -30°C and below, in which case polymerization of styrene would be impractical. In general, polymerization is not generally carried out at low temperatures. High temperatures can reduce molecular weight (oily oligomers) and may cause side reactions, possibly causing degradation of the resulting polymer. A low pressure (vacuum) is generally used in polycondensation (better removal of the low-molecular reaction product), high (above 1000 MPa) is required for LDPE production. In this production, for example, the presence of a small amount of oxygen, which is undesirable in production of HDPE (oxygen in this case acts as a catalytic poison which reduces or neutralizes the efficiency of catalyst), is unconditionally necessary.

Ad. d) Type and content of ingredients

Only relatively few semi-finished products or products are made of pure plastic. Even the products prepared by block polymerization usually contain a small amount of additives in the form of dyes, UV stabilizers, and the like. In the case that the raw plastic material is needed to process the finished product or the product further, the auxiliary materials are usually necessary. These substances may have the following tasks:

- Modify the processing properties of the polymeric material
- Modify the utility properties of the polymer material
- In some cases, even reduce the price of the product

In the case of processing properties, they may be lubricants (waxes, oils, etc.) which are used to prevent the processed plastic mixture from sticking to the processing plants, or when the initial plastic mixture has the nature of a liquid system (pastes, dispersions, solutions) thickeners or thinners (viscosity modifiers), thixotropic additives, etc. The processing aids must not adversely affect utility properties of the products (a possible defect is their so-called blooming on the surface of the product which then affects its appearance or touch).





Note: Thixotropic substances reduce their viscosity depending on mechanical stress - mixing.

A typical ingredient that has the task of lowering the price of the product is a filler. Cheap powdered inorganic fillers (e.g., CaCO_3 -based) usually reduce ductility and sometimes the impact strength of the blanks. They can, however, increase its strength, reduce friction, increase thermal conductivity, etc. Usually, they make workability workable. (Dvořák, 2008)

Fibbers in the form of short filaments can increase the impact strength, and this is the purpose for the phenol-based or urea-form of hydride resins. There are also so-called active fillers which generally improve mechanical properties of the polymer composition. A typical representative is carbon black in rubber blends. Similarly, so-called nano fillers behave. This means that the filler cannot generally be regarded merely as a cheaper additive but also as an adjunct to the utility properties of the product.

Important ingredients include plasticizers. Its most common task is to extend the rubber region of the polymer, i.e. reduce the T_g . In general, its addition reduces rigidity and increases flexibility of the polymer product. In polar polymers, polar plasticizers are mostly based on esters. Non-polar polymers use oils. Conversely, stiffeners are used to increase the stiffness of the polymer composition. These are mostly low molecular weight sprays such as rosin, abiesters, etc. Colours are used to obtain dyed colours, both soluble in the polymer mixture and in the form of insoluble colored pigments. Stabilizers provide increased resistance to the effects of elevated temperature (thermal stabilizers), oxygen (antioxidants), ozone (antiozonants), UV (UV absorbers), etc. According to the purpose, the polymeric compositions may contain optical brighteners, non-combustible or self-extinguishing, antistatic agents, micro-organisms, etc.

Polymer compositions from which a lighter structure product is obtained may contain blowing agents (i.e., heat release agents). All additives should be compatible with the base polymer, and when using special additives, other performance properties of the product should not be reduced.



To ensure specific properties, another polymer may also be added. Tough PS can be prepared by adding about 4% of SBR powder. The rubber here acts as a filler.

