Surface modification of polymeric fibers and nonwovens textiles

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The diploma works will be focused on possible modification of polymer fibres and nonwoven textiles prepared via melt spinning process. Application of environmentally friendly materials used for fibres production as well as for surface modification will be taken into the consideration in theoretical part as well as in the experimental work dealing with fibres and nonwovens structure preparation and consequent surface modifications.

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ABSTRACT

The diploma thesis will focus on the possible modification of polymer fibers and nonwovens prepared by the melt spinning process. The application of ecological materials used for the production of fibers and for surface treatment will be taken into account in the theoretical part and in the experimental work dealing with the preparation of the structure of fibers and nonwovens and subsequent surface treatments.

Keywords: Modifications, polymer fibers, nonwoven fabrics, spinning

ABSTRACT

Diplomová práce bude zaměřena na možnou modifikaci polymerních vláken a netkaných textilií připravených procesem zvlákňování z taveniny. Aplikace ekologických materiálů používaných pro výrobu vláken a pro povrchovou úpravu bude zohledněna v teoretické části a v experimentální části zabývající se přípravou struktury vláken a netkaných textilií a následnými povrchovými úpravami.

Keywords: modifikace, polymerní vlákna, netkané textilie, zvlákňování

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I declare that the submitted version of the bachelor's / diploma thesis and the electronic version uploaded to IS / STAG are identical.

CONTENT

INTRODUCTION

Synthetic polymer fibers and nonwovens are an integral part of the textile industry. Nonwovens are a product of exceptional properties, specific characteristics, can take countless forms, many forms and can be dimensioned in many modifications. Depending on the choice of fiber, the method of processing, including the surface treatments, both of the fibers themselves and of the fiber structures, nonwovens built on the same material base can have different properties. They can be dimensioned as absorbent, breathable, non-flammable, heat-sealable, lint-free, light and soft, malleable, stable, rigid, tear-resistant, water-repellent and the vast majority of these properties can be further combined. This work is focused mainly on the possibility of final modification of the properties of fibrous nonwoven structures with regard to the needs of their use in other applications.

The theoretical part is divided into chapters that describe in more detail the requirements for raw materials and technology for the spinning process, methods of fiber processing and finishing processes, aimed at modifying the surface properties of fiber products, processing and modification of surface properties in nonwovens.

The practical part will present the goal of experimental activities, technological and material basis, test parameters, analysis and interpretation of measurement results.

I. THEORY

1 POLYMERIC MATERIALS

The development of new materials is also connected with the growing requirements for the quality and usability of products. Both consumers and producers are subject to different requirements for these materials. Polymeric materials are an important part of technical development. They excel in their durability, reliability, list of possible modifications of the basic raw material. The production technology is economical and acceptable within the ecological requirements. [1]

Polymeric materials are macromolecular substances of natural or synthetic origin and are used in many industries. At present, the development of synthetic polymer in particular is important, which is often rightly referred to as a modern construction material and yet, as a "modern" material, it belongs, according to the volume of production and consumption, to the most important industry segment of all. (2) Polymeric materials are important for their variability of properties and possibilities of both structural and surface modifications. They are easy to process, have a suitable ratio between useful properties and costs for raw materials and processing. Compared to metals, the consumption of energy and labor that must be expended is significantly lower. Compared to metals, polymeric materials have a higher resistance to chemicals, excel in electrical insulating properties or the ability to dampen vibrations and shock stresses. However, they also have their disadvantages, especially low heat resistance, which are closely related to changes in mechanical properties. Most of the factors that can endanger polymeric materials and articles thereof can be greatly minimized by various modifications, by adding additives to the basic raw material, such as antioxidants, flame retardants, plasticizers or colorants. [2]

Polymer materials can be divided according to various criteria. These criteria can be, for example, what are the polymers of origin, preparation technology, molecular structure, arrangement of macromolecules, according to their polarity or also according to their position on the market, whether they are commodity plastics, engineering plastics or high-tech polymers. For the needs of this diploma thesis, we will focus on synthetic polymers, especially polyesters and polyolefins and their use in the production of fibrous structures and nonwovens. [3]

2 FIBER-FORMING POLYMERS

In order for the polymer to be processed into fibers, the raw material must meet several basic requirements. The first is uniform molecular weight. At low values of the average degree of polymerization, the processing properties of the raw material deteriorate, and at a high value, the spinnability of the material deteriorates. Furthermore, the macromolecules need to be linear, without bulky side chains, and thus ensure at least an approximately parallel arrangement of the macromolecular segments. [1] In some cases, it is necessary to repeat the polar group in the chains, which creates strong interchain bonds. [2] However, this requirement is not necessary, for example in applications of the strongest polyethylene fibers, only weak Van der Waals forces are used. A spatially regular chain structure is also important for the possibility of fibrous structure formation and at least partial crystallization. Sufficient bending stiffness of the chain allows the formation of crystals with folded strings. Conversely, for some types of fibers, high stiffness is required to allow formation crystallites with tight chains.An important property is also the ability to melt or dissolve the polymer so that the fiber can be prepared by spinning technology. [4] Only for some special cases of polymers, another method of fiber production can be used, but these are not the subject of this diploma thesis.

The requirements for the choice of fibrous material must include other parameters, such as its:

- required properties, whether mechanical, chemical, thermal or electrical,
- economic parameters, the price of the raw material, the economics of production or, for example, the product life required by the consumer,
- feasibility, possibilities of material modification, colorability, possibilities of workability and bonding,
- maintenance of both technological equipment and raw material and final product,
- an important aspect is the possible toxicity of individual modifying raw materials, such as additives, plasticisers or retarders or dyes, from which different substances or particles may be released, with different toxicity values,
- and last but not least, the possibility of applying various material modifications. [4]

Synthetic fibers have a characteristic internal structure that distinguishes them from other polymeric raw materials. The basic property is the high orientation of the polymer chains. The direction of orientation of the chains of macromolecules agrees with the axis of the fiber. The linear chains of macromolecules are not arranged randomly. Another characteristic that gives the fibers characteristic properties is the alternation of amorphous and crystalline regions. The amorphous phase affects the strength and ductility, or the initial modulus during the deformation of the fibers and thus the stiffness and creasability of the material, its dyeability and dimensional stability. [5]

3 MANUFACTURE OF SYNTHETIC FIBERS

Chemical fibers of synthetic polymers are produced by a polymer solution or melt spinning process. These fibers are processed in the form of endless fibers, so-called monofilaments (one endless fiber) or multifilaments (several endless fibers. For further processing, these endless fibers are cut or chopped to the final, so-called Staple length as needed. [6]

In the textile industry, tex [g / km] is used to characterize the mechanical properties. This is the definition of the length density of a material, which gives the weight of one kilometer of fiber in grams. This unit is mainly characterized by the fineness of the fiber. The linear weight of the fibers is usually given in dtex. In the range of 1.3 - 20 dtex, medium fineness fibers are produced, which are most often used in the textile industry. For special purposes, even finer fibers are produced, around 0.5 dtex, or very coarse fibers, which reach values of up to 200 dtex. The difficulty of processability is closely related to the requirement of fiber fineness. With higher fineness, the complexity of the production process also increases. The mechanical properties of the fiber, such as strength, are reported in N / tex, which is the value in Newtons per fiber density. [7]

3.1 Polymer spinning

The basic conditions for spinning are, above all, the thermal and chemical stability of the polymer, under spinning conditions, the integrity of the liquid jet before solidification and the fiber-oriented drawing.

The spinning process is significantly affected by the viscosity of the melt. The viscosity value also increases with increasing molecular weight, and at the same time the viscosity decreases with increasing temperature. [8]

In the production of fibers, the initial step is to prepare the fiber-forming substance for spinning, the polymer solution or the melt. Subsequently, during the spinning process, the fiber-forming substance is forced through the openings in the spinning nozzle into the environment in which coagulation or gradual solidification takes place. This process produces an undrawn fiber that has a small orientation, is prone to embrittlement, and is not stable.

In the next phase of the production of the polymer fiber, a drawing process takes place, during which the final properties of the fiber are set. [9] An important parameter of drawn fibers is the so-called drawing ratio λ, which expresses the ratio between the length of the stretched and unstretched section of the fiber, and ranges from 3 to 5, especially more. [6]

Most strings in a thread have a random orientation before the drawing process. Stretching still changes the orientation (in the direction of the fiber axis), up to 90% of the chains. During the drawing process, there is a consequent increase in strength, a decrease in the elongation of the fiber and the formation of the fiber structure itself. [6] During the drawing process, the fiber is irreversibly elongated and narrowed. The individual fibers become finer, becoming dimensionally stable. As part of the stabilization of the fiber, the strength of the fiber increases at the same time, the susceptibility to abrasion decreases and in most cases the values of moisture content and the possibility of dyeability of the fibers change.

The fiber drawing phase is followed by the process of its fixation. By fixation we mean the thermal stabilization of the fiber, the purpose of which is to stabilize the dimensions and relax the tension in the fiber. Depending on the type of fixation, mechanical properties such as strength or elongation of the fiber are modified. Fixation is performed with the help of hot air, steam or with the help of so-called plasticizing agents, such as swelling agents. [2]

A large number of properties of polymer fibers are affected by bonds between atoms in the main chain and between chains. The different strengths of these bonds allow the deformation to be strengthened during the process of drawing, shaping, fixing, stabilizing or dyeing. In the main chain, the individual atoms are bound by strong covalent bonds. Breaking covalent bonds requires relatively high energy. Cohesion bonds caused by hydrogen bonds, the already mentioned van der Waals forces, act between the polymer chains.

Table 1Bond energy in polymers [eV = 1.6. J] [5]

Binding type	Energy [eV]
Covalent bonds	4 to 8
Hydrogen bridges	0.2 to 0.5
Van der Waals forces	0.01 to 0.1
Thermal energy at 30 ° C	0.03

Table 1 shows the values of typical bonds that occur in fiber-forming polymers. Interchain forces are not as strong as the primary bonds in the chains of macromolecules, but they are numerous and induce the cohesion of the polymer and its solubility in solvents. Interchain electrostatic bonds are important for all types of polymer fibers. Van der Waals forces represent dipole electrostatic interactions. [5]

3.2 Types of spinning processes

In practice, spinning is carried out in four main ways, melt spinning, dry spinning, wet spinning or electrostatic spinning. (8) The spinning method depends on whether it is carried out from a melt or a polymer solution. The shape of the fibers is determined by the shape of the spinnerets. As required, it is possible to produce fibers of circular or other profile cross-section. [9]

3.2.1 Polymer melt spinning

In the melt spinning process, the decomposition temperature of the polymer is sufficiently above the melting point, Tr - Tm > 30 ° C. Spinning is carried out in a cooling shaft and its speed, which is conditioned by the intensity of cooling, ranges from 400 to 10,000 m / min. For example, the spinning of a fine fiber with a size of 2 dtex is up to 6000 m / min. For very coarse fibers with a diameter of 0.1 to 1 mm, the spinning speed is 20-30 m / min. [6]

In the case of two-component spinning, where the basic raw materials are combined, the resulting properties depend on the choice of the type of raw material and their proportion. In this way we can combine different properties of individual types of used polymer raw materials. In this way, for example, polyester core fibers with a polyamide surface can be produced, which are characterized by simple dyeability and dimensional stability.[9]

The parameters of bicomponent fibers are given by the amount of raw materials used, their relative amount, the arrangement in the fiber and the thickness of the fiber. [10] Elongated inclusions are formed when fibers are drawn from polymers that have different melting points.

3.2.2 Spinning from a polymer solution

Spinning from a polymer solution is performed in two ways. The first method is "dry" spinning, where the polymer solution is forced through a spinning nozzle into the spinning shaft, where the solvent is evaporated by means of hot air and subsequently the fiber is drawn. [11] The second method is "wet" spinning, where the polymer solution is forced through a spinning nozzle into a precipitation-spinning bath, followed by the orientation of the fiber and its stretching. [11]

3.2.3 Electrostatic spinning

Electrostatic spinning produces polymeric nanofibers. The process of forming a polymer melt in a fiber by a strong electrostatic field. The resulting fibers are simultaneously deposited on the substrate due to the field. [9]

The fibers formed by electrospinning technology are very fine (1-20 microns) and the diameter of the fibers depends on the potential difference between the electrodes, the distance between the electrodes, the wire diameter, the thickness of the fiber layer before impact on the substrate and thus the degree of interconnection.(12) The products show low mechanical cohesion, the fibers are uneven with respect to diameter, cross-sectional shape and degree of elongation. (12) The diameter of the nanofibers ranges from 20-500 nm. Nanofibers have a large number of types of applications, such as filter materials in industry or healthcare, for the production of protective clothing and respirators. They are also used in the construction and automotive industries as composite materials. [3]

3.3 Selected modifications of polymer fibers

The dimensioning of the properties of polymer fibers, and thus also the conditions of production and the choice of raw materials, depend on the intended use of the produced material and consumer requirements. Products made from polymer fibers excel in their durability, strength or biodegradability, so polymer fibers are often used as part of highly stressed products such as protective clothing and aids, high quality sports equipment, components for the automotive and aerospace industries or in medicine. [1] The internal structure and properties of chemical bonds fundamentally affect the properties of the polymer and these can be influenced in its production by, for example, adding fillers or reinforcements, using a suitable catalyst, [13]

The internal structure and properties of chemical bonds fundamentally affect the properties of the polymer and these can be influenced in its production, for example by adding fillers or reinforcements, using a suitable catalyst, choosing the processing conditions and using a certain technology, molecular weight or various monomer combinations. [14]

Additives-additives are an important component in the preparation of raw materials for the production of fibrous products and the possibility of modifying the final properties. Additives are low molecular weight compounds that have a stabilizing, supportive or other effect on the polymeric substance. [1] The additives are usually mixed with the polymer just before the granulation or spinning process. It is important to ensure thorough mixing of the mixture and even distribution of the ingredients.

