The Potential of Using Bio Plastic Materials in Automotive Applications

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The purpose of this article is to present an overview of the trend of using, on a wider scale, plastics in the automotive industry. It is presented the realization of PLA-TPU-Blends with a biogenic mass greater than 90%, by mixing thermoplastic Polyurethan (TPU) with Polylactid-Acid (PLA) at IKT University of Stuttgart. In order to estimate the possibilities of use of bio-materials made from PLA and TPU, the properties were compared with standard thermoplastics such as Polypropylen (PP), Polyethylen (PE), Polyamid (PA), as well as with better performing materials from the engineering thermoplastics range. PBT, ASA and their derivatives. Notable are the properties of PLA-TPU-Blends compared with standard thermoplastics PP, PE, PA. The results show PLA-TPU-Blends superiority in Yeld strength compared to the types of Polypropylene homopolymer (PP-H), block-copolymer (PP-B) and randompolymer (PP-R), the properties being adaptable by flexible modification of the ratio between the components, according to the requirements of the application. Using suitable additives to make components compatible, there were created blends which were partially cross-linked, but their properties remain of thermoplast. When reinforcing PLA-TPU-Blends with fibers (glass and natural), the components also react with the groups (-OH) on the fiber surface, thus making a good connection between fibers and blends, which prevents the so-called pull-out-effect. PLA-TPU-Blends reinforced with natural fibers can be used to make the interior body elements of vehicles. The paper also presents a comparison between bio-materials made at IKT University of Stuttgart with Polyethylen (PE) and other industry standard bio-materials.

Keywords: automotive industry, plastic materials, biopolymers, renewable materials, fibre reinforced materials, Polylactid-Acid, blends, Polyurethan, PLA-TPU-Blends

The demands of the automotive industry have been and always will be challenging. The aim is to continuously increase dynamic and power performance but at the same time improve reliability and safety, an increased comfort, low fuel consumption, style, attractive price and, gradually, a lower impact on the environment [1, 2]. Plastics are in the category of those materials that could solve the challenge of these seemingly conflicting requirements. Due to their unique combination of properties, plastics are suitable to provide a range of technological innovations, taking into account cost efficiency and sustainability.

The demand for plastics is explained by the fact that they have good resistance properties, they are versatile and flexible and they allow technological innovations and freedom in design [3-5]. Engineers in the automotive field are looking for materials that can be adapted to a complicated aesthetic, to offer safety, comfort, fuel efficiency, performance in the electronic field, all from the point of view of efficiency. In addition to the benefits they bring to car design and performance, manufacturers' choice of plastics is also made for their environmental benefits and their contribution to sustainable development, using global resources in a way that does not limit the range of economic, social and environmental options open to future generations.

The continuous improvement of safety and comfort has led, over time, to a slight increase in the average total weight of vehicles, from 1 015 kg, in 1990, to 1 132 kg, in 1998. But the plastic components have ensured a balance between safety and efficiency, meaning that the constant reduction of weight due to the use of plastics did not affect the safety features. It is estimated that, without plastics, today's vehicles would be at least 200 kg heavier, which would have resulted in increased fuel consumption. It is estimated that 100 kg of plastics have replaced between 200 and 300 kg of conventional materials in the modern car. This weight reduction leads to a reduction in fuel consumption by 750 liters for a distance of 150,000 km. Further calculations suggest that overall this will lead to a reduction in oil consumption by 12 million tonnes and CO2 emissions by 30 million tonnes per year in Western Europe [6].

In recent years, there has been a tendency to replace metallic materials with plastics or composites [7, 8]. Typically, glass fibre reinforced polyester composites are used instead of metallic materials due to their low density, strength and high rigidity [9].

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Moreover, plastics continue to find applicability even in the area of the propulsion system, not only to reduce weight, but also to make internal combustion engines more efficient.

Reducing fuel consumption and polluting emissions has been and remains a continuous goal for researchers in the field. The dramatic progress in the realm of internal combustion engine technology is also due to the use of special materials that lead to the optimization of the thermal transfer and the improvement of the combustion process [1, 2, 10, 11]..

Plastic components are more durable than some of the conventional materials. In addition, the plastics used in the car body treatment protect against corrosion and significantly contribute to prolonging the life of the vehicle.