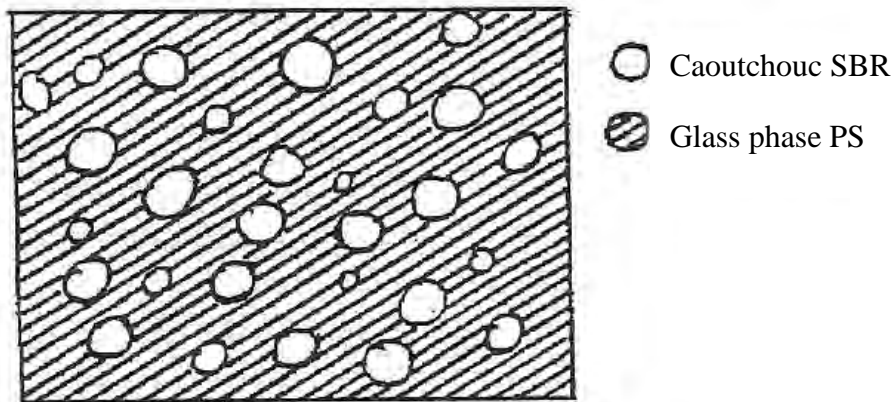


Figure 16. The structure of tough PS with SBR filler

Note. Tough PS is currently produced as a grafted or blocked copolymer or replaced by an ABS terpolymer.

Frost-resistant PVC (foil or leather) are prepared with the addition of butadiene acrylonitrile rubber, which acts as a plasticizer.

Ad. e) Method of processing

The actual processing of the raw polymer can usually be divided into two stages. The first so-called preparatory stage involves mixing the base polymer with the additives necessary to obtain the required polymer composition. In the case of liquid polymer systems, typically different types of mixers are used. Solid polymers must be homogenized using double rolls or kneaders in many cases even at elevated temperatures. The homogenized composition is then converted to a shape that is suitable for further processing. In the case of elastomeric rubbers, they are usually strips or coats of different thicknesses, for thermoplastics, mostly granules in the form of lenses or rollers, the semi-finished products for further processing of thermoses are tablets which replace the previously used powder.

In the case of a polymeric liquid system processing, the semi-product or product can be obtained by:



- Soaking when a heated form of the desired size and shape is immersed in the polymer mixture. The polymer is trapped on the surface of the mold. Thickness of the product wall is usually controlled by the immersion time. Drying, vulcanization or PVC gelling paste follows. Typical products include gloves, condoms.
- Coating - The liquid system is continuously coated on the mat using a knife or cylinder. Heat treatment of the resulting layer follows. Depending on the type of the substrate, foils (steel or silicone belt) can be obtained, or in the case of textile pads of leather, floor coverings and the like.
- Pouring - The liquid system is poured into a mold where it is tightened or cured by chemical reaction. It is often used for products made of reactive resins (PES, epoxy or PUR). Classic casting using gravitational force is used to manufacture small items such as imitation jewellery. Larger products, such as bars, need to be machined after casting. The replacement of simple gravity with centrifugal force by rotary casting is also possible to produce relatively massive shaped products or, on the other hand, fine, very precise products (Wichterle's eye lenses are made by rotary casting technology). Liquid polymer systems are widely used to bond other solids to form a composite. When the finished piece (textile, wood, concrete, etc.) is connected, this technology is called impregnation.

Note: By casting a PVC trap, a POURING FOOTWEAR is produced (the liquid system is removed from the form after a partial moistening).

The following technologies are used for solid state polymer processing:

- stamping is an operation that is currently predominantly used to process composites capable of forming a spatial network, that is to say, not only to mold the product but also to vulcanize the rubber or crosslink the thermoactive resins. Technologically, it is a method of processing plastics at elevated temperatures and pressures, in which the heated material receives a desired shape.



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Note: In the past, thermoplastics were also processed by pressing. In this case, the hot plasticized polymer was pressed in a cold form. This technology has now been replaced by injection technology.

Plastic **vacuum molding** technology is used to form solid plastic films or plates. The film heated to the molding temperature is attributed by vacuum to the cold mold surface which has the shape of a desired article.

- Extrusion is a technology whereby the material is initially stiffened in a heated cylinder fitted with a screw feeder and then pushed through the profiled device (nozzle or nozzle) into free space.