The aim of adding various additive components to the polymer raw material is to achieve the desired properties. The most common types of modified fibers are non-flammable applications, UV-resistant materials, matt fibers, dyed both in the mass and on the surface of the fiber, antistatic fibers or electrically conductive fibers. [4]

By modifying the fibers, whether the raw material before technological processing, during processing or as post-process modifications, the negative properties of the fibers can be removed, or positive properties can be obtained. Modified fibers are generally referred to as II fibers. generation. [14]

3.3.1 Mass-modified fibers - during polymer preparation

The group of modifications applied in the preparation of the polymer raw material includes, in particular, a change in the relative molecular weight. In this case, only the adjustment of the polycondensation time and conditions, the adjustment of the polyreaction temperature and pressure are common. Polymers are generally spinnable only in a narrow range of melt viscosities, so this possibility is partially limited. Adjusting or reducing the relative molecular weight results in a small reduction in the flexural strength and resistance of the fibers. However, we obtain a material which, in the final use, does not form lumps and improves the possibility of dyeability of the fiber. [14]

Another type of treatment during polymer preparation is the preparation of copolymers. Appropriate types of copolymerization are selected as required. The result is the resulting static, block or branched copolymers. In their processing, we achieve in particular

- regulation of fiber coagulation, when according to technological conditions fibers are formed
  - highly precipitating (hot water),
  - differentially coagulating (coagulating in air, at high temperatures, approx. 170 ° C),
  - possibly self-expanding fibers.
- improving dyeability,
- reduction of flammability. [14]

The additions of additives are dispersed in the mass of polymer raw material. They are added to the polymer melt or polymer solution before the spinning process. [4]

Due to the fact that during the processing of the polymer raw material it is heated to the melting point, it is necessary to prevent thermal or thermal-oxidative degeneration of macromolecular chains by using stabilizers. Stabilizers include components that act as flame retardants, UV antidegradants, UV absorbers. [1]

Other typical additives are, for example, antimicrobial agents, pigments and absorbents. The pigments can be both organic and inorganic additives, which are most often added in powder form to the fiber-forming raw material in order to obtain colored products. [1] Pigmented fibers excel in excellent stability. The choice of the type of pigment depends on its stability to the heat required for the processing of the polymer, there must be no degradation of the pigment component.

Absorbents are in most cases water-insoluble crosslinked polymers, able to absorb liquids and form a so-called hydrogel, in which water is retained under pressure. This property is mainly used in hygienic applications of nonwovens. [1]

3.3.2 Modifications during fiber preparation

During the preparation of the fibers, it is possible, if necessary, to modify in particular the physical properties of the fibers, namely:

- by adjusting the conditions for drawing and fixing the fiber. Their mechanical and sorption properties depend on the conditions of drawing and fixation of fibers,
- by adjusting the fiber cross-section. By this we mean the preparation of fibers of non-circular cross-section. An example is three-pointed or multi-angular cross-sections, which have structurally straight planes and thus increase the gloss of the material. The profiled fibers have a lower tendency to lint and the change in cross-section will also result in a change in the feel of the textile raw material. [14]
- By creating very fine fibers-microfibers, nanofibers. The advantages of fine fibers are, for example, breathability, transport of moisture between the fibers and easy removal of dirt. Microfibers are particularly suitable for filtration applications where the fabric traps particles that are larger than the pore size between the fibers.
- The process of shaping - increasing the volume of fibers. The shaping can be performed, for example, by forming an asymmetrical structure (production of bicomponent fibers), asymmetric heat treatment, or spinning of the material at an oblique angle. [14]

3.3.3 Post-process modifications

These are applications on already produced fibers, on already produced textiles, finishing and fixing of material. We can include processes in these types of modifications:

- grafting - the formation of a branched polymer, where the most important step is the formation of free radicals, namely by chemical initiation, irradiation or cold plasma.
- additional crystallization, in particular to improve the dyeability of the fiber surface,
- controlled destruction on the surface of the fibers, when the surface structure is disturbed, and thus the specific surface area is increased. At the same time, this damaged surface becomes hydrophilic and the sorption properties of the material are improved.

Surface modifications of the fibers include the application of special layers. It is mainly the silanization of the surface, the production of metallized fibers, for various special purposes, especially the production of antistatic filters or protective clothing. [4] Other modifications can be, for example

- fiber reinforcement and fiber layers, calendering,
- fiber texturing, to increase the volume and flexibility of the fibers. During texturing, the multifilaments are loosened into individual elementary fibers. At the same time, deformation and back-fixation takes place by twisting the fiber, which gives a higher fineness of the fiber, fullness and flexibility of the material. Texturing also affects the thermal insulation properties, the ability to remove moisture. It is used for all thermoformable types of polymers, such as polyesters, polyamides, polypropylene. (peasant)
- Thread length adjustment. The length of the fiber is most often adjusted by cutting or chopping to the so-called staple length - staple fiber.
- Fiber lubrication. Part of the fibrous raw material, for the modification of the fibrous structure is the application of preparation - fabric softener. Softener applied to the surface of the fibrous layer and further determines the resulting surface properties of the material. The type of fabric softener can affect the smoothness of the surface, the coefficient of friction, wettability by liquids or oils, the formation of electrostatic charge.

The fabric softener is applied to the surface of the fiber or fiber layer by a rotating roller, which is partially immersed in the lower part of the fabric softener reservoir. The softener is applied, according to the requirements of the end use of the material, in various amounts, generally the value of 0.3 - 1% of the weight of the fiber is given. [9] Fibers can have different water retention capacities, this property is especially important in the production of wet nonwovens. It is an advantage when a high fiber to water ratio is not required, longer fibers can be used during the wet process, the suspension lasts longer. [10] Due to the subsequent drying, this property is a disadvantage. Higher moisture modulus can cause problems, where small forces, within the stiffness of the material itself acting in the wet fiber production process, can cause deformations. [13]

4 SELECTED TYPES OF POLYMER FIBERS

The properties and parameters of synthetic fibers can be combined or improved practically, almost indefinitely, while maintaining the high quality of the material. Synthetic fibers have a number of properties that natural fibers lack. Above all, they excel in their high strength, durability, crease resistance or shape stability. [14] The production of fibers uses relatively simple technologies that are environmentally friendly and that are at economically acceptable values, both for manufacturing companies and for the final consumer. Due to these properties, these materials can rightly be described as innovative. Synthetic polymer fibers are widely used in the textile industry, both in the production of fibers, textile products and products from nonwoven structures. [13]

In the following subchapters, selected types of fibers of primarily synthetic polymers will be described.

4.1 Polyolefin fibers

In principle, these are the two most important types of polyolefins, namely polypropylene and polyethylene. Polyolefin fibers are not wettable. Due to their low price, they are often mixed with other fibers. These fibers cannot be dyed by conventional methods after production. Therefore, the pigments themselves color the actual polymeric material. The disadvantage may be insufficient light resistance, however, dyes can minimize this disadvantage.

The production of fibers takes place by melt spinning. All types of polyolefins show very low melting points (lower thermal stability of the material) and low light stability [1]

Polyethylene fibers are most often used as a fibrous binder for technical applications. Two types of polyethylene are mainly used, namely HDP - High Density Polymer, for the production of very fine fibers and LDP - Low Density Polymer, for the production of films and fiber binders. (15)

Polypropylene is generally a material with excellent strength characteristics, has low surface energy, permeability to gaseous and liquid substances. Polypropylene is obtained by high-temperature cracking of petroleum hydrocarbons and propane. [16] Polypropylene fibers are produced mainly in the shape of a circular cross-section of the fiber. They are non-sorbent and difficult to dye. (15)

4.2 Polyester fibers

Polyester fibers are made of synthetic polymers. These fibers do not occur in nature. [3] It is one of the most industrially important types of chemical fibers. They meet the parameters of the required properties, such as high toughness, low cold flowability, resistance to deformation, resistance to acids or oxidizing agents [17] There are many polyester fibers, their types, but the production is the same for all types - production of polycondensations. All types also contain an ester functional group COO. (3) Possible disadvantages of this material include the tendency to form entangled bundles of fibers on the surface of the fabric (formation of lumps on the surface of the fibers). [3] Polyester is a thermoplastic polymer that can be reused for production and thus easily recycled.

It is typical for polyester fibers to have a highly crystalline structure, low moisture absorption and the ability to accumulate electrostatic charge on the surface of the fibers. Up to a certain value of the concentration of active chemicals, the fibers are resistant to certain acids, bases and organic solvents. [3] Polyesters excel in resistance to common bleaches, cleaning agents or surface-active materials: [17] The fibers produced are strong and rigid, with good resistance to abrasion and deformation. Thanks to their low absorption capacity, they then dry quickly. Due to their physical and chemical properties, they are a suitable element in composite applications. [17]

4.2.1 Polyethylene terephthalate

The most important and important type of polyester is polyethylene terephthalate (PET), which is produced by the polycondensation reaction of ethylene diglycol and terephthalic acid at a temperature of 290 ° C and a pressure of 400 kPa. (18) PET fiber is very strong. Its toughness is about 5 g / dtex. Because the fiber is characterized by minimal absorption - at 65% relative humidity, its humidity is only 0.4%, there is an easy accumulation of electrostatic charge, (18) which can lead to excessive addition of dust and environmental contaminants. In this case, if within the requirements of the final product, the PET fibers are combined with a hydrophobic material. (19)

PET fibers are the most important synthetic fiber in terms of worldwide production volume and possible applications (19), especially in terms of processability, product performance and low price. Depending on the processing method, PET is applied as an amorphous or semicrystalline material. In general, in the drawing process, in the production of fibers, the increased orientation of the macromolecular chains leads to higher crystallinity. The amorphous structure of PET is transparent, so it is used in the packaging industry. The semicrystalline structure is then characterized primarily by its increased thermal stability. [17]

4.3 Polyamide fibers

In the production of nonwovens, polyamide fibers have been used for the longest time. One of the first polyamide fibers was created as part of the work of Professor Wichterle, in the field of polyamide chemistry research, in the Research Chemical Workshops of the Baťa company in Zlín. This is the formation of polyamide 6 (Silon), whose workability in the spinning area, compared to polyamide 66 (Nylon), was problem-free, the fibers produced by this process are strong and suitable for further processing. [20]

During spinning (from solution and melt), polyamide fibers undergo various thermal solidification processes. The individual phases, processing conditions and subsequent changes in the microstructure are important for controlling the stability of dimensions and the resulting mechanical properties. [21] The heat treatment of polyamide fibers makes it possible to increase the crystallinity, control the size and 'perfection' of the crystals in the structure. (22)However, the thermal adjustment is complicated due to the polymorphic transition and moisture sorption. [21]

Polyamide fibers also include aramid fibers. These are aromatic polyamide fibers with a long hydrocarbon chain. The molecules of aramid fibers show a high orientation and level of crystallization, a strong interfacial connection, and therefore excel in high modulus and toughness of the fiber. [23] Due to their properties and high power-to-weight ratio, these fibers are an object in the development of light bulletproof materials. [24] In view of the high melting point of aromatic polyamides, these fibers are spun from solution.

5 NON-WOVEN FABRICS

Nonwovens are referred to as uniquely treated fabrics that offer a cost-effective solution. Most nonwoven applications are advanced and functional products that are capable of performing demanding functions, for example, they can be extremely absorbent, able to retain fluids, can be very fine and soft, have high barrier capabilities, and are widely used in medicine. [2]

The parameters influencing the choice of fibrous material include mechanical, chemical and electrical properties. The price and service life of the material, its processability, subsequent sustainability, the possibility of releasing various substances and particles with a probable degree of toxicity, or the variability and diversity of applicability of modifications or uses themselves are largely decisive. [22]

The marked development of nonwovens in Europe can be traced back to the mid-1960s, when this material took a firm place with producers and processors, under the two names "nonwoven textiles" and "nonwovens". The development of nonwovens is mainly due to the lack of raw materials and the need to minimize costs during the Second World War, when it was necessary to use second quality fibers and recycled fiber waste. However, this is not a cheap replacement or low-quality material. [2] During the development of the non-woven industry, as part of the expansion of production technologies, high-speed, economically undemanding progressive processes were implemented in the methods of production of natural and synthetic fibers and polymers. The development of technologies in the non-woven industry is mainly influenced by the availability of fibers and polymer raw materials, which are processed by these technologies, the development of technologies is directly connected with the development of raw materials. [9] Nonwovens are an innovative and versatile material, which is why they have a place in virtually all sectors of industry and life for each of us.

There are three leading industrial areas in which nonwovens have developed as separate industries. It is Japan, Western Europe and the USA. [2]

The basic characteristic of nonwovens, as is evident from their name Non Woven, not knitted or not woven. The difference between a classic woven or knitted fabric is that the fibers forming the nonwoven fabric do not go through the preparatory or transition phase of spinning the yarn into the desired pattern. [2]

Each branch of nonwovens uses differently and is characterized by an approach to this material, as well as to the preparation and production processes, or the possibility of applying individual types of nonwovens. In general, the insulating capabilities of nonwovens are used in industry, for example in the form of insulators for cabling, abrasives, battery separators. Within the clothing industry, nonwovens are mainly used as insulating and protective industrial and chemical resistant suits, linings and as a part of footwear. Furthermore, nonwovens are used in the food and packaging industries. [22] The widest areas of application of nonwovens are healthcare, hygiene, agriculture and the construction industry. In agriculture, nonwovens are used in soil stabilization applications or as filter elements. In the field of hygiene, absorbent products for the personal hygiene of children and adults, in the form of diapers and pads, dominate. Surgical drapes, gowns, masks, bandages and tampons and other products for medical use and healthcare needs. [2]

Nonwovens undoubtedly have exceptional properties, specific characteristics, but also weaknesses. Nonwoven fabrics can take innumerable forms and many forms and be sized in many modifications. Depending on the choice of fiber and the method of processing, nonwovens can have various properties. They can be dimensioned as absorbent, breathable, flowing, non-flammable, heat-sealable, lint-free, light and soft, malleable, stable, rigid, tear-resistant, water-repellent and the vast majority of these properties can be further combined.

The properties that we need to achieve with individual types of nonwoven fabric are given mainly on the choice of fiber from which the nonwoven fabric will be made. These fibers can be made of both natural and artificial fibers, organic and inorganic materials. [2]

5.1 Formation of fibrous layers

Consolidation of the belt after its formation is the second step in the nonwoven fabrication process. This reinforcement largely sets the final properties of the fabric and should therefore, if possible, be chosen with regard to the final application. Such consolidations can be performed by chemical means (chemical bonding), such as binders. [22] These can be applied evenly by impregnation, coating or spraying or intermittently, as when gluing a print. Consolidation can also be achieved by thermal means (cohesive bonding), such as partial fusion of the forming fibers. Such fusions can be achieved, for example, by calendering or blowing with air or by ultrasonic shock. [24]

Finally, consolidation can be achieved by mechanical means (frictional connection), such as needling, sewing, water jet braiding, or a combination of these different means. [24]

Customers' needs can be further met by modifying or supplementing the existing properties of the fabric through finishing. Various chemicals can be used before or after gluing, or various mechanical processes can be applied to nonwovens at the final stage of the manufacturing process [1]

The choice of raw material and final forming fibrous element, the application of fibers as fibrous material with different densities, the choice of consolidating and finishing agents all create a number of parameters which can be further worked with in order to achieve the desired properties.[2]

A nonwoven fabric is a material that is composed of separate, ordered fibers. These fibers are bonded. The choice of fibers and binders of the material is of great importance for the final properties of the material. Fiber binders can have a major impact on the quality of the resulting structure. [1]

5.1.1 Spun-bond technology

Fiber layers are prepared from the polymer melt using spun-bond technology. This method is very common in the production of the fibrous layer and is considered to be highly productive. Spun-bond technology has several basic phases. Part of the melting and spinning of the polymer is identical to the technology of producing fibers from the melt. [3] Linear fiber-forming polymers such as polypropylene, polyesters or polyamides are used for production. This technology can also be used to produce bicomponent fibers. During the spun-bond process, the fibers under the spinneret may be drawn off

- by its own gravity, the result is an endless fiber, which, however, shows very little strength,
- extraction by a stream of air, when partially elongated fibers are formed, or
- galettes, where elongated fibers with high strength are formed. [22]

After drawing the fibers, after they have cooled, the fibers are distributed on a conveyor belt. Chemical, thermal or mechanical bonding is used to strengthen the layer.