The initiatives of several European cities to reduce CO2 emissions and improve air quality have led to the adoption of alternative propulsion solutions. Electric propulsion variants are increasingly using plastics in their basic structural components to reduce weight and increase their autonomy. Looking ahead, plastics will progressively play an important role in the production and use of fuel cells, an interesting idea for the supply of energy for electric vehicles.

On the other hand, despite the multiple benefits, plastics are associated with high levels of waste and residual runoff in the environment [12]. Considering the impact on the environment in the wider framework of sustainable development, innovation is encouraged throughout the life cycle, rather than just a recovery at the end of the product's life. Prevention, by reducing the use of natural resources first and foremost, is the first environmental objective, and the focus on recovery should not reduce the significant opportunity to recover natural resources during the life of the products [6].

Returning to the weight of the different materials used in the construction of a vehicle, if we take as a study element a middle-class vehicle, we can say that, in its construction, approximately 150 kg of plastics and composites of different types are used (a weight of 10- 15% of the total mass), while a mass of about 1163 kg is represented by ferrous materials (steel and cast iron) [13]. Up to 13 types of polymers are used in the construction of a single car model, and of these, three hold up to 66% of the total weight: polypropylene (32%), polyurethane (17%) and PVC (16%) [6].

Due to the increasing use of plastics, the industry in the field has developed surprisingly in recent years trying, through different methods, to generate composite materials with properties similar to metals. Since the mid-1990s, it is preferred to prepare plastics in twin screw extruder, as it has a reactor role. Technological specialists are constantly seeking new possibilities for discrete and differentiated adaptation of properties to various applications. Using these machines it was realized either the reinforcement of the plastics with natural or glass fibres, or the functionalization of immiscible materials and their coupling by cross-linking, thus resulting the so-called polymer-blends with remarkable properties. Additives, capable of covalently reacting with the basic components of the mixture, are required to make the immiscible materials compatible. Materials generated in this way contain two phases: a dispersed phase and a so-called matrix, between which the appropriate additives form covalently interposed, forming a network (cross-linked-network) in the continuous thermoplast matrix, thus increasing the stability of the materials. Table 1 presents three types of blends: thermoplastic vulcanized rubber, Polymerblends and Thermoplast modifying blends [14].

Table 1

EXAMPLES OF NEW MATERIALS WITH PROPERTIES DIFFERENT FROM THOSE OF THE BASE MATERIALS

Thermoplastic vulcanized rubber	Polymerblends	Thermoplast modified
□ PP/EPDM -TPV (with perox. cross linking) □ PA12/EVA - TPV □ PA12/EO-COPO-TPV	□ PP/PA6 - Blends □ PBT/ASA - Blends □ Heterophasic Polypropylene	□ PLA/TPU - Systeme □ PBT/TPU - Systeme □ POM/TPU - Systeme

Experimental part

The present paper presents the realization of PLA-TPU-Blends by mixing thermoplastic Polyurethan (TPU) with Polylactid-Acid (PLA) and the mechanical properties of these blends. This modification can be achieved using both a synthetic Polyurethan and a biological Polyurethan. Polylactid-Acid (PLA), which is intended to be modified to improve properties such as reducing rigidity and breaking properties, as well as reducing adhesion to injection molding tools, is a biodegradable material of biological origin, which is produced at the present industrial time, with properties already well known. In the most used production processes, such as the Nature Works manufacturer, the lactic acid diester, the lactide, is first dimerized and purified. Then a synthesis of Polylactide by ring-opening polymerization takes place. The percentages and ordering of the three lactide stereoisomers in macromolecules influence the properties of the polymers, such as: molar mass, stiffness, elongation at break, and degree of crystallinity, which can be influenced during the production process [15, 16]. Due to its attractive price, Polylactide is a preferred bio-material in many applications. For many applications, however, it is necessary to change the properties and, in particular, to reduce brittleness and improve impact resistance. When using TPU as an impact strength modifier, the compatibility of the two phases is of decisive importance. For this purpose, several types of suitable additives have been studied, which can react with both basic components, PLA and TPU [16, 17].