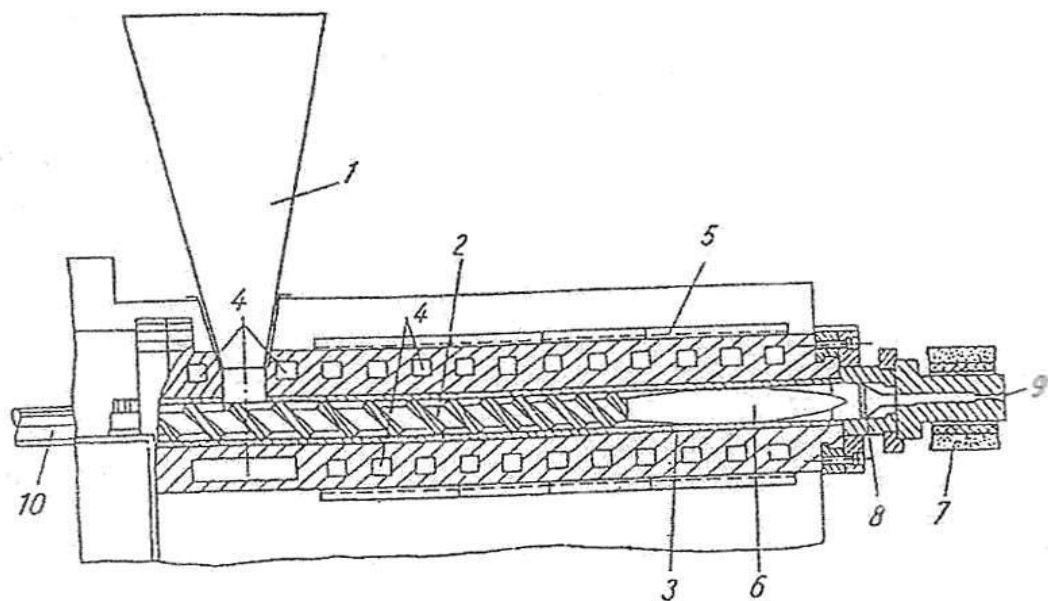


Figure 17. Worm Extruder - 1 - hopper, 2 - auger, 3 - worm sleeve (cylinder), 4 - cooling, 5 - heating, 6 - torpedo, 7 - nozzle, 8 - axis

To fix the shape of the profile, the thermoplastic is cooled, profiles of vulcanizable elastomers pass through the vulcanization tunnel. (Stoklasa,2007) The process is mostly continuous and serves, for example, for production of tubes, belts, sealing profiles, cable sheathing, etc. In many cases, the extruder can be used to homogenize thermoplastic polymer compositions before further processing into finished products, granules used for injection technology. (Kalpakjian,2014)

Note: When discontinuous extrusion of thermoses, the screw feeder is replaced with a piston.



- Injection - is a method of processing thermoplastics (and, more recently, elastomers) resulting in a finished product. In this technology, a polymerized material from the injection chamber is pushed through the piston into a mold to reproduce a desired shape of the article. In the previous injection molding machines, the injection chamber is filled with a solid polymer (usually in the form of granules) and plasticizing the material (also called a plasticizing chamber), the current devices are operated on the principle of a screw-hole, where the feed auger fills the chamber with the molten plastic filled form.

- Rolling is a technology used to produce foils or boards. The stiffened mixture passes between two counter-rotating rollers. The control of the slits between the rolls makes it possible to produce plates or foils of different thicknesses which, in the case of use of gravitational (drawn) rolls, can obtain a tread pattern.

- Blowing is a technology that produces foil in the form of a "sleeve". The apparatus comprises an extruder having a pressurized air nozzle in the centre of the nozzle. The technology is used for a continuous production of foils, pipes and the like, but can also be used for production of hollow containers (bottles, tanks), which are additionally cured in a mold in the plastic state.

Individual plastics and their applications

At present, the industry offers a wide range of plastics with a wide range of usable features and application options. There are also plastics for special applications.

The most common types include polyolefins. The basis of its structure is a hydrocarbon chain without double bonds and bulky or polar substituent. The simplest plastic of the type is polyethylenes (PE), which have generally good electrical and chemical properties. They are hygienically safe. Other properties of each PE type are dependent on the structure and molecular weight. Two types of PE are commonly found on the market: low density (LDPE) and high density (HDPE). However, there are also other types of UHMWPE, i.e. PE with a very high molecular weight, from which very strong filaments can be obtained after orientation. Commonly produced PE have wide application possibilities. It is made from household utensils, it serves as packaging material for production of structural semi-finished products such as pipes, pipes and the like.