Textiles produced by the spun-bond technology are used primarily for the application of personal hygiene products, medical products, as well as in the packaging industry, the geotextile industry, and the production of filters and protective clothing. [3]

5.1.2 Flash spinning technology

This is a variant of spun-bond technology. It is a spinning from a polymer solution, the most common raw material processed in this way is polyethylene. The polymer solution is conveyed to the spinning nozzle at a constant temperature and pressure. When extruded under the die, the solvent evaporates. The resulting layer is most often connected by a calender. The fiber layer produced by the flash-spinning method is characterized by high tensile strength, surface softness and breathability. [2]

5.1.3 Melt-blown technology

Typical fibers made with the melt-blown technology are fibers with a diameter of 2-4 microns, which are characterized by a large specific surface area. This technology most often processes polymeric raw materials such as polypropylene, polyethylene, polyesters and polyamides. The production process is divided into several phases. [9] In the first phase, the polymeric material is processed in the form of a melt, in a melt extruder and conveyed to a spinning die. The discharge nozzle is provided with many spinning holes. Under the nozzle, the fiber is formed and cooled by a stream of hot air. The fibers are thus irregularly drawn. The fibers are further formed on a conveyor belt. This is followed by bonding, most often with a calender and winding on a spool. [3]

Textiles produced by melt-blown technology are most often used in industry, such as sorbents and the production of protective clothing. The fiber layer is able to absorb various chemicals, dust or bacteria, so they are very often used for the production of surgical clothing, drapes or masks and filters. [9]

5.1.4 Electrostatic spinning

The fibers formed by the force of the electrostatic field are deposited on a textile substrate which moves on the surface of the opposite electrode. Almost all types of fusible polymer raw materials can be processed by electrostatic spinning. The surface distribution of the material is uniform, because the electric charge of the fibers in the emerging layer is the same, and so the fibers are directed automatically to the places where the value of the mass concentration is lower.

The diameter of the produced fibers depends on the technological conditions, on the potential difference between the electrodes, their mutual distance, the thickness of the material layer, the viscosity of the raw material and its surface tension. In general, the fibers are very fine, uneven, depending on the degree of drawing. The resulting fibrous layer has a lower mechanical cohesion, therefore applications made by electrospinning are provided with support materials. [9] These textiles are used primarily because the fibrous layer has an electrostatic charge which is long-term bound to the textile material produced. Fibrous materials produced by electrospinning are used primarily as filter media. Thanks to the bound electrostatic field, the material is able to bind very small particles to each other.

6 SURFACE MODIFICATION OF NONWOVENS

Nonwovens undoubtedly have exceptional properties, specific characteristics, but also weaknesses. Nonwoven fabrics can take innumerable forms and many shapes and can be sized in many modifications. Depending on the choice of fiber and the method of processing, nonwovens can have various properties. They can be dimensioned as absorbent, breathable, non-flammable, heat-sealable, lint-free, light and soft, malleable, stable, rigid, tear-resistant, water-repellent and the vast majority of these properties can be further combined. [2] For some applications, it is necessary to process fibers with exceptional properties that conventional fibers cannot provide. These include properties such as high strength, heat resistance to heat, fire, chemicals, elasticity, low friction, biodegradability, such as polylactide fibers, or biological resistance, low friction, electrical conductivity, bulk, low melting point (binders) or non-circular fiber cross-sections. [3]

According to the required properties of the final product, we divide the types of modifications into pre-treatment, dyeing or printing of textiles, special purpose modifications and final modifications of surface appearance and properties. [9]

Pretreatment of textiles is performed before the actual modification of the surface layer. The material is free of all unwanted particles. Modifications of synthetic materials mainly include washing, fiber fixing or bleaching, but also cutting to the required dimensions. [3]

Mechanical finishing of nonwovens includes processes of calendering, pressing, cutting, punching, perforation or, for example, ultrasonic and high-frequency welding. For chemical treatments, especially dyeing and printing and other antistatic, absorbent or fire-resistant surface treatments. (25)

6.1 Calendering the surface of nonwovens

Calenders and presses are used for basic surface finishing of nonwovens. The calendering process can take place in two variants, either batchwise or continuously. The batch process takes place on forming presses. It is mainly used for strips of textiles that have been shortened to a certain length. In continuous calendering, the nonwoven fabric is fed between one or more pairs of heated rollers under a certain pressure. Calendering rollers can have a smooth polished surface or can have various embossed patterns. The patterns can be of different heights and give the fabric a three-dimensional surface structure. [3]

6.2 Ultrasonic welding

Fabrics made of thermoplastic fibers are suitable for ultrasonic welding technology. The AC frequency is used in the process. The energy of the oscillator is converted into mechanical vibrations. This technique is used primarily for surface treatment of products such as tea bags and personal care products. [2]

6.3 Dyeing and printing

Dyeing and printing, with some exceptions, are performed by wet processes. Fiber dyeing is especially important for synthetic fibers. Staining methods can be batch or continuous. (26) Continuous dyeing is performed by coating followed by evaporation and fixation of the dye. Excipients such as wetting agents, penetrants, dispersants and fixing chemicals are used for the dyeing process. [3] Rotary screen printing is most often used for printing, when the fabric is attached to the printing surface or the substrate with the dye. Furthermore, the dye is again fixed by steaming. Pigment printing is used especially for textiles produced by the spunlaid process. Drying and steaming are replaced by condensation. In some cases, it is also possible to use transfer printing. (26) The sublimation dye is transferred from the release paper to the nonwoven fabric under the influence of pressure and heat. This dye transfer method is particularly suitable for fabrics made of polyester fibers. Polyester fibers strongly bind the dye to each other and provide sufficient color fastness. [2] Rotary and surface printing is one of the most important methods of printing large volumes of fabrics. [3]

6.4 Antistatic surface treatment of nonwovens

Nonwovens can be prone to dirt and dust particles. Textiles made of synthetic fibers in particular have this problem. [3] This type of textile treatment is used mainly in applications for home textiles and in the finishing of dustproof nonwovens. [2]

6.5 Hygienic treatment of nonwovens

In some applications, an antibacterial, antifungal coating is required. These are mainly applications in the hygiene and healthcare sector. This treatment can be applied to the surface of the fibers or to the fibrous raw material before the actual production of the nonwoven fabric.[4] Antimicrobial and biocidal coating of nonwovens is required in particular for applications that may be susceptible to biodegradation due to the growth of undesirable organisms. [3] These applications include sportswear, insulation materials, bedding, hygiene products and medical devices. [3]

6.6 Absorbent surface treatment of textiles

The absorbency of the fabric is a property of the fabric important especially for hygienic and medical applications. This may involve the use of wetting agents which promote absorption or absorbent fillers. These substances must be properly fixed to the fabric structure. As these are mostly products that come into contact with the skin, it is necessary that the agents be physiologically harmless. Physiological safety is not so important for absorbents for technical uses. (27)

6.7 Application of surface treatments

Various coating methods are used to apply surface modifications to nonwoven fabrics. Coating is performed using special application adjustable rollers, knives, sprays and other components. [3]

6.7.1 Coating of nonwovens

The applied coatings are mostly water-based in the form of dispersions or solutions. The application of the aqueous base is followed by drying and curing with hot air or, for example, an infrared radiator. Depending on the final application, the coating can be applied in several layers to avoid various surface defects or gaps in the coating. The coating can be applied to the fabric using a release liner, similar to transfer dyeing. In the case of powder coating, thermally activated dry powders based on polyamides or polyesters are used. [3] The powder coating is applied by a rotating screen or by contact of a heated engraved cylinder. [3]

7 ECOLOGY OF NONWOVENS

It is true that most nonwoven applications are disposable, however, much of them are intended for long-term use. This part of the production represents, for example, linings in the textile industry, applications in roofing or floor coverings in the construction industry, and geotextiles in agriculture.

Disposablehowever, products have an irreplaceable place. Disposable products have never been used before, ie they guarantee their quality and it is not possible for them not to be able to fulfill their purpose, they cannot be damaged, for example, by washing or previous use. [2] Non-woven waste may also arise from the disposal of used non-woven products (ie consumer waste). Such waste and quantity depends on the life cycle of the nonwoven products themselves. Again, the amount of non-woven technology waste is relatively low in terms of paper or textile waste, but non-woven products alone do not create problems greater than paper or textiles. Nonwoven waste can therefore be handled safely (as far as the nonwoven part is concerned) and, at least in theory, all waste management solutions can be used.

The utility properties of nonwovens should not overlook the many environmental benefits that result from the use of nonwovens, for example in air and oil filtration, oil absorption, protective workwear, geotextiles, agriculture. [2]

7.1 Recycling, regeneration

Within the waste management of polymeric materials, two groups of waste are generated, namely returnable waste, which is generated mainly during production, and collection waste, generated after the consumption of the product by the user. Polymer waste can be processed in several different ways.

One of these methods is degradation by reductive pyrolysis, degradation of the polymer at elevated temperatures, the action of carbon monoxide and water - the polymer is transformed into a heating fuel. Such combustion is not complicated, the polymers are easily combustible at temperatures of about 900 ° C and economically acceptable, however, combustion can lead to the formation of highly aggressive substances, which must be costly removed. [2]

Approximately half of the polymer waste is exported to landfills, this disposal solution is simple and least costly, however, the polymers do not undergo chemical changes fast enough, the exposure time for polymer degradation is too long. [2]

8 ECONOMIC COMPLEXITY OF PRODUCTION OF FIBERS, NONWOVENS AND THEIR MODIFICATIONS

As already mentioned, the beginnings of the development of nonwovens are linked to the crisis, the scarcity of raw materials and the need to use recycled fibrous waste and fibers generated as waste in industrial processes, and as a result the prevailing view is cheap low-quality products. [3] Within the industrial sectors, non-woven products are described as high quality. [9]

However, nonwoven products are not merely a substitute for the original materials, often outperforming the original materials in terms of their properties and cost savings, and still creating other structures that are able to replace different materials and are increasingly efficient and at least comparable in cost, in addition to raw materials have non-woven fabrics of great own potential and creativity and the opportunity to constantly innovate and sophisticate nonwovens themselves. [2]

New textile production technologies, which developed after the Second World War, were to be economically competitive with conventional production technologies for material processing, production of woven, knitted and lace textiles. These new technologies have been collectively referred to as nonwoven technology. [9] The competitiveness of the nonwoven production technology itself is both the unit price of production, the need for share capital needed for production, that is, an indisputable advantage within the necessary costs and the possibility of easy and reliable distribution on the market. The expansion of the textile market also supports the development of progressive methods of nonwoven production, not only the development of technologies for mass production of the product, but also the development of materials and the processing of basic raw materials, which are able to meet high consumer demands, quality and performance standards at an affordable price. [8]

II. ANALYSIS

9 THE AIM OF THE WORK

The aim of the work is to characterize the dependence of the leakage time of the nonwoven fabric with a suitably selected liquid, its absorbency, the value of the contact angle depending on the parameters of the selected surface treatment of the nonwoven fabric and its applied amount.

9.1 Selection and description of technology for experimental activities

Nonwoven fabric production - The fibrous layer of the nonwoven fabric was made by melt-blown melt spinning technology, in which a bundle of synthetic fibers extruded through the orifices of a spinning nozzle was entrained, drawn and cooled with hot air. The fibers were then fed onto a conveyor belt and formed by calender rolls. The calender and take-up rollers had a constant rotational speed throughout the spinning process. The whole process, including the application of the surface treatment, was performed continuously.

The fiber layer was passed through an applicator roller partially immersed in a fabric softener container, constantly heated to 40 ° C. During the application of the fabric softener, the roller rotated against the direction of withdrawal of the fibrous layer of fabric. After applying the layer, the fabric was guided by drawing through an infrared radiator, in which the fabric softener was fixed on the fabric surface and partially dried.

Next, the fabric was wound on a spool. The rotation speed of the coating roller was controlled separately. The fabric softener was applied by application rollers to individual types of textiles in 5 gears, which also controlled the amount of applied layer of individual types of fabric softeners.

Table 2 Finishing speed by application roller

Finishing speed			Rotation speed of the coating roller
	[with]	no.	
1	38	2	78
2	30	2	100
3	18	2	166
4	14	2	214
5	8	2	375

9.2 Selection and description of materials for experimental work

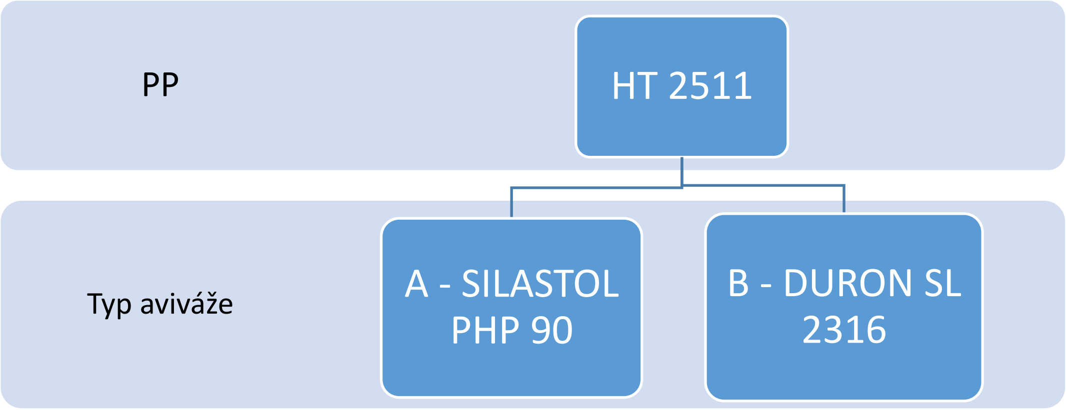
Materials selected for material characterization - polypropylene - PP, polylactide - PLA.