Table 2
MATERIALS USED IN THE STANDARD COMPOUNDING PROCESS

Component	Type	Properties	Preferred amount*
PLA	Nature Works, Type 2002D	E-Module 1800 [MPa]	80 – 60 %
PLA	Nature Works, Type 3251D	E-Module 3500 [MPa]	80 – 60 %
TPU	BASF Elastollan B85A	Shore A 83	20 – 40 %
Isocyanate MDI	Lupranat MP 102	modif. MDI	2.5 – 3.5 %

** other mixtures as well as other types of compatibilizer were studied*

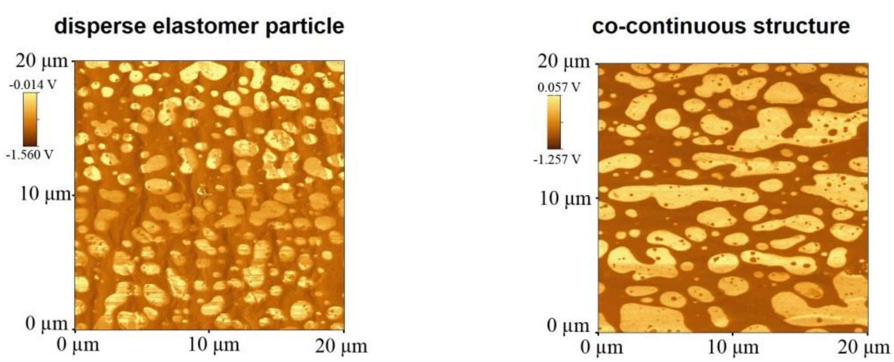
Table 2 shows examples of basic materials used in the preparation of blends and the additive Lupranat MP102, produced by BASF, which is a modified 4,4-Diphenylmethandiisocyanats MDI.

The process for producing blends made of Polylactides (PLA) and of thermoplastic polyurethanes (TPU) was studied in detail at the Institute fuer Kunststofftechnik (IKT), University of Stuttgart. At IKT University of Stuttgart the production of blends from thermoplastic polyurethanes (TPU) and Polylactides (PLA) was achieved by (stage A) reacting at least one thermoplastic polyurethane with at least one Diisocyanate or a Diisocyanate Prepolymer, which comprises at least two isocyanate groups, or a mixture thereof, in the melt reducing the molecular weight of the thermoplastic polyurethane and forming a thermoplastic polyurethane having an excess of isocyanate end groups, B) introducing at least one Polylactide into the melt of the product from stage A and reacting the product from stage A with the Polylactide at a temperature of less than 190 °C, and C) cooling the blend thus obtained, wherein no polyols are added in stages A) to C). When PLA is modified with a synthetic TPU, materials with a bio mass content greater than 50% are obtained, and when using a Bio-Polyurethan as a modifier, blends with a biogenic mass content of over 90% can be generated [16 - 18].

Compatibility of the composite phases

Upon the addition of modified 4,4-Diphenylmethandiisocyanats (MDI), with at least one isocyanate group in the molecule, at increasing temperature in the twin-screw-extruder the urethane groups are cleaved. Polyurethan molecular chains split shorter and the surplus of isocyanate groups can react to the dosage of Polylactide with them, forming covalent bonds with NCO groups at the ends of molecules and OH-Groups of Polylactide (PLA). Through these reactions a Block-copolymer is generated at the border between the two phases, which prevents the separation of the two phases in the following processes [17]. Figure 1 shows two types of PLA-TPU-Blends morphology: (a) dispersed elastomer particles and (b) co-continuous structure.

The types of morphology depend on the ratio of the basic components. Following studies with Atomic Force Microscope (AFM) found a very good correlation between the structure and mechanical properties of PLA-TPU-Blends. When making composites, the main function of the twin screw extruder is the dispersion of Polyurethane in the PLA matrix.



(a) (b)

Fig. 1. Typical morphology of PLA-TPU-Blends

Another advantage of using MDI: In the case of processing of glass or natural fibre materials, isocyanate groups can react with OH groups on their surface, thus requiring good compatibility between PLA, TPU and fibre components [19]. By reinforcing with fiberglass the materials alter both their dimensional stability under heat and mechanical properties. For example, for PA6GF30, which is a composite of Polyamide PA6 reinforced with 30% (gravimetric) glass fibres, the dimensional stability under heat increases from 50-80°C, for PA6, to 190-215 °C, for PA6GF30. In the case of PA66GF30, the dimensional stability under heat is modified by reinforcing with 30% glass fibers (gravimetric) from 70-100 °C, to 235-250 °C for PA66GF30 [20].