Polyolefin polypropylene has similar properties to PE. The high crystalline content (especially after orientation) makes it a high quality material for production of fibers or foils. It has a higher thermal resistance than PE and therefore, for example, serves for production of hot water pipes and fittings. Other polyolefins include polyisobutylene (PIB) or polybuten, known more as butyl rubber. It has a low gas permeability, so it serves, among other things, to produce an inner tube.

Note: Copolymers of polyolefins are also expanded. Ethylene - propylene copolymers (EPs) are characterized by high toughness, ethylene - vinyl acetate copolymer (EVA) is, in contrast to PE, soluble in organic solvents and serves inter alia for production of adhesives, the ethylene vinyl alcohol (EVOH) copolymer has the lowest permeability and is suitable as packaging material not only for food but also for perfumes, etc.

The structure of a saturated hydrocarbon with a bulky substituent in the form of a benzene nucleus has polystyrene (PS). It is an amorphous solid-chain polymer having a Tg of about 100 ° C. This is due to the fact that PS products are relatively brittle, which limits its usability in a "pure" form. In practice, a so-called shock-resistant PS is usually used. It produces, for example, consumer electronics cabinets, toys, furniture components, etc. "Clean" PS has a wide use in foam form. It is used for thermal insulation (it has to meet the requirement of self-extinguishing), for packing of sensitive instruments, etc. The PS copolymers are also widely used. The block copolymer of butadiene styrene is known as thermoplastic rubber and serves, among other things, for production of soles, butadiene styrene acrylonitrile terpolymer ABS used for manufacturing of household appliances, automotive components and the like.

Polyvinyl chloride (PVC) is the most well-known halogen-containing polymer. It has a wide range of applications, but it is partially extruded from the market by other polymers such as polyolefins (packaging technology). Its main disadvantage is a more difficult disposal of waste (combustion releases toxic fumes such as Cl₂, phosgene, etc.). It is processed in a solid form as a non-softened or plasticizer-softened PVC. Unpainted PVC is used for production of pipes, fittings, acid-resistant tiles, etc. The following products are made from soft PVC, for example, wire and cable covers, upholstery covers, flooring, packaging for documentation, etc.





Other PVC polymers include polyvinylidene chloride (PVCl) mainly used in packaging and polytetrafluoroethylene (PTFE) - known as teflon, for products requiring high heat resistance and chemical stability, in the form of container coatings, mainly for the chemical industry (previously used in households as Teflon pans for fat-free frying), as electrical insulation for high-voltage cables, etc.

The ester substituent comprises polymers derived from the ester of unsaturated acids. This includes polyacrylates and polymethacrylates. This is a broad group of polymers, with the properties of individual polymers affecting the alcoholic group used to esterify the unsaturated acid. E.g. with respect to water sorption, hydrophilic polyethylene glycol acrylate, which is also the base of soft eye lenses or hydrophobic polybutyl methacrylate used for, inter alia, leather treatment. Polymethyl methacrylate (PMMA) with excellent optical properties can be considered as the most important polymer of this type. PMMA made by block polymerization is known as organic glass. PMMA granules are processed to replace glass in reflectors, displays, etc. The MMA styrene copolymer is characterized by high impact resistance and serves to produce road markings and some furniture components.

The ester group also contains polyvinyl acetate (PVAc), a chemical ester of polyvinyl alcohol (PVA) and acetic acid. Polymers on this basis have good strength, stiffness, creep resistance and abrasion resistance. The disadvantage is sensitivity to organic especially polar solvents. Sensitivity to solvents, on the contrary, causes PVAc to be easily softened by low molecular weight plasticizers. Plasticized PVAc in the form of a dispersion is used to make adhesives, varnishes and the like.

A large part of PVAc production is used to produce PVA (polyvinyl alcohol), which serves, for example, as a thickener, sizing agent in the textile industry, and the like. PVA reactions with aldehydes are obtained by polyvinyl acetates. These highly crystalline polymers have high strength, high elastic modulus and good dimensional stability, allowing them to compete for some products with metals such as aluminium or zinc. Good friction resistance and a low coefficient of friction, together with good resistance to chemicals and solvents, enable their application as bearings or shafts for devices operating in aggressive environments.