Selected types of fabric softeners applied to the fabric surface:

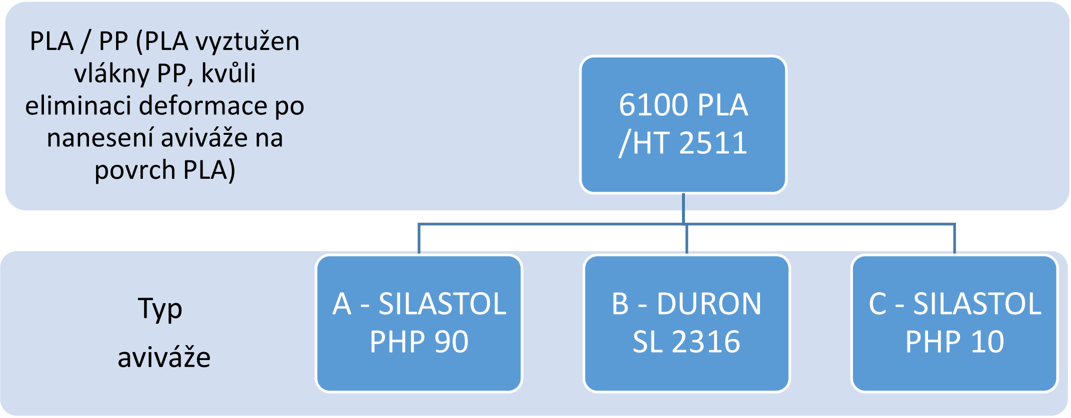
Table 3 Types of fabric softeners used

Designation	type	dilution (parts of used components)
A	SILASTOL PHP 90	1:16 AM (PHP 90: WATER)
B	DURON SL 2316	1:12 (160ml: 1920ml)
C	SILASTOL PHP 10	1:16 (PHP 10: WATER, 120ml: 1920ml)

Since the values should be realistically useful in evaluating the suitability for use of disposable baby diapers, 9% saline was chosen as the test fluid in evaluating the leakage and absorbency of the materials.



Two types of fabric softener, type A and B, were used on the fabric made of polypropylene fibers.



All types of fabric softeners, type A, B and C, were used for textiles made of polylactide fibers.

Samples with a diameter of 35 mm were used to characterize the leakage.

When determining the contact angle of the liquid and the material, the values had to be reflected from the ideal liquid, to determine the contact angle of the liquid on uncoated materials, as a reference value, the contact angle of the ideal liquid was determined using hexane.

Picture 1 Contact angle evaluation device

Fabric samples measuring 150 x 45 mm were used to characterize the contact angle.

All samples used to characterize the material and its properties were selected from various locations on the nonwoven web and cut on a laser device to ensure measurement accuracy.

Picture 2 Laser device for precise cutting of samples

Each sample was weighed before and after the test. A RADWAG XA 52 / X balance was used to weigh the samples.

Picture 3 Weight used to determine the weight of the samples

Characterization of the loss of applied material from the sample was also performed, where each sample was immersed in a container with acetone for 10 s, then dried in a dryer for 2 minutes and weighed again.

9.3 Analysis and evaluation of the output of the practical part

In the following subchapters, the testing conditions and individual types of materials will be discussed.

9.3.1 Liquid seepage time

Leakage testing of samples was performed using a vacuum filtration apparatus GV 025/2.

Test sample - diameter 35 mm

Liquid used as reference - 9% saline.

Picture 4 Vacuum filtration equipment for measuring the rate of liquid leakage of the sample

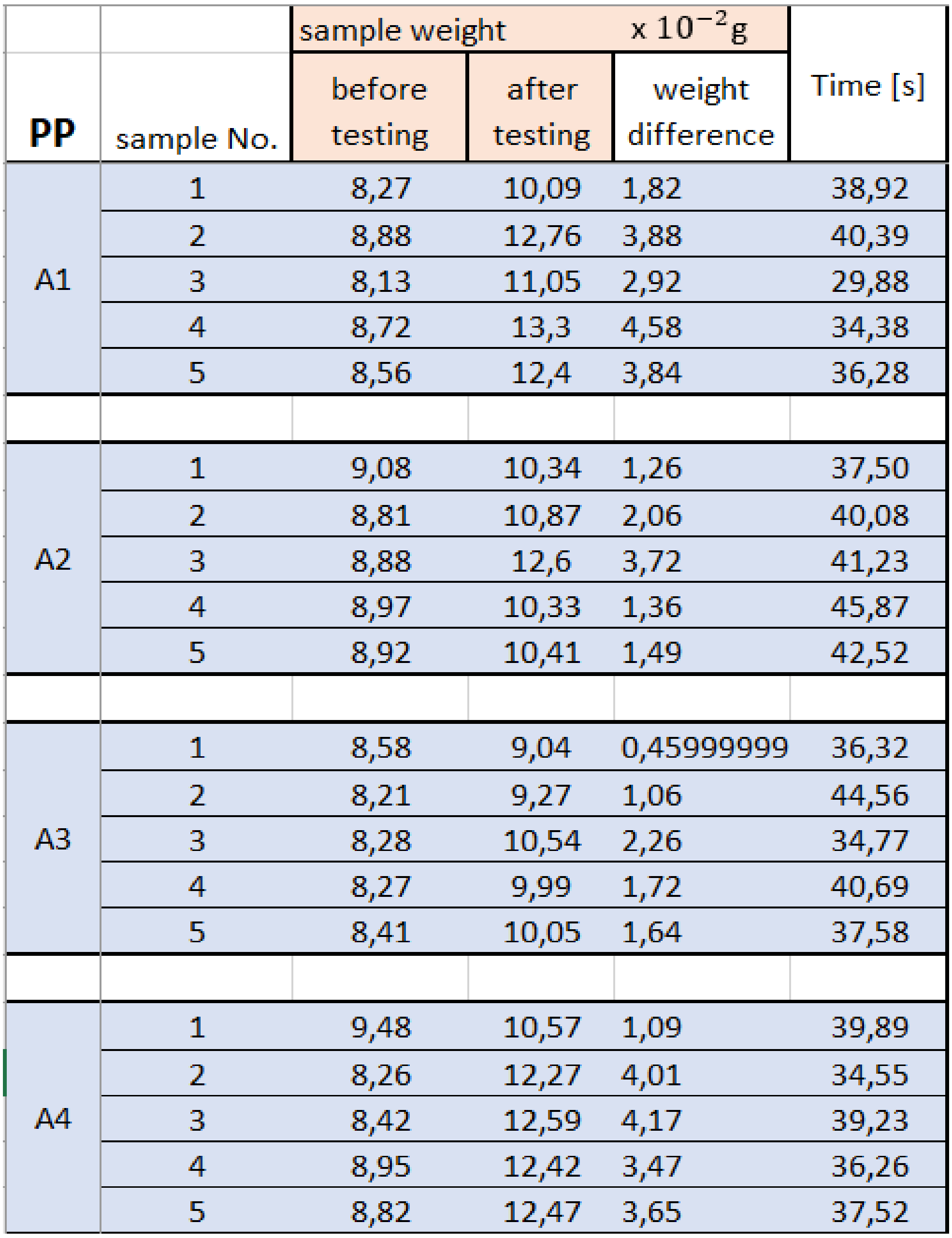
Measurement values:

The test was set to a maximum solution permeation time of a maximum of 10 minutes for a solution volume of 150 ml.

Reference test on sample without finishing:

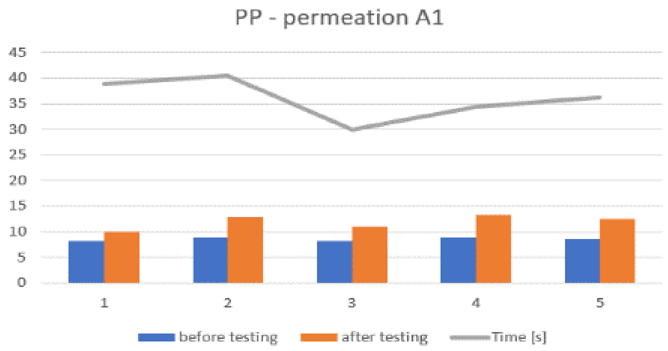
- for a sample of PP material - 19 minutes
- for a sample of PLA materiál – 20 ml / 65 minutes

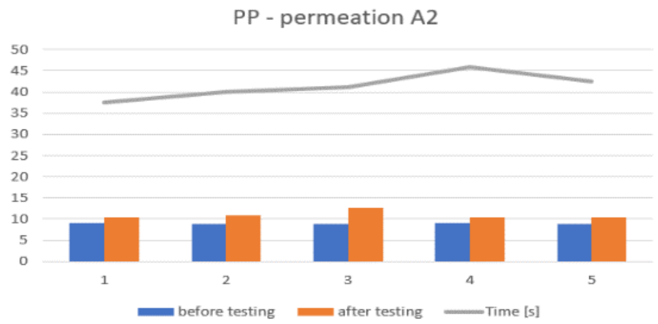
Table 4 PP measurement results A1 - 4

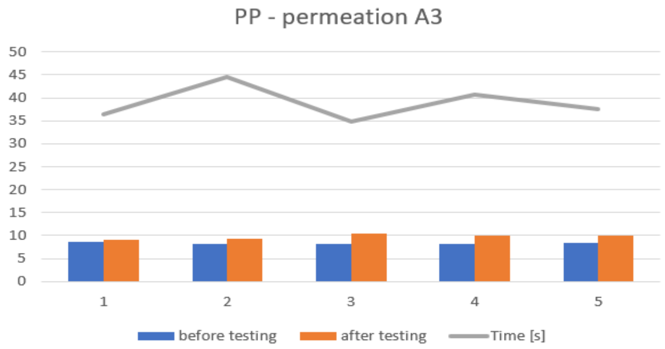


		sample weight x 10^{-2}g			
PP	sample No.	before testing	after testing	weight difference	Time [s]
A1	1	8,27	10,09	1,82	38,92
	2	8,88	12,76	3,88	40,39
	3	8,13	11,05	2,92	29,88
	4	8,72	13,3	4,58	34,38
	5	8,56	12,4	3,84	36,28
A2	1	9,08	10,34	1,26	37,50
	2	8,81	10,87	2,06	40,08
	3	8,88	12,6	3,72	41,23
	4	8,97	10,33	1,36	45,87
	5	8,92	10,41	1,49	42,52
A3	1	8,58	9,04	0,45999999	36,32
	2	8,21	9,27	1,06	44,56
	3	8,28	10,54	2,26	34,77
	4	8,27	9,99	1,72	40,69
	5	8,41	10,05	1,64	37,58
A4	1	9,48	10,57	1,09	39,89
	2	8,26	12,27	4,01	34,55
	3	8,42	12,59	4,17	39,23
	4	8,95	12,42	3,47	36,26
	5	8,82	12,47	3,65	37,52

A graphical representation:







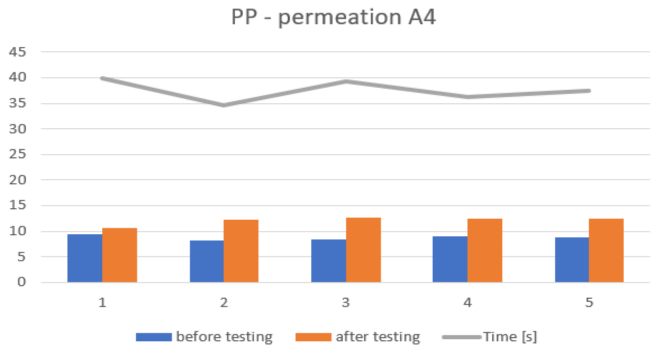
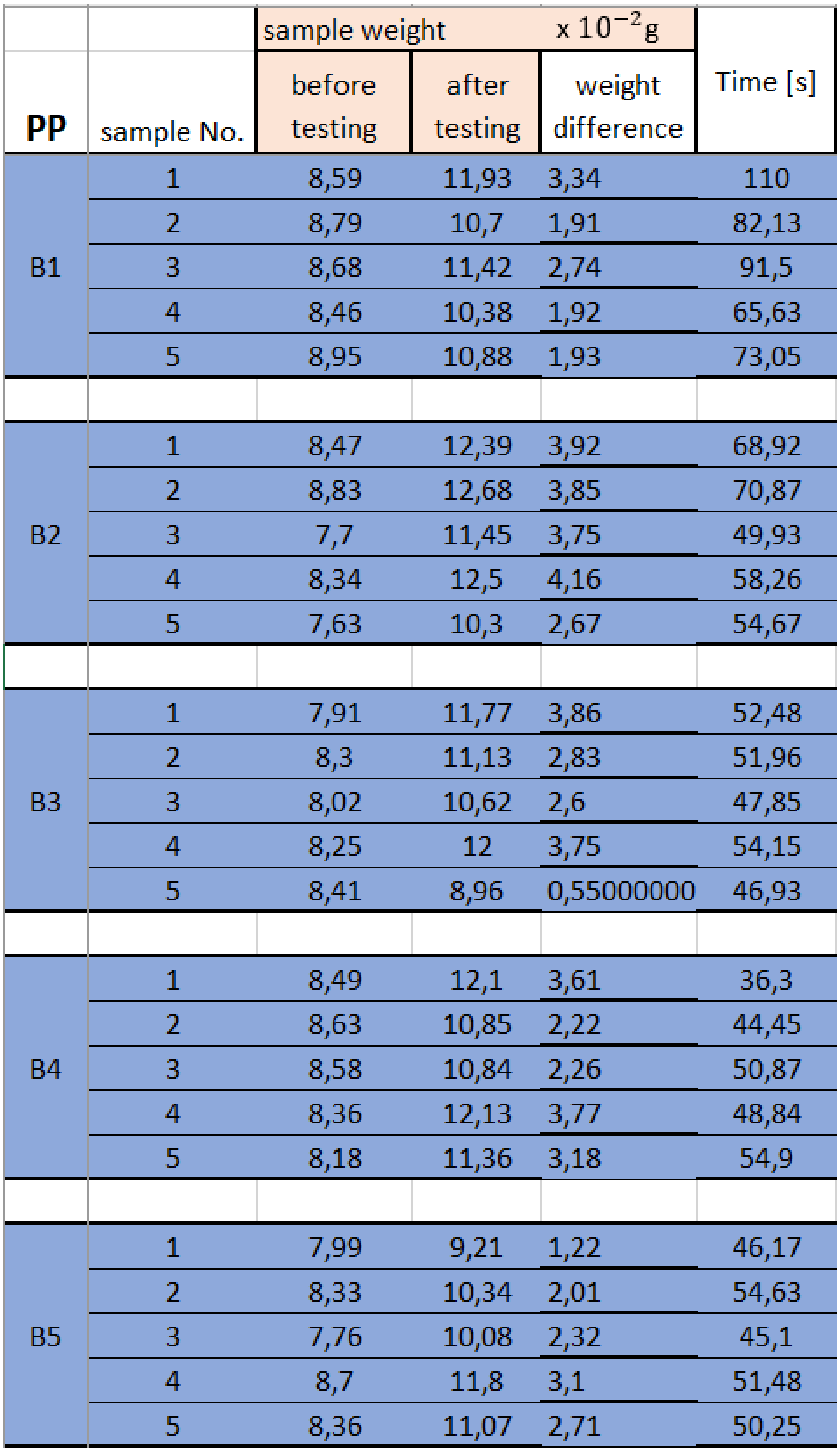
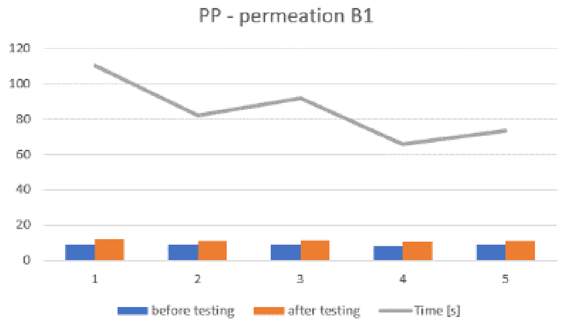