Resulting mechanical properties

For a first series of blends intended for extrusion or thermoforming, it was used a PLA Nature Works ® Ingeo TM 2002D, with an 1800 MPa E-Module and a Thermoplastic Polyurethane Type B85A, with Shore A 83. The variation of the PLA/TPU ratio and the change in the quantity of MDI copler results in a reduction of the material stiffness in relation to the quantity of TPU dosed. Figure 2 shows the E-Module drop from 1800 MPa for PLA without Polyurethane addition, to approx. 400 MPa, at 50% TPU blends. Even 5% Polyurethane causes a decrease of the E-Module to approx. 1600 MPa. Figure 3 shows a change in the elasticity of the composites at a TPU addition of approx. 10%, the elasticity of the samples increasing exponentially with the addition of TPU. Samples with a proportion greater than 40% could not be broken under the test conditions [DIN ISO 527 for plastics]. As the amount of MDI in the PLA-TPU mixture increases, there are also different elongations of the samples.

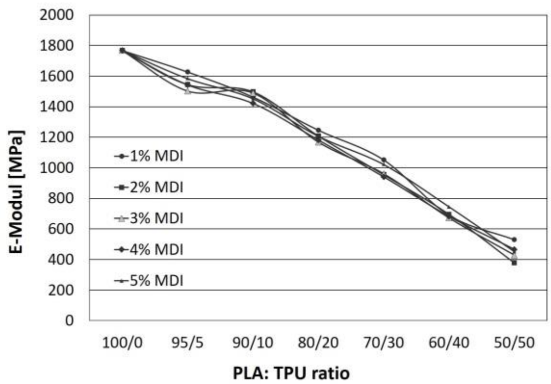


Fig. 2. Rigidity of PLA-TPU-Blends with Polyurethan B85A

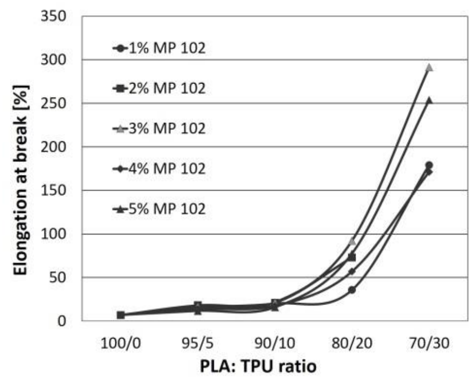


Fig. 3. Elasticity of PLA-TPU-Blends with Polyurethan B85A

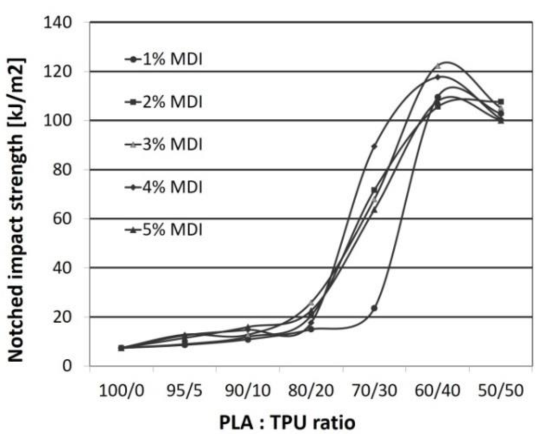


Fig. 4. Influence of TPU on notched impact strength in blends

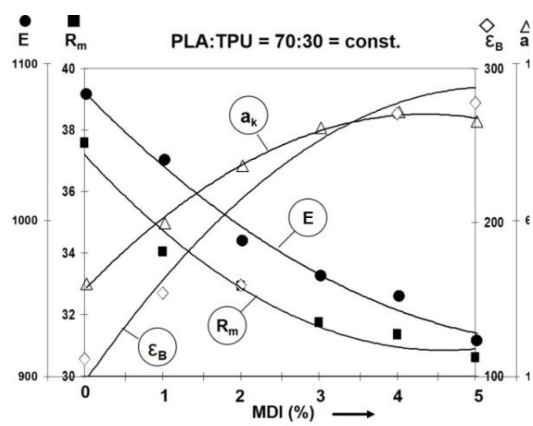


Fig. 5. The influence of MDI concentration on PLA-TPU-blends properties (70:30)
Legend: E = E-Module [MPa], Rm = Yield tensile strength [MPa], εB = elongation at break [%], ak = Charpy notched impact strength [kJ/m²]

Notched impact strength (Figure 4) changes from very small quantities of Polyurethan thermoplastic. Until PLA/TPU ratio: 80:20 there is a breakage of the samples, and from the ratios of TPU greater than 20%, a partial breakage of the tested samples takes place.