Polyamides (PA), i.e., polymers containing the group $-\text{CO}-\text{NH}-$ are generally characterized by high strength, toughness and wear resistance. The disadvantage is a low hydrolytic stability in the acidic environment. It is used for production of textile fibers, which are also usable for production of high-stressed semi-products such as tire cords, conveyor belts, etc. In the engineering industry, it is used for production of gears, cylinders, etc., a small consumer encounters them (except for textile products), combs, unbreakable toys, and the like. In practice, we usually encounter PA 6 (based on polycaprolactam) or PA 66 (Nylon). There are also special polyamides such as PA 6.10, PA 6.12 or PA 11 resp. PA 12 which are used for special purposes (e.g. PA 11 for sports footwear). High-strength tear-resistant aramids are mainly used for preparation of fibrous composites.

Polyesters (PES) are known on the market in two variants, such as thermoplastics or thermosetting resins. Polyethylene terephthalate (PET) is the most important polyethylene terephthalate (PET) used for production of PES fibers, PET bottles and the like. As a construction material it is used for production of pump units, electromechanical components, etc. Thermoset PES resins are used for production of fiberglass, etc.

One of the most important engineering plastics is polycarbonate (PC). They are characterized by high toughness (including notched toughness) even at low temperatures. They are used, among other things, for production of lighting fixtures, surgical instruments (sterilization), body kits, etc. New types of PC, such as polycarbonate polycarbonates (PPC), serve as microwave ovens or solar panels. Its disadvantage is relatively low resistance to petrol or mineral oils. This deficiency is solved by using blends such as PET or ABS.

From a wide range of polymers with a thermoplastic structure, special polymers can be mentioned, which preserve mechanical properties even at high temperatures. For example, aromatic polyether ether ketone (PEEK) has a resistance of up to 300°C , polyetherketone (PEK) up to 330°C , polyamidoimide (PAI) 250°C and the like.

Thermoset plastics (reactor plastics) are the oldest phenolformaldehyde resins (ba-kelit). Their uses are currently restricted by strict hygiene regulations and are used only for manufacturing of electrotechnical goods (sleeves, switches) of laminated wood or laminated paper or textile, but there is also an attempt to replace them with other types of polymer, e.g.



hygienic aminoplasts (urea condensates or melamine with formaldehyde). On this basis, a laminated paper known as umakart is also conceived.

Other polyesters and epoxides are important for other reactors. "Epoxy resins" is a common name for a wide range of materials characterized by the epoxide group ($-CH-CH-$). These are usually two or more component systems containing the basic component and curing agents. Resin curing gives a space network. The properties of the resulting product are dependent on the base prepolymer component (the epoxy resin may contain other monomers or oligomers based on styrene, MMA, etc.), the type of curing agents and the curing conditions. This material is used as adhesives, laminate resins, paints or casting resins.

There are also special thermosetting resins. The most well-known ones are polyimide ladder polymers. Special features include a high heat resistance (polyimide film can be used from cryogenic temperatures up to $520^{\circ}C$ and is mainly used in electrotechnics and cosmonauts). Complex multistage preparation means that it is a very expensive polymeric material.

The transition between the thermoplastics and the elastomers are silicones. These are polymers of which carbon atom is not the carbon atom but the silicon. It is possible to include a broad group of polymers of different consistency from liquid oils through viscous greases to elastic rubbers or hard resins. Their basic properties include high resistance to water, chemicals, low and high temperatures, aging, weathering, etc. Applications are found in electronics, medicine, food and chemical industry, aviation, etc.

The oldest elastomer that was expediently used by humans is natural rubber (NR). It has been known in Europe since the beginning of the 16th century, but it was not until the 19th century when it was discovered that it was possible to vulcanize it with sulfur. The hard rubber is obtained from juice of some tropical plants (the most famous one is Brazilian rubber) - latex.

Note: Stabilized or otherwise modified (e.g., thickened) latex from natural rubber may be the starting material for production of certain types of adhesives, impregnating agents, soaked goods, etc.)





Raw rubber (NR) is obtained from coagulation (precipitating) latex, which can be supplied to the customer as a white crepe (actually yellowish) or smoked rubber after further processing.