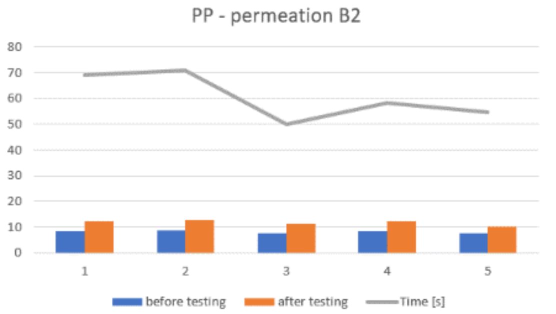
Table 5 Measurement PP B 1-5

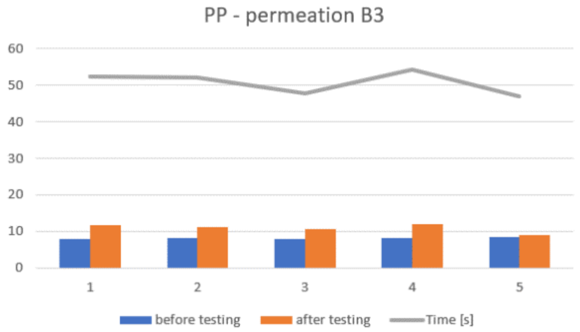


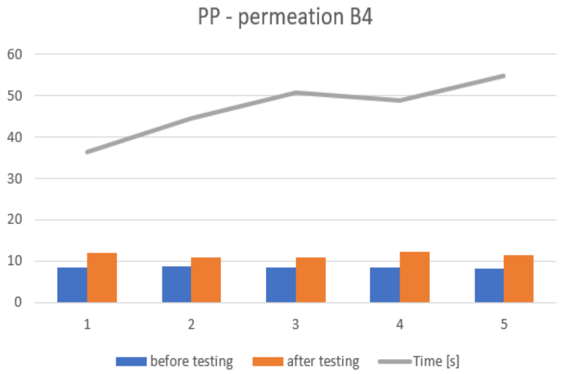
		sample weight		x 10^{-2}g	
PP	sample No.	before testing	after testing	weight difference	Time [s]
B1	1	8,59	11,93	3,34	110
	2	8,79	10,7	1,91	82,13
	3	8,68	11,42	2,74	91,5
	4	8,46	10,38	1,92	65,63
	5	8,95	10,88	1,93	73,05
B2	1	8,47	12,39	3,92	68,92
	2	8,83	12,68	3,85	70,87
	3	7,7	11,45	3,75	49,93
	4	8,34	12,5	4,16	58,26
	5	7,63	10,3	2,67	54,67
B3	1	7,91	11,77	3,86	52,48
	2	8,3	11,13	2,83	51,96
	3	8,02	10,62	2,6	47,85
	4	8,25	12	3,75	54,15
	5	8,41	8,96	0,55000000	46,93
B4	1	8,49	12,1	3,61	36,3
	2	8,63	10,85	2,22	44,45
	3	8,58	10,84	2,26	50,87
	4	8,36	12,13	3,77	48,84
	5	8,18	11,36	3,18	54,9
B5	1	7,99	9,21	1,22	46,17
	2	8,33	10,34	2,01	54,63
	3	7,76	10,08	2,32	45,1
	4	8,7	11,8	3,1	51,48
	5	8,36	11,07	2,71	50,25

A graphical representation:









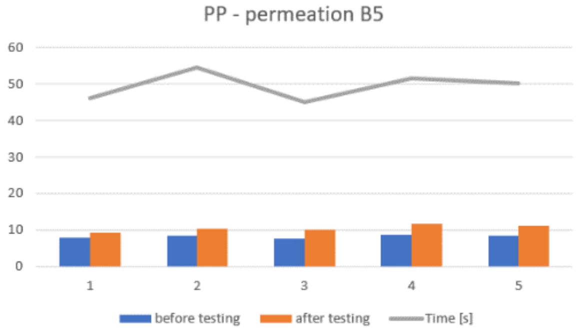
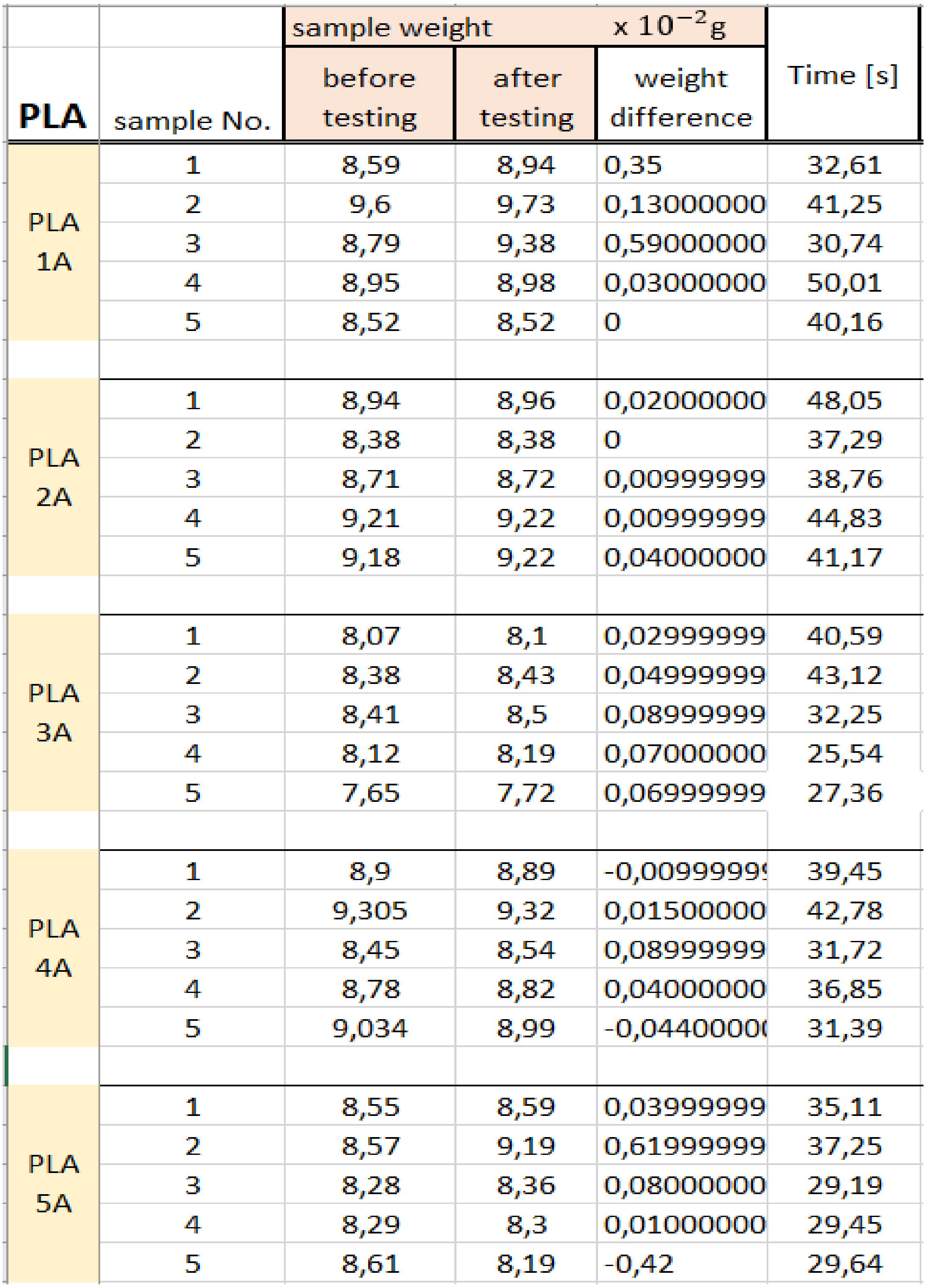
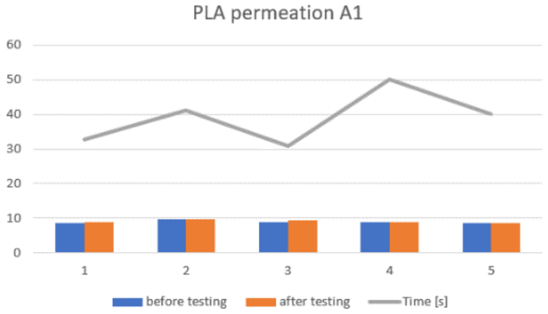


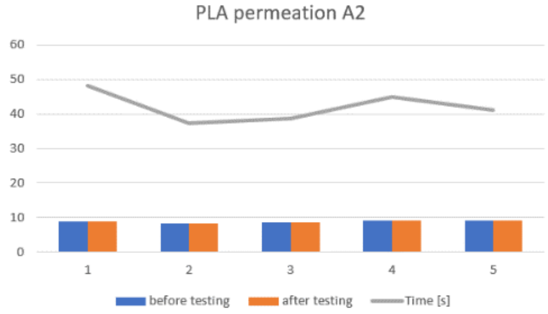
Table 6 PLA Measurement results PLA A1 - 5

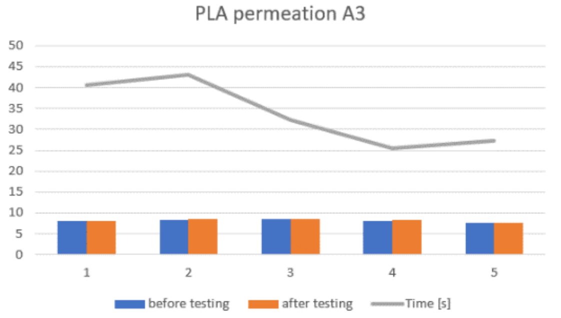


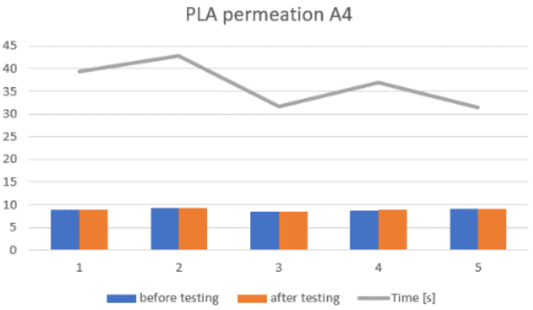
PLA	sample No.	sample weight x 10^{-2}g before testing	after testing	weight difference	Time [s]
PLA 1A	1	8,59	8,94	0,35	32,61
	2	9,6	9,73	0,13000000	41,25
	3	8,79	9,38	0,59000000	30,74
	4	8,95	8,98	0,03000000	50,01
	5	8,52	8,52	0	40,16
PLA 2A	1	8,94	8,96	0,02000000	48,05
	2	8,38	8,38	0	37,29
	3	8,71	8,72	0,00999999	38,76
	4	9,21	9,22	0,00999999	44,83
	5	9,18	9,22	0,04000000	41,17
PLA 3A	1	8,07	8,1	0,02999999	40,59
	2	8,38	8,43	0,04999999	43,12
	3	8,41	8,5	0,08999999	32,25
	4	8,12	8,19	0,07000000	25,54
	5	7,65	7,72	0,06999999	27,36
PLA 4A	1	8,9	8,89	-0,0099999	39,45
	2	9,305	9,32	0,01500000	42,78
	3	8,45	8,54	0,08999999	31,72
	4	8,78	8,82	0,04000000	36,85
	5	9,034	8,99	-0,0440000	31,39
PLA 5A	1	8,55	8,59	0,03999999	35,11
	2	8,57	9,19	0,61999999	37,25
	3	8,28	8,36	0,08000000	29,19
	4	8,29	8,3	0,01000000	29,45
	5	8,61	8,19	-0,42	29,64

A graphical representation:









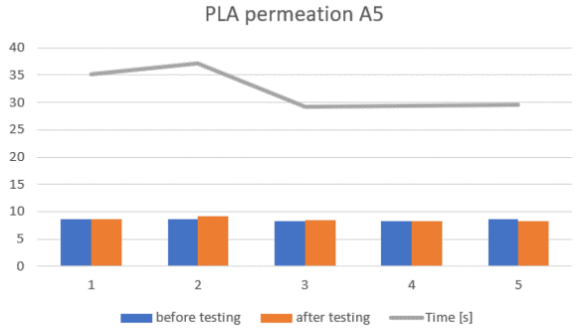
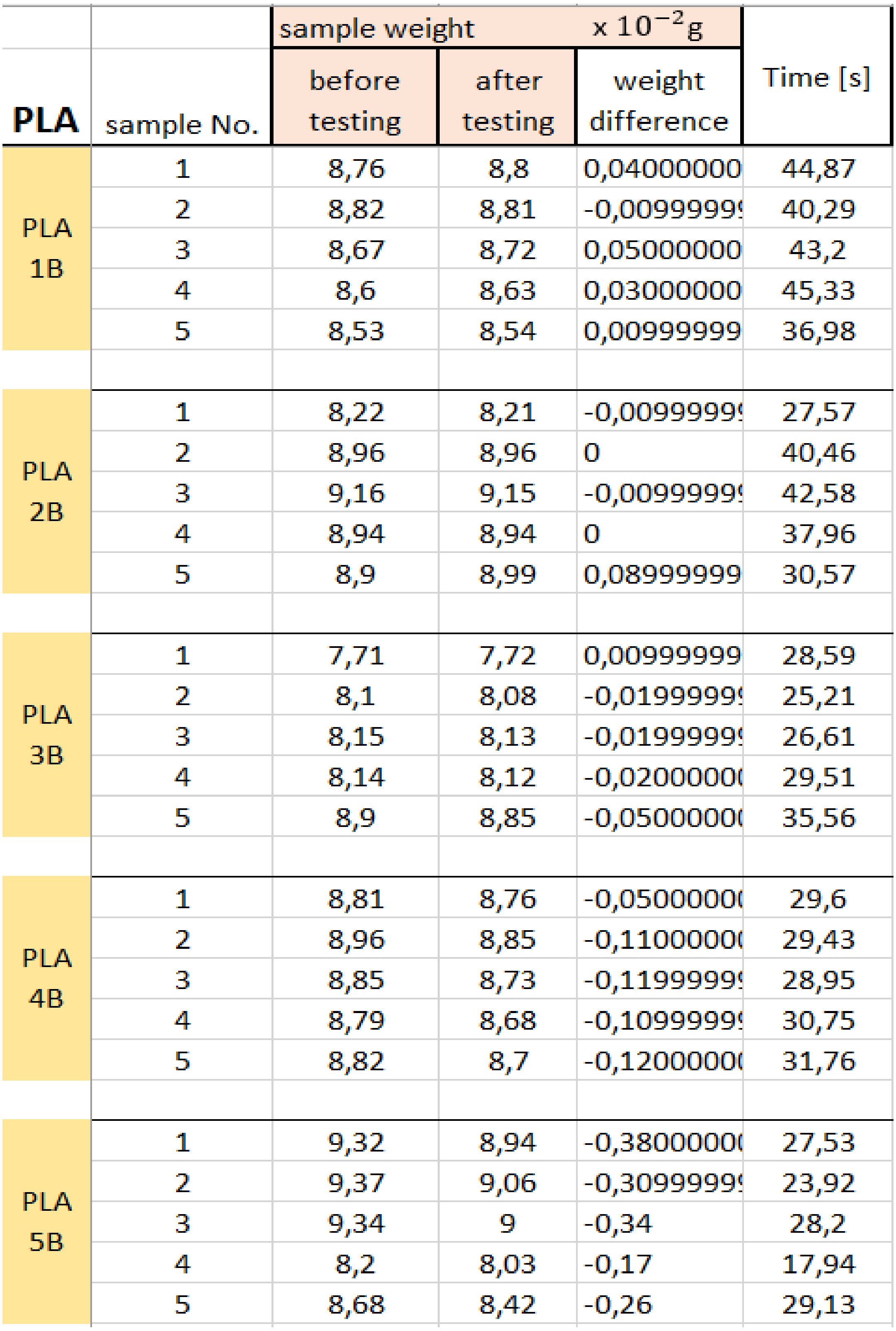
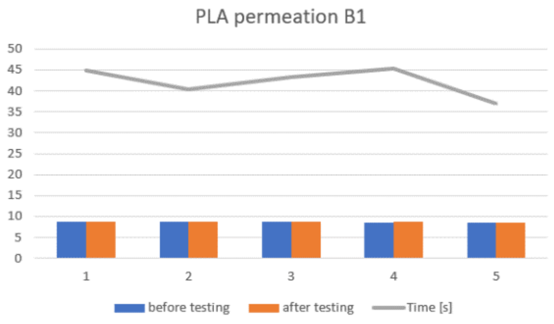


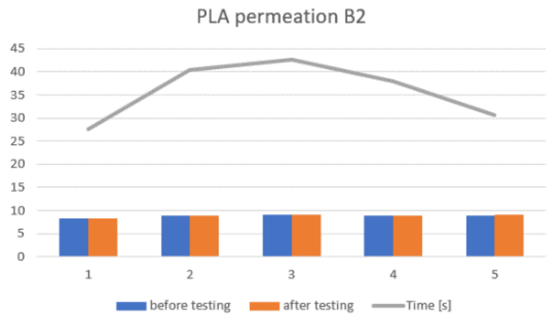
Table 7 Measurement results PLA B1-5

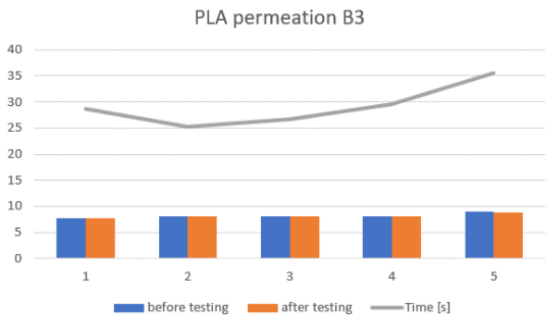


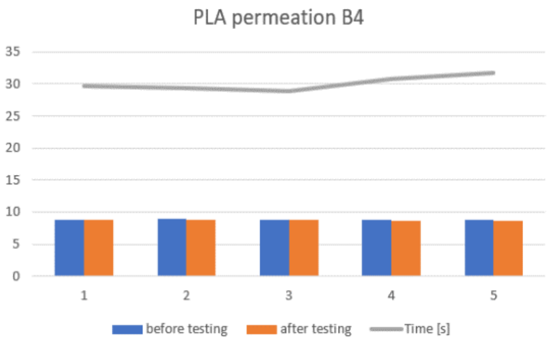
		sample weight		x 10^{-2}g	
PLA	sample No.	before testing	after testing	weight difference	Time [s]
PLA 1B	1	8,76	8,8	0,04000000	44,87
	2	8,82	8,81	-0,0099999	40,29
	3	8,67	8,72	0,05000000	43,2
	4	8,6	8,63	0,03000000	45,33
	5	8,53	8,54	0,00999999	36,98
PLA 2B	1	8,22	8,21	-0,0099999	27,57
	2	8,96	8,96	0	40,46
	3	9,16	9,15	-0,0099999	42,58
	4	8,94	8,94	0	37,96
	5	8,9	8,99	0,08999999	30,57
PLA 3B	1	7,71	7,72	0,00999999	28,59
	2	8,1	8,08	-0,0199999	25,21
	3	8,15	8,13	-0,0199999	26,61
	4	8,14	8,12	-0,0200000	29,51
	5	8,9	8,85	-0,0500000	35,56
PLA 4B	1	8,81	8,76	-0,0500000	29,6
	2	8,96	8,85	-0,1100000	29,43
	3	8,85	8,73	-0,1199999	28,95
	4	8,79	8,68	-0,1099999	30,75
	5	8,82	8,7	-0,1200000	31,76
PLA 5B	1	9,32	8,94	-0,3800000	27,53
	2	9,37	9,06	-0,3099999	23,92
	3	9,34	9	-0,34	28,2
	4	8,2	8,03	-0,17	17,94
	5	8,68	8,42	-0,26	29,13

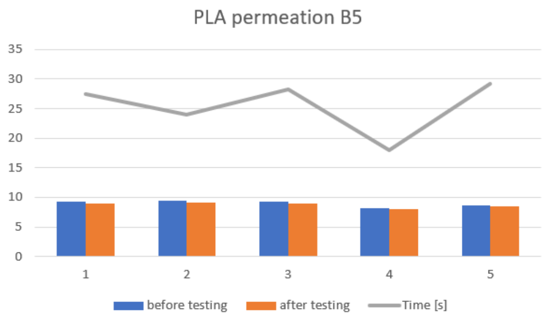
A graphical representation:



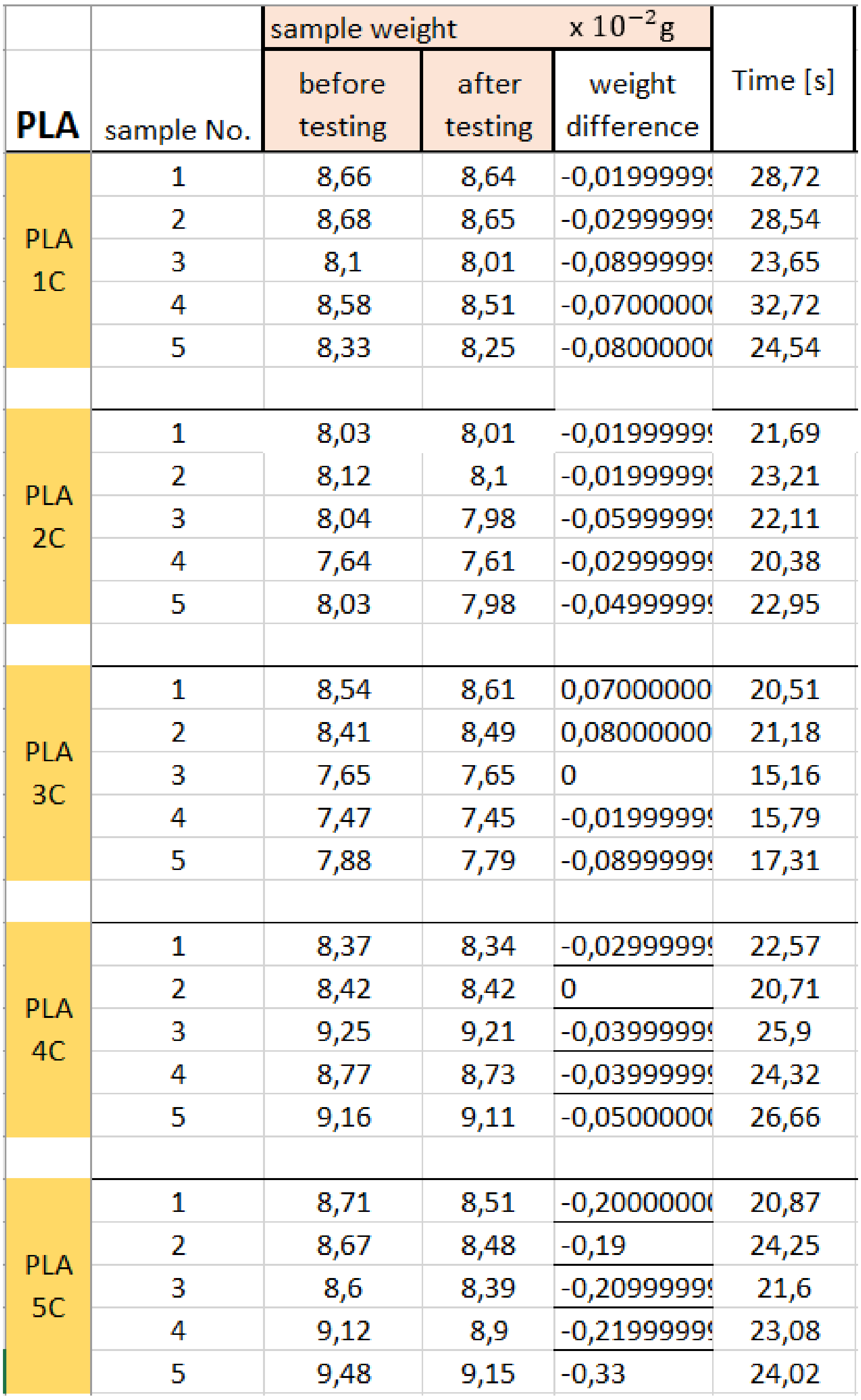






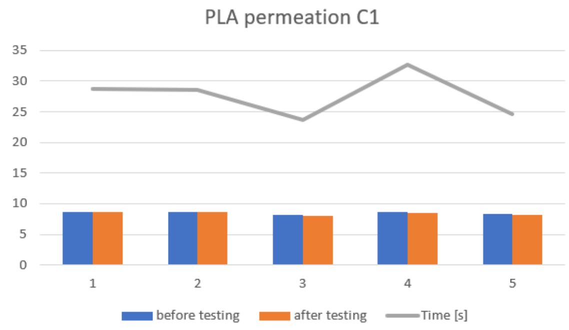


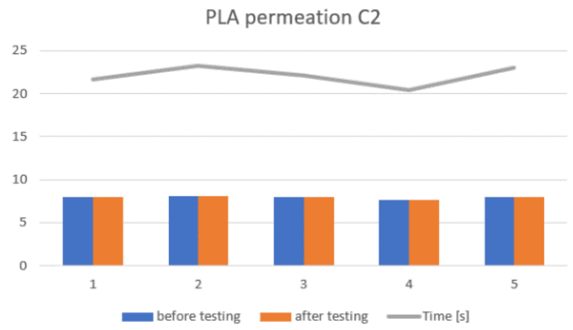
Tabulka 8 Measurement results PLA C1-5

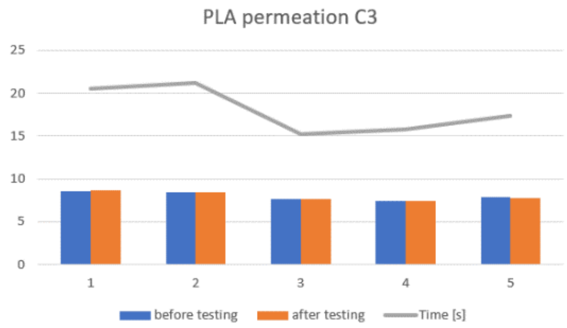


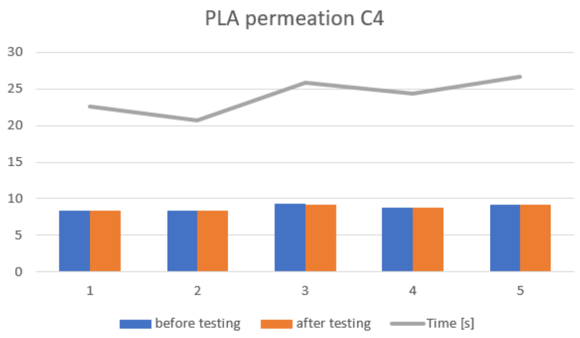
		sample weight	x 10^{-2}g		
PLA	sample No.	before testing	after testing	weight difference	Time [s]
PLA 1C	1	8,66	8,64	-0,0199999	28,72
	2	8,68	8,65	-0,0299999	28,54
	3	8,1	8,01	-0,0899999	23,65
	4	8,58	8,51	-0,0700000	32,72
	5	8,33	8,25	-0,0800000	24,54
PLA 2C	1	8,03	8,01	-0,0199999	21,69
	2	8,12	8,1	-0,0199999	23,21
	3	8,04	7,98	-0,0599999	22,11
	4	7,64	7,61	-0,0299999	20,38
	5	8,03	7,98	-0,0499999	22,95
PLA 3C	1	8,54	8,61	0,07000000	20,51
	2	8,41	8,49	0,08000000	21,18
	3	7,65	7,65	0	15,16
	4	7,47	7,45	-0,0199999	15,79
	5	7,88	7,79	-0,0899999	17,31
PLA 4C	1	8,37	8,34	-0,0299999	22,57
	2	8,42	8,42	0	20,71
	3	9,25	9,21	-0,0399999	25,9
	4	8,77	8,73	-0,0399999	24,32
	5	9,16	9,11	-0,0500000	26,66
PLA 5C	1	8,71	8,51	-0,2000000	20,87
	2	8,67	8,48	-0,19	24,25
	3	8,6	8,39	-0,2099999	21,6
	4	9,12	8,9	-0,2199999	23,08
	5	9,48	9,15	-0,33	24,02