The influence of the MDI coupler quantity, which also determines the degree of interaction between the two phases of the composite, can be seen in figure 5, when at the PLA/TPU ratio, which is kept constant at 70:30, an amount between 0 and 5% MDI compatibilizer is dosed. Increasing the number of Isocyanate groups in the mixture of PLA and TPU allows a more intensive coupling of the two components. In the measurements for determining the viscosity of the materials, changes were observed that clearly indicate a realization of several block-copolymers at the boundary between the phases and a partial cross-linking of the TPU by forming allophanate bonds, but the PLA-TPU-blends properties remain thermoplastic.

Films realized using PLA-TPU-Blends at IKT University of Stuttgart were successfully used for the development of fold core materials for sandwich structures, based on regenerative for aircraft industry. The foldcore materials are the basic elements of lightweight construction with good stability and stiffness and are composed of several layers. A possible variant consists of a core and two plates, which are bonded to the core. The core has the function of keeping the two cover plates at a distance, thus the cover plates can take over the load force, which would cause bending. The sheets made from PLA-TPU-Blends have a very good workability in the molds for making foldcore materials for sandwich structures with remarcable mechanical properties [21].

In another series of experiments, the modification of the Nature Works ® Ingeo TM 3251D (type for injection molding parts) Polylactide (PLA) was successfully performed at the Institute for Kunststofftechnik (IKT) of the University of Stuttgart with a Bio-Polyurethan (produced by BASF), with properties similar to the synthetic Typ Elastollan B85A. A decrease in PLA-TPU-Blends stiffness is observed even from a 10% (gravimetric) Bio-Polyurethane addition (see figure 6). Starting with a concentration of 20% Bio-Polyurethan, however, there is a clear change in the elasticity of the samples up to the breaking point, the elongation of these samples being greater than the samples with 10% Bio-Polyurethan. In proportion to the decrease in stiffness, the Yield stress changes with increasing proportion of Bio-Polyurethane in the mixture (see Figure 7) [18].

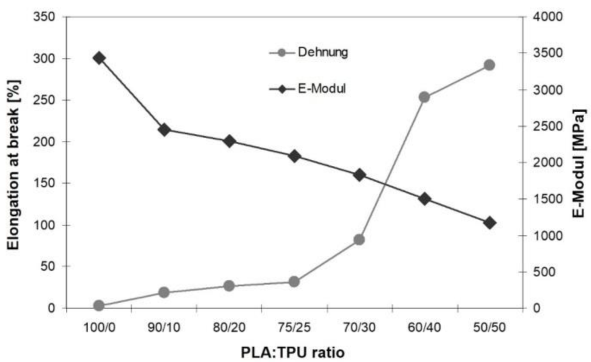


Fig. 6. The influence of PLA-Bio-TPU-Blends on rigidity and elasticity

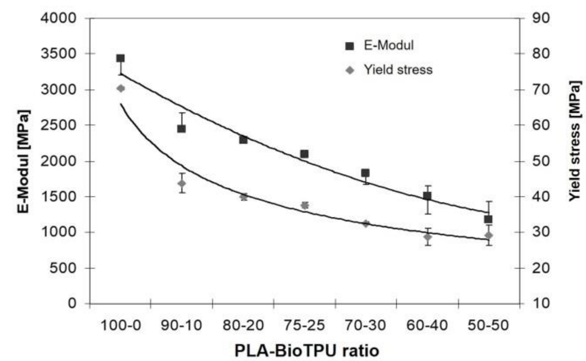


Fig. 7. The influence of Bio-TPU on E-Module and Yield stress

Compared to PLA-Bio-TPU with a percentage of Bio-Polyurethan of 10%, which has a notched impact strength of approx. 2.5 kJ/m², there was a 10% increase in notched impact strength when the Bio-Polyurethane concentration increased to 40%. The samples with a 50:50 ratio are found in the phase inversion area, the PLA matrix yielding in this case the Bio-Polyurethan place in the respective composites [18].

