Plastic

research & technology…

…from material to finished product

Transfercenter für Kunststofftechnik GmbH

TCKT

Welcome to the polymer world

Adjacent Digital Politics Ltd explores the importance of polymer sciences and the European Polymer Federation's part in bringing researchers together throughout Europe...

One of the forefathers of polymer science is undoubtedly the German scientist Hermann Staudinger, who, in 1953 won the Nobel Prize in chemistry for his research in this area. It was Staudinger that made the first proposal in the 1920's to make it possible to have large molecules, made up of thousands of atoms. At that time, it was believed that the structures of materials such as rubber and bakelite were small molecules held together by an unknown force. He fought hard to prove his theory to a community of sceptical scientists, and with the help of his colleagues synthesised a series of organic molecules called poly (methanals).

In Staudinger's 1953 Nobel Prize Banquet Speech, he said:

"The technically important questions of macromolecular chemistry, the issues of fiber and plastic production, are now handled in the whole world..." He recognised that macromolecular chemistry had "opened new vistas in biology".

During the 1930's, the American chemist Wallace Hume Carothers verified Staudinger's theory and developed neoprene rubber and polymide (nylon) fibres.

It was the Second World War that marked the real emergence of a polymer industry that demanded synthetic substitutes for rubber and silk. Polymers were routinely used to insulate cables that were needed for the vital radar equipment used by the British.

Since the Second World War, plastics, fibres, elastomers, rubbers, proteins and cellulose have become part of our everyday life – used in products from toys to lightweight bullet-proof vests. We undoubtedly live in a polymer world with new developments in this area constantly evolving.

Some recent important advances in polymer science include[1]:

- Polymers with excellent thermal and oxidative stability – for use in high-performance aerospace applications;

- Engineering plastics – polymers designed to replace metals;
- High-strength aromatic fibres, some based on liquid crystal technology, for use in variety of applications from tire cord to cables for anchoring oceanic oil-drilling platforms;
- Non-flammable polymers, including some which emit a minimum of smoke or toxic fumes;
- Non-flammable polymers, which not only help reduce the volume of unsightly plastics waste but also allow for controlled release of drugs or agricultural chemicals;
- Polymers for broad spectrum of medical applications from degradable sutures to artificial organs;
- Conducting polymers – polymers that exhibit electrical conductivities comparable to those of metals;
- Polymers that serve as insoluble supports for catalysts or for automated protein or nucleic acid synthesis.

The waste dilemma

However, accepting that we live in a 'polymer world' and recognising the importance of these materials does have one downside. The majority of plastic waste comes from packaging that is used only once and then sent to landfill. Increasingly, consumers, and manufacturers have realised the importance of recycling, but now, biodegradable plastics are becoming more common. For instance, photodegradable plastics degrade when exposed to light, and biodegradable plastics can be decomposed by bacteria. This still leaves several issues to solve. There is a limited supply of oxygen and water to anaerobically break down biodegradable plastics, and the reaction from this can produce methane. The EU Landfill Directive limits how much plastic can be sent to landfill in an attempt to control greenhouse gas production. This in itself leads to another issue of more research being required in this area to solve the dilemma.

EPF inception

Scientific research, funding, and the free exchange of information is increasingly the backbone of the European economy. In 1986, with the financial help of the European Science Foundation (ESF) a meeting was organised and attended by 16 different European countries. The outcome of the meeting was that research on polymers, both in industry and in academia, was of great importance in Europe where original research was actively pursued. It was therefore decided that polymer science deserved an organisation of some kind devoted to the topic. Following the meeting, the statutes of the European Polymer Federation (EPF) were then drafted and signed by all the participants'[2].

The European Polymer Federation (EPF) has a key chartered goal: 'to co-ordinate and stimulate the activities of European countries in the areas of sciences, technology and applications of synthetic and natural macromolecules, and more specifically to encourage cooperation and advancement of education, research and development of polymer science and technology'

EPF activities

It is only through the activities of the EPF, and a whole host of academics, that our understanding of, and developments within the vast field of polymer science can be furthered. Our 'polymer world' has much still to achieve. With a high level of dedication and funding, our future looks bright.

The EPF has played a role in the crucial development of bringing together a number of experts in this field. The first European Polymer Congress in July 2001 in Eindhoven, The Netherlands was organised with great success. The meeting addressed important issues such as education and interaction between academia and industry.

Growing each year, The European Polymer Congress is now in its 12th year and is seen as one of the major biannual conferences on polymer science. It attracts an ever growing participation and from this it is clear that The European Polymer Federation throughout the years has made great strides to bring together researchers and scientists in the wide ranging area of polymer science.