The white crepe is obtained from a perfectly washed coagulum processed on a two-roll calender, dried at 39-40 ° C (or by vacuum at 70 ° C) in dark driers. It is chemically stabilized.

Smoked Rubber - dried leaves of the coagulate are added, thereby increasing the chemical stability of the suction material. In practice, more than white crepe is used.

Both types of raw rubber are further divided into other quality groups that further specify their usability and method of processing.

Chemically, natural polyisoprene rubber with a molecular weight of 200,000-500,000.

Note: Conveniently, by agreement, hydrogen has a molecular weight of 1.

Synthetically produced isoprene rubber (IR) has an analogous chemical composition, but its properties may differ from NR (differently the position of the CH₃ group in the polymer chain). In practice, the combination of NR and IR rubber is often used.

Butadiene Rubber (BR) was the first Synthetic Rubber (Lebedev). Compared to NR, it is worse to process and the vulcanizates with BR have worse mechanical properties and heat resistance. Copolymerization with styrene yields butadiene styrene rubber (SBR), which is the most widely used synthetic rubber. The types differ in styrene content, generally ranging from 8-90%. High-cut rubber rubbers are often processed as plastic. The styrene content of conventional SBR rubbers ranges between 22-24%. Other characteristics such as Mooney viscosity, type of stabilization, admixture content, etc. are covered by a Material or Technical Data Sheet. SBR rubbers are widely used. They are used in production of tires, soles, sealing profiles, rubber products and the like.

Another important copolymer of butadiene is butadiene acrylonitrile rubber (NBR). The acrylonitrile range is of 18-40%. This parameter influences the workability of the rubber





itself, but mainly the end product's resistance to organic solvents and to low or high temperatures.

Chloroprene rubber (CR) is a special kind of rubber for production of oil resistant materials to weathering and weathering (neoprene suits resist seawater). Metal oxides are used to vulcanize it. The product range includes materials with varying degrees of crystalline, with high-crystalline grades achieving good strength parameters without vulcanizing additives.

For special applications there is a wide range of specialty rubber. It is worth mentioning fluorophores with thermal resistance above 300 ° C, acrylic rubbers, silicone rubbers (for low temperatures) and the like.

Most raw rubbers are supplied in casings, which must be worked on a calender or in a kneader and mixed with the additives needed to form the vulcanization mixture. Some types of rubber are supplied in the form of irregular pieces, "shavings", semolina or powdered rubbers. These molds are intended to facilitate mixing of the rubber compound.

Raw rubbers as such have in practice limited applicability. They are used in the form of solutions or dispersions mainly for production of adhesives, impregnating agents, coatings, etc. However, rubber compositions also contain additives in the form of vulcanizing agents, resins and the like.

Most rubber products are processed into semi-products and vulcanized products. Although the basic properties required can be influenced by a choice of the main type of polymer (for example, NBR rubber). Many properties of vulcanizates, e.g. rubber, can be influenced by suitably chosen additives and vulcanization of the rubber mixture. In this way, for example, resistance to ozone, wear, elasticity, partial thermal resistance, etc. can be controlled. Basically, for each type of rubber, there is a set of characteristic properties that is part of a numerical code or is described in a material sheet. The material sheet may also include some additional properties, possibilities for use, possibly previous production data, recommendations for further processing, etc.





SUMMARY

Study support contains only very brief basic technology:

1. Separation
2. Coupling
3. Shaping of deformations
4. Forming
5. Chip machining
6. Adjusting the physical properties
7. Surface treatments

which are mainly focused on mechanical technologies and the basics of plastic technologies that represent chemical technologies.



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LIST OF ABBREVIATIONS

ABS	Acrylonitrile butadiene styrene
CR	Chloroprene rubber
IR	Isoprene rubber
NR	Raw rubber
PA	Polyamide
PAN	Polyacrylonitrile
PES	Polyester
PS	Polystyrene
PUR	Polyurethane
PVA	Polyvinyl alcohol
PVAc	Polyvinyl acetate
PVC	Polyvinyl chloride
SBR	Styrene butadiene rubber





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