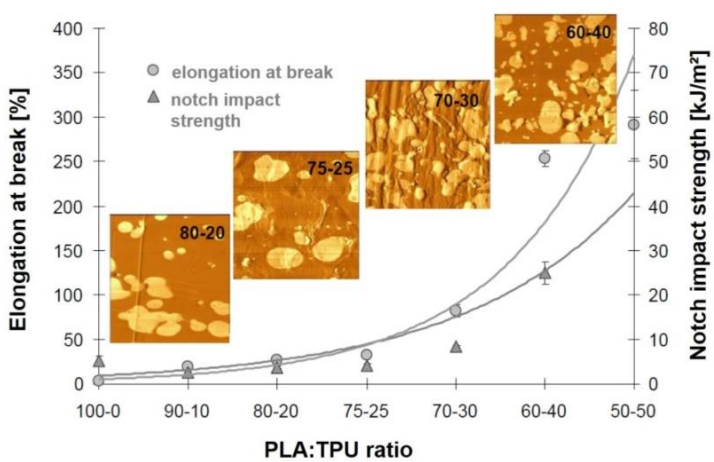


Fig. 8. The influence of Bio-TPU on elasticity and impact strength

The influence of the Bio-TPU on the elasticity of the samples is very well observed in Figure 8. The data clearly show a good correlation between the resistance of the samples to rupture and the morphology (structure of the composites). At a higher content in Bio-Polyurethane notched impact strength increases from a very low value for PLA, to values of approx. 40-50 kJ/m² for a PLA-Bio-TPU ratio of 50:50 [16, 18, 20].

When reinforcing PLA-TPU Blends with glass or natural fibers such as flax or hemp, the compatibilizer type 4,4-Diphenylmethandiisocyanats (MDI) also reacts with groups (-OH) from the surface of the fibers forming covalent bonds, thus inducing a good adhesion between the fibres of the plastic material and prevents the so-called pull-out effect of the fibres [19].

Due to the good compatibility with the natural fibres and glass of PLA-TPU-Blends and the good adhesion to the decorative elements, such as Polyurethane foils, wood imitation foils, they can be successfully used when making the interior elements of the vehicle body.

Results and discussions

Comparison between synthetic materials and bio-materials

When selecting PLA-TPU-Blends for different applications, it is necessary to know the properties compared to the standard materials used for the car components. In order to estimate the possibilities of use of bio-materials made from PLA and TPU, the properties were compared with standard thermoplastics such as Polypropylen (PP), Polyethylen (PE), Polyamid (PA), as well as with better performing materials from the engineering thermoplastics range Polybutylenrerephtalat (PBT), Acrylnitril-Styrol-Acrylester-Copolymere (ASA) and their derivatives. Plastics used in the comparisons were selected from a so-called "Werkstoffpyramide der Polymere"("Raw Material Pyramid of Polymers"). The position of the materials in this pyramid is determined by dimensional stability under heat. Depending on the scope, price and quantity used in various applications, the materials are classified in standard thermoplastics, engineering thermoplastics and high performance thermoplastics. Engineering thermoplastics have better dimensional stability under the heat than standard thermoplasics [20, 21]. The properties of the compared materials are presented in table 3.

Table 3
MECHANICAL PROPERTIES OF THE COMPARED MATERIALS

Type	Polymer	E-Module* [MPa]	Yield strength* [MPa]	Elongation at break* [%]	Notched impact strength* [kJ/m²]
Bio-material	PLA, Nature Works 3251D	3430	70	3	5
Standard thermoplastics	PE-LD	200 - 400	8 - 10	600	5,5
	PE-HD	600 - 1400	18 - 30		
	PP-H	1300 - 1800	25 - 40	>50	3**
	PP-R	600 - 1200	18 - 30	>50	20**
	PP-B	800 - 1300	20-30	>50	9**
	PA6 dried	2600 - 3200	70 - 90		
	PA6 cond.	750 - 1500	30 - 60		
	PA66 dried	2700 - 3300	75 - 100		
	PA66 cond.	1300 - 2000	50 - 70		
Engineering thermoplastics	PBT	2500 - 2800	50 - 60	20 - >50	
	PBT+ASA	2500	53	>50	
	ASA	2300 - 2900	40 - 55	10 - 30	
Bio-Blends	PLA-B85-Blend (80:20)	1210 - 1220	43 - 45	55 - 60	20 - 23
	PLA-B85-Blend (70:30)	950 - 1050	38 - 40	100 - 105	80 - 100
	PLA-B85-Blend (60:40)	690 - 700	26 - 29	200 - >500	129 - 139
	PLA-B85-Blend (50:50)	470 - 480	33 - 35	390 - >500	134 - 150

*Data from [20], **Data from [21]

Polypropylene (PP) is one of the most versatile polymers available, has good processing properties and many applications. PP block copolymer (PP-B) often used in the manufacture of auto parts is a material with an optimal balance resulting in high stiffness and very good impact strength. PP has superior properties related to mechanical strength, rigidity and high temperature resistance compared to those of polyethylene (PE) [13] and has better scratch resistance. Basically PP is a so-called "better variant" of the EP. PP-H (PP-Homopolymer) is stiffer and more impact resistant than Block-Copolymer PP-B. At lower temperatures PP-H becomes brittle [20]. Polyamides (PA) are among the most important technical thermoplasts, which are used especially in the automotive field, where they have increasingly replaced metal parts [23, 24].