[1] http://plastics.tamu.edu/content/11-brief-history-polymers

[2] https://sites.google.com/site/europolyfed/home/history

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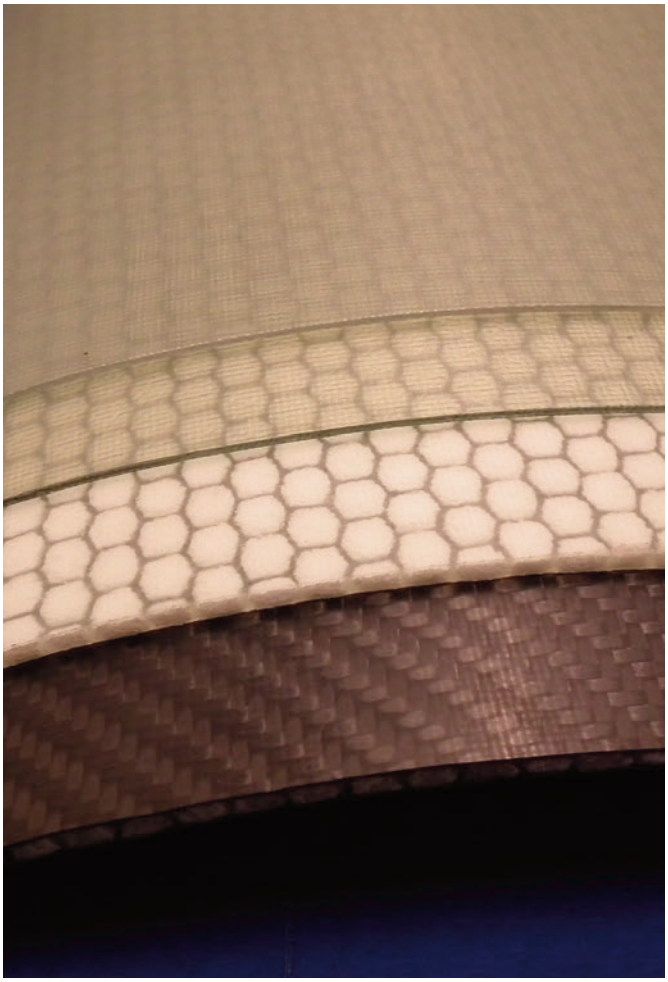
Application oriented Polymer Research in Upper Austria

Austria has a small but healthy polymer industry, generating approximately €13bn sales. Upper Austria, one of the nine provinces, achieves about €7.6bn with more than 220 companies in Upper Austria involved in the polymer industry starting at raw material suppliers like BOREALIS, manufacturers of plastic processing machines like ENGEL, tool makers, plastic converters or manufacturers of recycling machines. Some of the companies are world market leaders in their niche. The structure of the Austrian and Upper Austrian polymer industry is distinguished by small and medium enterprises (SME). However, the research expenditure of the Upper Austrian companies involved in polymer industry is round about 4% of their sale.

Within this scenery the Transfer Center for Polymer Technology (TCKT) was founded in 2001 as an application oriented R&D institute, whose primary purpose was to assist Upper Austrian SME's with their problems in regard to plastics. In the first years up to 2008 the TCKT was a department of the Upper Austrian Research GmbH, which is the leading organization for non-university research of the federal province of Upper Austria. In 2008 the TCKT became a separate legal entity with the main owner being the Upper Austrian Research GmbH. The Johannes Kepler University Linz and the University of Applied Sciences Upper Austria also joined as minority shareholders in 2008. The focus is still to support the SME base in Upper Austria but also SME's and bigger companies in Europe and all over the world.

As mentioned before, the companies in Upper Austria represent the whole value chain starting with the raw material across the wide range of polymer processing to the point of recycling of plastic waste. Along this chain of value the TCKT sets its key areas as material development, material testing, computer aided engineering and process technology.

In the area of material development the TCKT has its focus on novel fillers, reinforcements by technical or natural fibers, as well as additives for property modification of polymers.



To verify the results in material development a well-equipped test laboratory was established. In 2004 this test laboratory became an accredited laboratory in which the request of our customers in regard to mechanical, thermal, rheological or physical testing of polymer materials can be fulfilled.

In the area of computer aided engineering the scope lies with two different topics. One is the simulation of injection molding processes, and in correlation with the test laboratory the generation of material data for simulation. The other topic is the simulation of strength and stiffness on loaded components made out of polymers. An outlook in this area is the combination of generated material data in process simulation with the input of structural simulation software.

The process technology is represented by investigations on the injection molding process, the extrusion process and on various processes of composite technologies like the resin transfer molding (RTM), the vacuum assisted resin infusion (VARI) and the autoclave technology. The first two are dealing with thermoplastic materials and the developments related to the processing of unreinforced and reinforced

materials as well as the processing of foamed thermoplastics. The research on processes in composite technology is driven by lowering the cycle time and achieving higher automation of the processes.