A graphical representation:









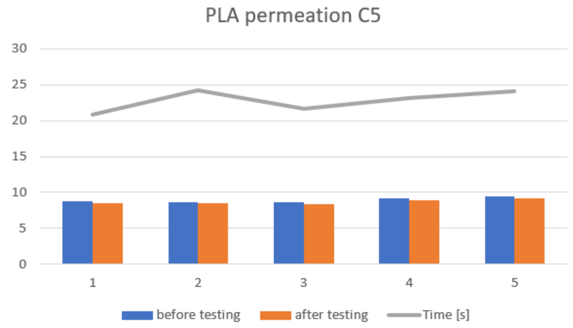
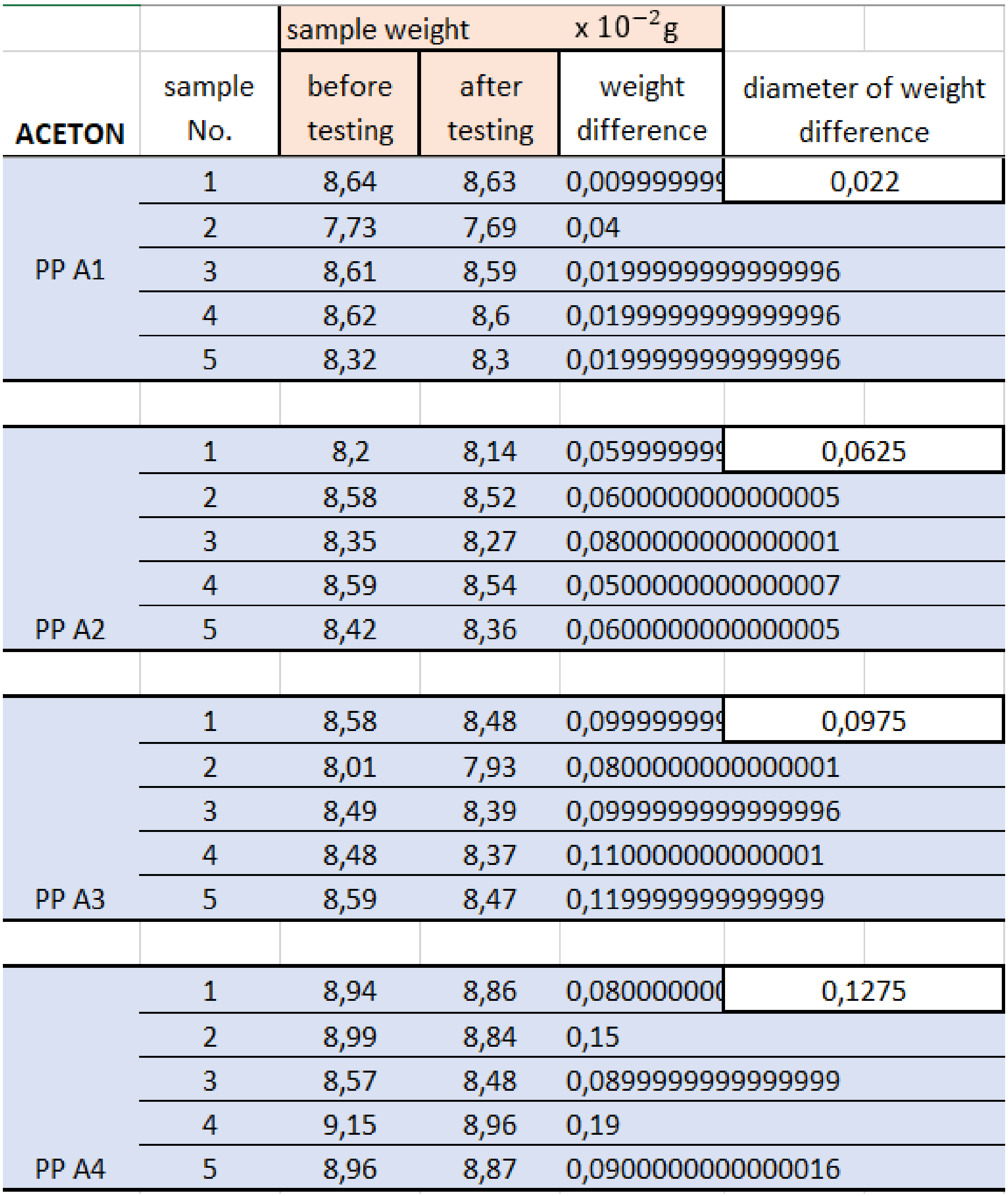
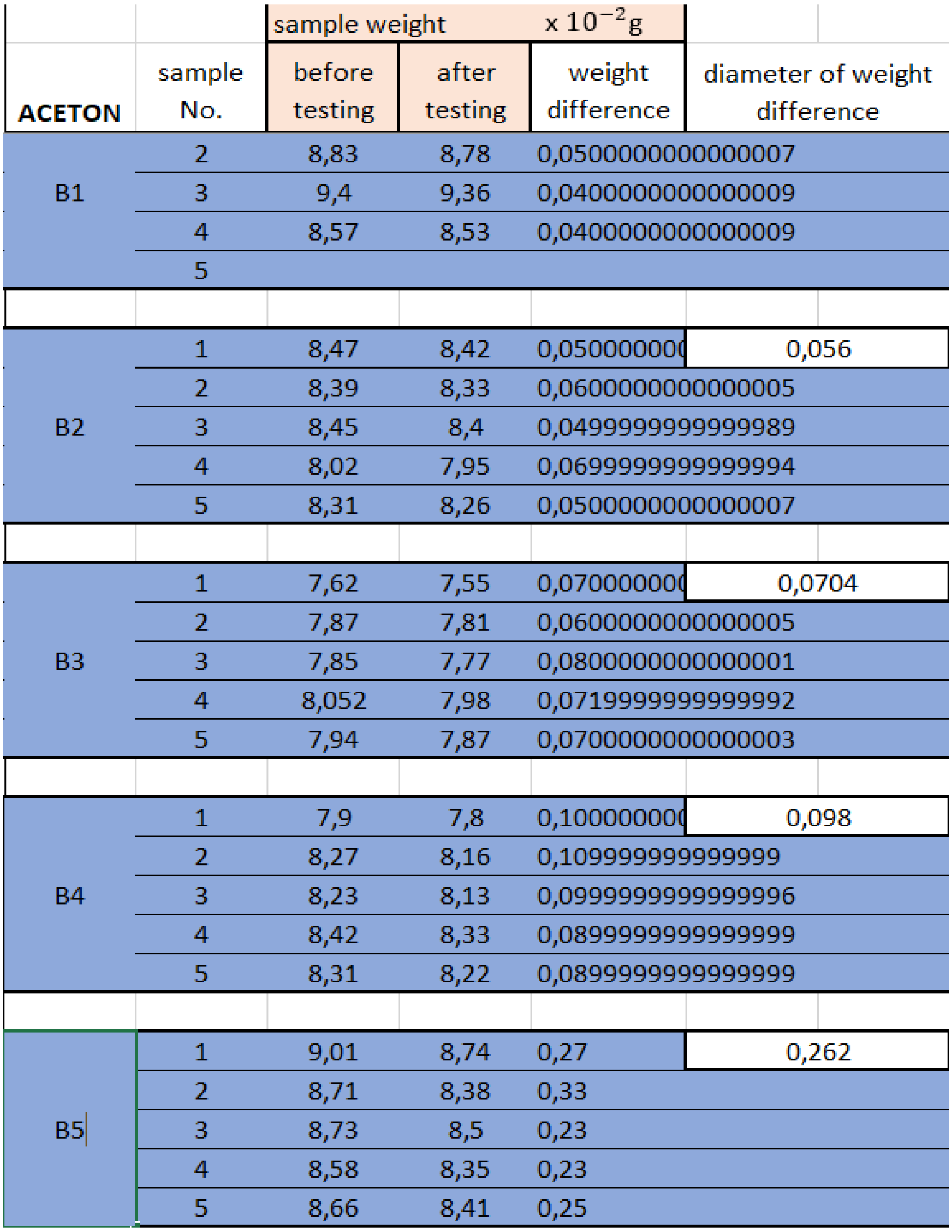


Table 9 Test - Acetone PP A1-5



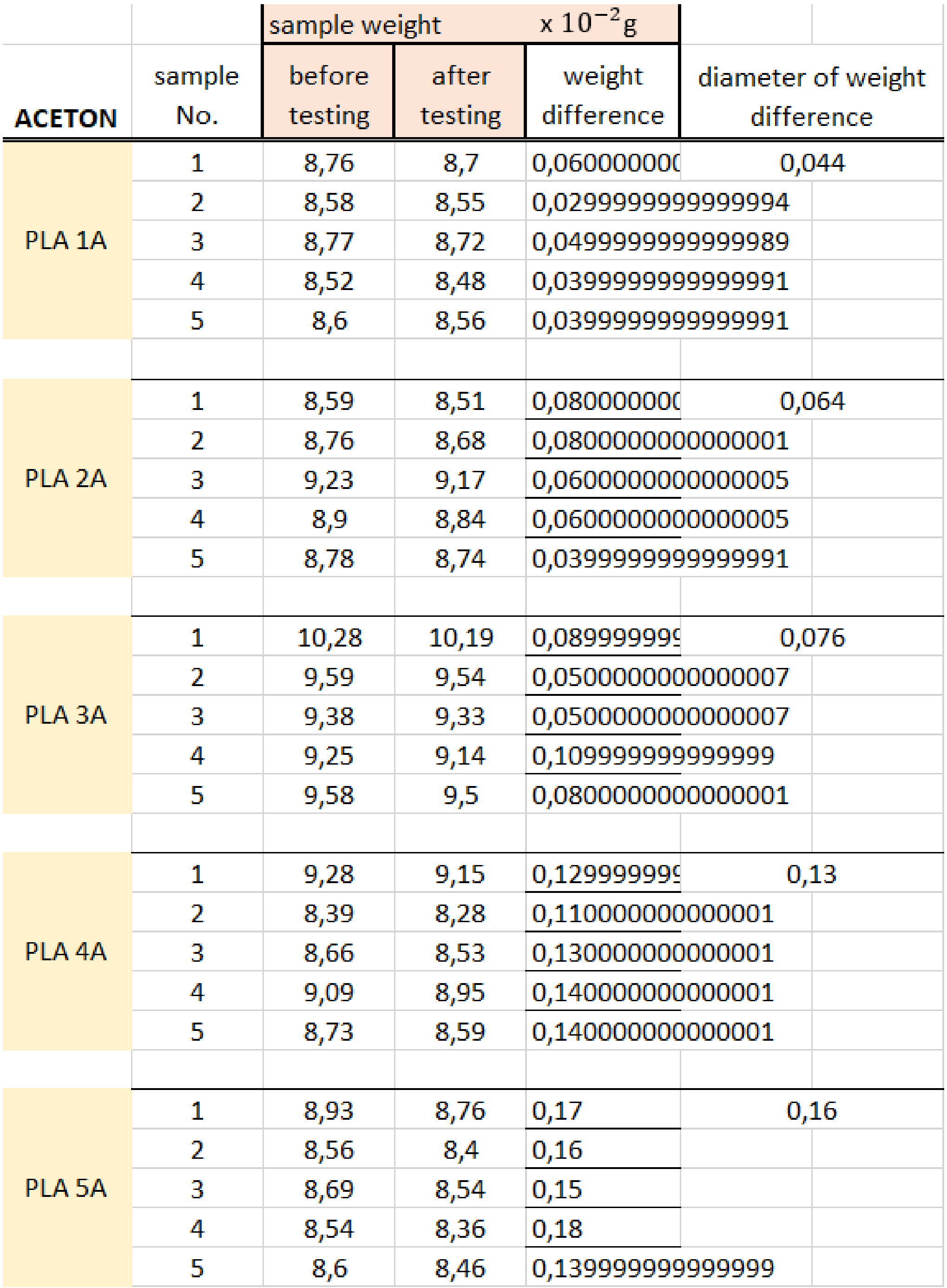
		sample weight	x 10^{-2}g		
ACETON	sample No.	before testing	after testing	weight difference	diameter of weight difference
PP A1	1	8,64	8,63	0,009999999	0,022
	2	7,73	7,69	0,04	
	3	8,61	8,59	0,0199999999999996	
	4	8,62	8,6	0,0199999999999996	
	5	8,32	8,3	0,0199999999999996	
	1	8,2	8,14	0,059999999	0,0625
	2	8,58	8,52	0,0600000000000005	
	3	8,35	8,27	0,0800000000000001	
	4	8,59	8,54	0,0500000000000007	
PP A2	5	8,42	8,36	0,0600000000000005	
	1	8,58	8,48	0,099999999	0,0975
	2	8,01	7,93	0,0800000000000001	
	3	8,49	8,39	0,0999999999999996	
	4	8,48	8,37	0,110000000000001	
PP A3	5	8,59	8,47	0,119999999999999	
	1	8,94	8,86	0,080000000	0,1275
	2	8,99	8,84	0,15	
	3	8,57	8,48	0,0899999999999999	
	4	9,15	8,96	0,19	
PP A4	5	8,96	8,87	0,0900000000000016	