Polyamide types do not differ too much in terms of properties. Polyamides are usually hard, rigid materials with good resistance to thermal effects. They also have a great chemical resistance to oils, fats, fuels, boiling water, Ketone. Polyamides absorb water by changing their properties (see PA-cond. in figure 9). By the absorption of water PA they become more elastic and with better mechanical strength (PA-cond.), but slightly stiffer and with lower dimensional stability [20].

The result of the comparison between PLA-TPU-Blends, standard thermoplastics PP, PE, PA and engineering thermoplastics PBT, ASA and their derivatives is shown in Figure 9. The average values of the materials in table 3 were used for comparison, notices close properties of PLA-TPU-Blends with standard thermoplastics PP, PE, PA. The results show the superiority of PLA-TPU-Blends in terms of Yield strength compared to the types of Polypropylene homo polymer (PP-H), block-copolymer (PP-B) and random polymer (PP-R).

The comparison of the impact strength of PLA-TPU-Blends with the types on Polypropylene PP-R, PP-H and PP-B shows the superiority of the Bio-Materials in terms of toughness compared to the standard materials, especially in blends with 20% and/or 30% (gravimetric percent) thermoplastic Polyurethan (TPU) in composition. Toughness is the ability of a material to resist breaking when force is applied. The results prove that the purpose of polylactide (PLA) modification with thermoplastic Polyurethan (TPU) is achieved, the resulting bio materials having a better toughness than PLA and PP.

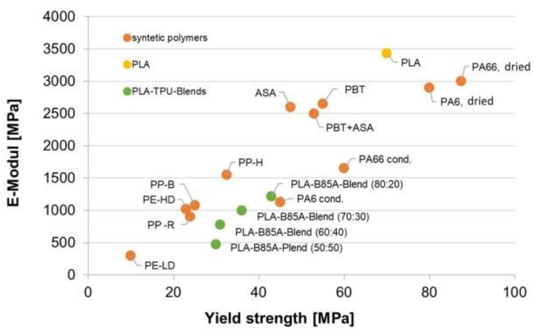


Fig. 9. Comparison of common syntetic polymers with PLA-TPU-Blends

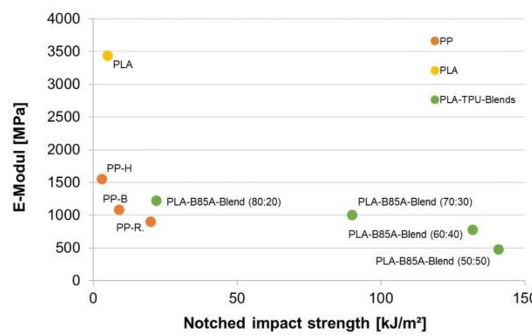


Fig. 10. Comparison of PLA-TPU-Blends toughness with Polypropylen PP

Bio-plastic materials

Comparison of bio-materials made at IKT University of Stuttgart with industry-standard bio-materials and Polyethylene (PE) is shown in Figure 11. Ecovio® F Blend C2224 (BASF SE), Ecoflex® F Blend C1200 (BASF SE) and Bio-Flex® F 1130 (FKuR, Germany) standardized bio-materials were used for comparison. Ecovio® F Blend C2224 is a biodegradable film product containing renewable resources consisting of 45% of renewable resources [25]. Ecoflex® is the first certified compostable Polymer by BASF on a fossil basis [26]. Bio-Flex® F 1130 is a product of FKuR (Willich, Germany) for compostable films [27].