The TCKT is organized by a matrix where the main fields of research overlap the four key areas. The main fields of research at TCKT are:

- Material development with additives and fillers in thermoplastics;
- Natural fiber reinforced polymers and biopolymers ;
- Composite technologies and lightweight structures both in thermosets and thermoplastic materials;
- Recycling of polymers, especially the behavior of multi material compounds;
- Interface in composite materials.

Material development

The business of material development at TCKT is well-directed in the setting of polymer properties by using additives, reinforcements or fillers using compounding technology. We have a wide experience of more than 10 years in compounding but not only in additives and fillers, but also in converting reinforcing fibers. A very wide range of material datasets were generated over the last years with common mineral reinforcements and fillers like talcum, calcium carbonate, wollastonite, glass fibers or the like. The range of Polymers starts with commodity types like polyolefins and ends at high temperature polymers like PEEK. A special focus lies with Natural Fiber reinforced Polymers (NFC) and Wood Plastic Composites (WPC). Another focus lies on biopolymers and their optimization for processing or mechanical or thermal properties. For this field of research TCKT has two compounding lines with twin-screw extruder in lab-scale and pilot plant scale available. Gravimetric feeding systems are standard for powder or pellets, dosing of liquids is also available. Materials that are sensitive in processing can also be converted in a kneading chamber.

Natural fiber reinforced polymers and biopolymers

The natural fiber reinforced materials (NFC), especially the Wood Plastic Composites (WPC) has been a research topic at TCKT since 2002. In the early stage of this field of research, investigations of WPC extrusion in a one-step process were done. A huge amount of WPC recipes were developed for individual applications like decking or garden tables. Not only was the extrusion process investigated for WPC and NFC, but we also generated a lot of know-how in injection molding for these kinds of materials. We realized the processes for injection moulding parts like a car door panel or a garden chair. Nowadays the extrusion process and the injection molding process are in control. The focus on investigations nowadays is in optimization of recipes concerning better stabilization or flame retardant of materials.

Currently, a research project called "EcoWPC" is ongoing at TCKT. In this project, 12 scientific and industrial partners are working together to build up a unique database on formulation-property-cost relationships. Within the scope of this project the processes of extrusion and injection moulding are investigated and the potential of optimization is worked out. Not least, the prices of the WPC formulations are considered so that, applications aside, the well-known decking processes are allowed a chance for growth. Constant quality, processes and the achievable properties are the aspired results by lowering the manufacturing costs by 25%. One of the realized parts in this project concerns injection moulded garden furniture using WPC, with a wood content of 30% in a polypropylene matrix.

Accredited test laboratory

In 2004, TCKT became an accredited test laboratory certified by the Austrian accreditation body, the Ministry of Economics. Meanwhile the accreditation was extended to more than 20 international standards regarding different testing methods for polymers. Furthermore, a lot of testing methods for material characterization or component part testing are executed at TCKT. Our testing methods are in the field of mechanical testing, thermal testing or rheological testing of polymer melts. Our expertise comprises material and testing know-how of thermoplastics as well as thermosets or foamed plastic. To underline our competence and quality in testing TCKT is participating on voluntary round robin tests. In this tests TCKT always achieve very good results.

With our test laboratory we are able to characterize and evaluate the essential material parameters of the developed materials in our house. Also, we are able to generate material data that is necessary for simulating converting processes like injection moulding in all common simulation software tools, or for the computation of the load behavior in polymer component parts.

Over the past few years TCKT has developed great experience in composite testing, resulting in us being an appreciated partner in development of lightweight structures.

Computer aided Engineering

In the field of Computer aided Engineering we pursue two different courses. First, we simulate the converting process like the injection moulding, and second, we calculate structural properties (e.g. strength, stiffness) of loaded polymer parts. The goal is to join both of the calculations.