Table 10 Test acetone PP B-5



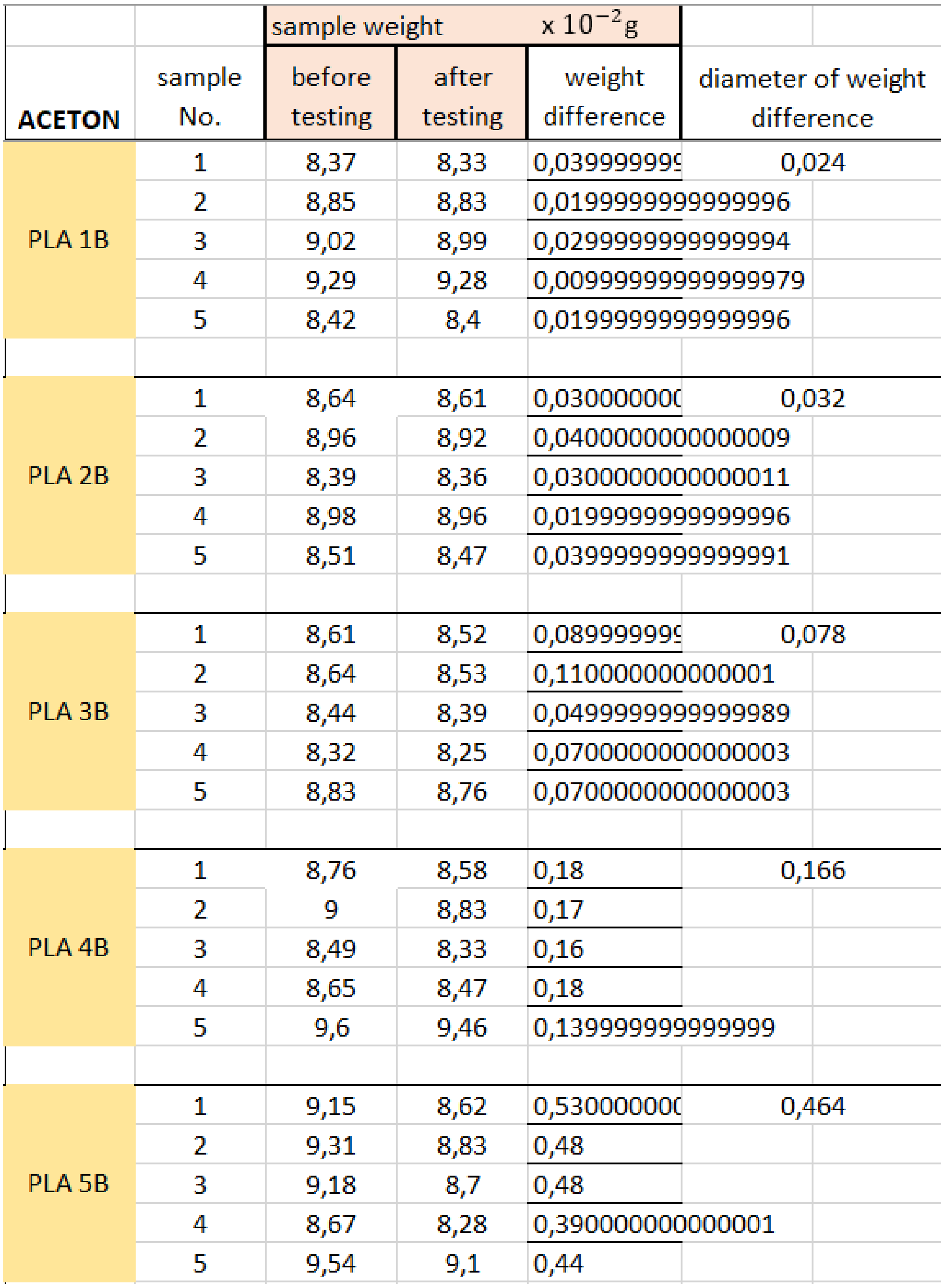
		sample weight $\times 10^{-2}$g			
ACETON	sample No.	before testing	after testing	weight difference	diameter of weight difference
B1	2	8,83	8,78	0,0500000000000007	
	3	9,4	9,36	0,0400000000000009	
	4	8,57	8,53	0,0400000000000009	
	5				
B2	1	8,47	8,42	0,050000000	0,056
	2	8,39	8,33	0,0600000000000005	
	3	8,45	8,4	0,0499999999999989	
	4	8,02	7,95	0,0699999999999994	
	5	8,31	8,26	0,0500000000000007	
B3	1	7,62	7,55	0,070000000	0,0704
	2	7,87	7,81	0,0600000000000005	
	3	7,85	7,77	0,0800000000000001	
	4	8,052	7,98	0,0719999999999992	
	5	7,94	7,87	0,0700000000000003	
B4	1	7,9	7,8	0,100000000	0,098
	2	8,27	8,16	0,109999999999999	
	3	8,23	8,13	0,0999999999999996	
	4	8,42	8,33	0,0899999999999999	
	5	8,31	8,22	0,0899999999999999	
B5	1	9,01	8,74	0,27	0,262
	2	8,71	8,38	0,33	
	3	8,73	8,5	0,23	
	4	8,58	8,35	0,23	
	5	8,66	8,41	0,25	

Table 11 Test acetone A1-5



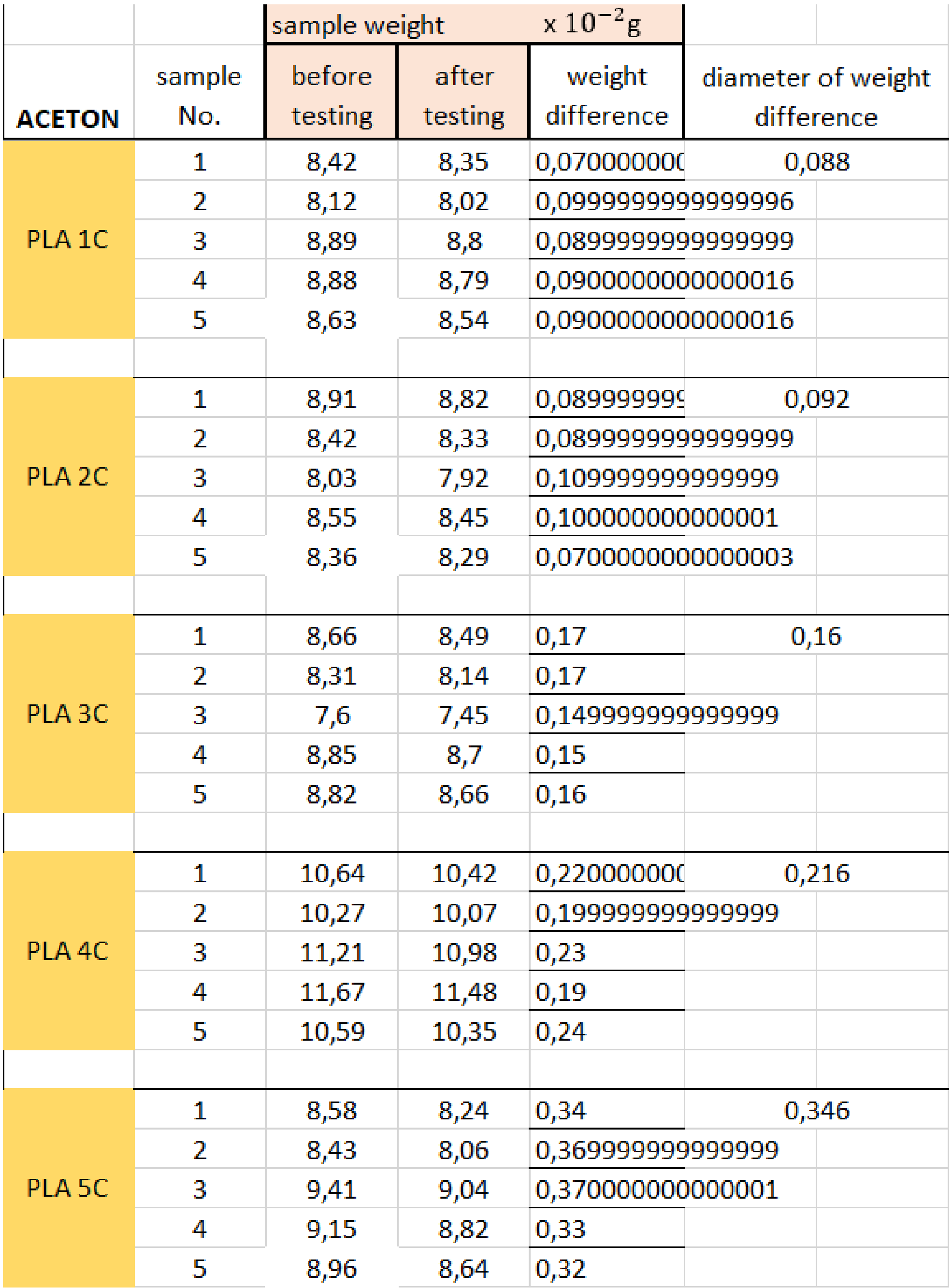
		sample weight	x 10^{-2}g		
ACETON	sample No.	before testing	after testing	weight difference	diameter of weight difference
PLA 1A	1	8,76	8,7	0,06000000	0,044
	2	8,58	8,55	0,0299999999999994	
	3	8,77	8,72	0,0499999999999989	
	4	8,52	8,48	0,0399999999999991	
	5	8,6	8,56	0,0399999999999991	
PLA 2A	1	8,59	8,51	0,08000000	0,064
	2	8,76	8,68	0,0800000000000001	
	3	9,23	9,17	0,0600000000000005	
	4	8,9	8,84	0,0600000000000005	
	5	8,78	8,74	0,0399999999999991	
PLA 3A	1	10,28	10,19	0,08999999	0,076
	2	9,59	9,54	0,0500000000000007	
	3	9,38	9,33	0,0500000000000007	
	4	9,25	9,14	0,109999999999999	
	5	9,58	9,5	0,0800000000000001	
PLA 4A	1	9,28	9,15	0,12999999	0,13
	2	8,39	8,28	0,110000000000001	
	3	8,66	8,53	0,130000000000001	
	4	9,09	8,95	0,140000000000001	
	5	8,73	8,59	0,140000000000001	
PLA 5A	1	8,93	8,76	0,17	0,16
	2	8,56	8,4	0,16	
	3	8,69	8,54	0,15	
	4	8,54	8,36	0,18	
	5	8,6	8,46	0,139999999999999	

Table 12 Test acetone PLA B1-5



		sample weight	$\times 10^{-2}$ g		
ACETON	sample No.	before testing	after testing	weight difference	diameter of weight difference
PLA 1B	1	8,37	8,33	0,03999999	0,024
	2	8,85	8,83	0,0199999999999996	
	3	9,02	8,99	0,0299999999999994	
	4	9,29	9,28	0,00999999999999979	
	5	8,42	8,4	0,0199999999999996	
PLA 2B	1	8,64	8,61	0,03000000	0,032
	2	8,96	8,92	0,0400000000000009	
	3	8,39	8,36	0,0300000000000011	
	4	8,98	8,96	0,0199999999999996	
	5	8,51	8,47	0,0399999999999991	
PLA 3B	1	8,61	8,52	0,08999999	0,078
	2	8,64	8,53	0,110000000000001	
	3	8,44	8,39	0,0499999999999989	
	4	8,32	8,25	0,0700000000000003	
	5	8,83	8,76	0,0700000000000003	
PLA 4B	1	8,76	8,58	0,18	0,166
	2	9	8,83	0,17	
	3	8,49	8,33	0,16	
	4	8,65	8,47	0,18	
	5	9,6	9,46	0,139999999999999	
PLA 5B	1	9,15	8,62	0,53000000	0,464
	2	9,31	8,83	0,48	
	3	9,18	8,7	0,48	
	4	8,67	8,28	0,390000000000001	
	5	9,54	9,1	0,44	

Table 13 Test acetone PLA C1-5



		sample weight	x 10^{-2}g		
ACETON	sample No.	before testing	after testing	weight difference	diameter of weight difference
PLA 1C	1	8,42	8,35	0,07000000	0,088
	2	8,12	8,02	0,0999999999999996	
	3	8,89	8,8	0,0899999999999999	
	4	8,88	8,79	0,0900000000000016	
	5	8,63	8,54	0,0900000000000016	
PLA 2C	1	8,91	8,82	0,08999999	0,092
	2	8,42	8,33	0,0899999999999999	
	3	8,03	7,92	0,109999999999999	
	4	8,55	8,45	0,100000000000001	
	5	8,36	8,29	0,0700000000000003	
PLA 3C	1	8,66	8,49	0,17	0,16
	2	8,31	8,14	0,17	
	3	7,6	7,45	0,149999999999999	
	4	8,85	8,7	0,15	
	5	8,82	8,66	0,16	
PLA 4C	1	10,64	10,42	0,22000000	0,216
	2	10,27	10,07	0,199999999999999	
	3	11,21	10,98	0,23	
	4	11,67	11,48	0,19	
	5	10,59	10,35	0,24	
PLA 5C	1	8,58	8,24	0,34	0,346
	2	8,43	8,06	0,369999999999999	
	3	9,41	9,04	0,370000000000001	
	4	9,15	8,82	0,33	
	5	8,96	8,64	0,32	

Evaluation of the testing of the amout of surface treatment – The trend of increasing amounts of fabric softener with increasing applocation rate is obvious.

CONCLUSION

The measurement and evaluation of the results of the practical part show that PLA, which is a biodegradable polymer and provides certain advantages in this regard, is not suitable for applications that are intended for contact with the skin. PLA is moist even after a relatively long time, it is also evident from the measurements that the fabric softener washes out of the surface. Due to the fact that the PLA fiber fabric had to be reinforced with PP fibers, even if only in a small amount (approx. 5%), in order to maintain the shape of the nonwoven fabric strip, the application becomes a bicomponent material. After contact with the fabric softener, the separate PLA also precipitates 2/3 of the area value. In this context, the biodegradability of PLA is losing its value. Subjective evaluation of the material, which should show a certain softness and a smooth soft touch, is PLA unpleasant and hard to the touch. Not suitable for skin contact.

Non-woven fabric made of PP fibers, functional leakage, material almost immediately dry, softness of the material pleasant, suitable for use in direct contact with the skin.

The goal of the analysis was met. Material finishing is functional. Reference times for the parameters of individual sample properties were characterized.

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LIST OF SYMBOLS AND ABBREVIATIONS USED

ABC	Meaning of the first abbreviation.
B	Meaning of the second abbreviation.
C	Meaning of the third abbreviation.

PICTURE LIST

Nenalezena položka seznamu obrázků.

LIST OF TABLES

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LIST OF ATTACHMENTS

ANNEX PI: TITLE OF THE ANNEX