Table 4
PROPERTIES OF BIODEGRADABLE MATERIALS

Type	Polymer	Producer	E-Module* [MPa]	Elongation at break* [%]
Bio-material	PLA, Nature Works 3251D	Nature Works	3430	3
Bio-Blends	PLA-Bio-TPU-Blend (80:20)	IKT Uni Stuttgart	2400-2450	30-40
	PLA-Bio-TPU-Blend (75:25)	IKT Uni Stuttgart	2100-2250	40-45
	PLA-Bio-TPU-Blend (70:30)	IKT Uni Stuttgart	1800-2000	75-80
	PLA-Bio-TPU-Blend (60:40)	IKT Uni Stuttgart	1500-1600	250-300
	PLA-Bio-TPU-Blend (50:50)	IKT Uni Stuttgart	1200-1250	>300
Others Bio-Blends	Ecovio® F Blend C2224	BASF SE	750 - 520	340
	Ecoflex® F Blend C1200	BASF SE	950	560
	Bio-Flex® F 1130	FKuR, Germany	390	600

When comparing bio materials (see figure 11) it is obvious that in all bio materials an improvement in elasticity compared to Polylatid (PLA) was realized. The Bio-Flex® F1130 and Ecoflex® F Blend C1200 materials even have an elasticity comparable to low density Polyethylene (PE-LD). IKT-Blends with Bio-TPU have higher modulus of elasticity than the other Ecoflex® and Bioflex® materials, while having a lower rigidity than PLA.

By using the partially biobased Polyurethane, a biobased content of more than 90% of the IKT-Blends could be achieved.

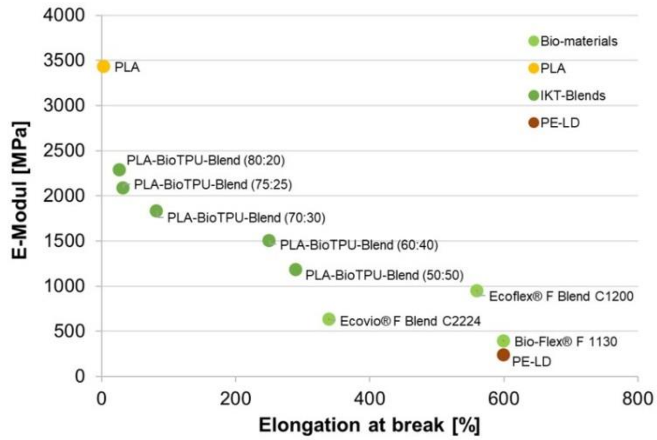


Fig. 11. Comparison of PLA-TPU-Blends with others commercial bio-plastic materials

Trends in the plastic industry

In the plastics industry, the aim is to optimize the existing processes, the technologies used and the machines, focusing on increasing the energy efficiency of the processes, efforts to achieve a shape formation without deteriorating the properties of the materials, as well as finding quality improvement or monitoring system solutions, these objectives can be successfully achieved by coupling material preparation processes and injection in one step process, as was done, for example, at KraussMaffei 200-1400 IMC injection molding Compounder, the process production, gaining in importance over the last few years. In this innovative machine a twin screw extruder is combined with an injection molding unit. The one step process using injection molding compounder (IMC) has particular advantages especially in reinforcing fibre materials: (1) reducing fibre shortening, (2) reducing material overheating, (3) increasing mechanical properties of products [28].

Conclusions

Modification of the Polylactide (PLA) Nature Works stiffness was successfully performed at IKT University of Stuttgart using a synthetic and bio-based Polyurethane thermoplastic (TPU). Using a type 4,4-Diphenylmethandiisocyanats (MDI) compatibilizer, both component compatibility and improved mechanical properties were achieved through partial cross-linking. When reinforcing composites with glass or natural fibers, Izocyanate groups can react with groups (-OH) on the surface of the fibers, preventing the so-called pull-out effect of the fibers. By comparing the composite materials from PLA and TPU, made at IKT University of Stuttgart with PP, PA and PE, it was found that IKT-Blends have similar properties to them. Compared to other biodegradable materials Bio-Flex® produced by FKuR and Ecoflex® / Ecovio® produced by BASF PLA-Bio-TPU-Blends have a higher biogenic mass, which can reach proportions greater than 90%. Similar to other standard materials, the PLA-TPU-Blends fiber reinforcement increases the dimensional stability under heat of the composite. Due to the good compatibility with the natural fibers and glass of PLA-TPU-Blends and the good adhesion with decorative elements inside the body, such as Polyurethane foils, wood imitation foils, these PLA-TPU-blends can be successfully used when making the interior elements of the car body. PLA-TPU-Blends can be successfully made in one-step process, which is a combination of compounding and injection molding, thus improving the quality of the final product.

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