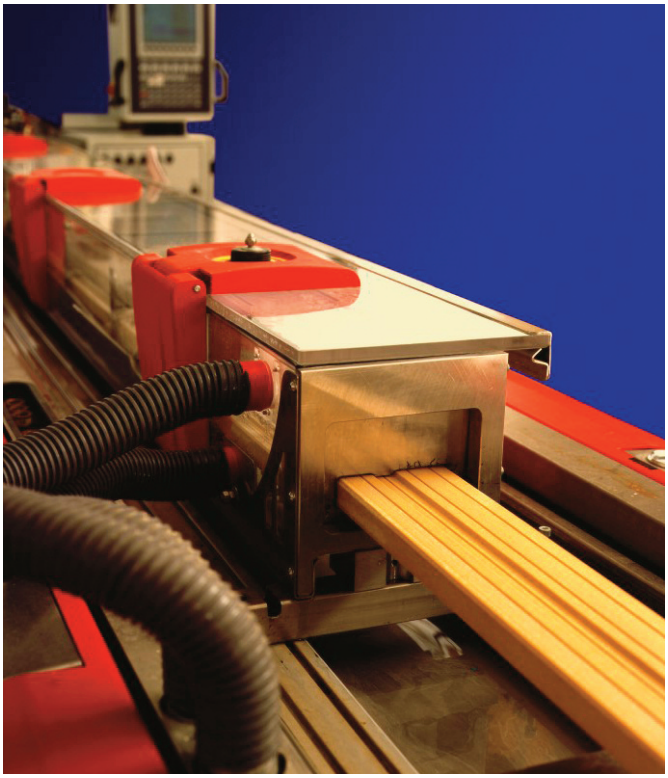
Simulating the converting process, the parameters of the polymer melt are very important. The quality of input parameters is essential for the quality of the simulation result. In many cases material specifications are not available in adequate precision. In cooperation with our test laboratory we can generate this material data and can support the mathematical models in the simulation software. Thereby we have a complete dataset for simulating converting processes at our disposal. This dataset can be imported into the simulation software.

In case of structural analyses, the stress-strain curve is the most significant information to dimension parts out of polymers. Measured raw data is not directly applicable for simulation. A data fitting for the simulation is necessary – meaning that stress-strain curves have to be smoothed, and data points have to be reduced to a reasonable number. At TCKT we can do this data fitting for our customers or for our own use.

Process technology

Process technology at TCKT is a support for our own material development on the one hand to ensure that all of the developed materials are processable on conventional converting machines like extruders or injection moulding machines, and, for our customers to optimize their processes and tools, or for sampling inspection of new tools on the other hand. In the injection moulding process for example, we optimize the warpage of the moulded parts also supported by simulation. Above all, we investigate the abrasive wear of polymer melts in converting tools. For this purpose especially, a new wear measuring tool was designed for the injection moulding machine.

In extrusion technology we offer profile extrusion especially NFC and WPC extrusion, film extrusion on a cast film extruder and a blown film extruder.



Thermoplastic foams are produced in the injection moulding process, in extrusion or in a special technology.

A project with six Austrian enterprises and the University of Applied Science Upper Austria was launched to develop wooden long-fibers for their use in WPC products. Not only the properties and modification of the wooden fiber has to be investigated, but also the process for treatment and compounding is content of this project. The consortium in this project has a good match along the value chain, and starts with the engine builder for processing wooden fibers, and ends with the WPC converters in extrusion and injection moulding.

Composite and lightweight structures

Composite materials and lightweight structures is one of the main fields of research in which the material development, the material characterization, as well as the process technology are investigated.

A huge project regards the building up of knowledge and infrastructure in the area of composite materials and lightweight structures. In the focus of this project we also view the whole value chain, beginning with material development across testing and processing of composite materials to the question of recycling of composites. So, by now TCKT can offer various processing technologies like hand lamina-

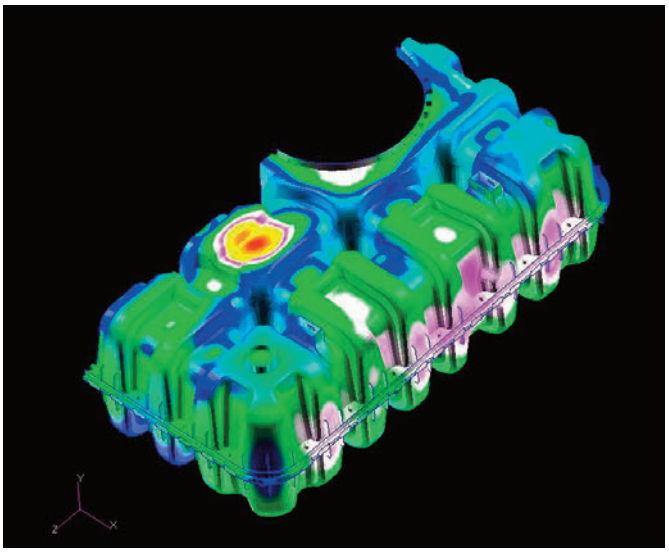
tion, pre-preg processing, infusion or injection processes. Manufacturing of solid laminates or sandwich structures with different core materials is possible. But not only the processing of the materials is necessary, also the investigation of material data like mechanical properties, or permeability of fiber fabrics for example is required. A really important question for future applications of composite materials is the usage at end of life. Therefore recycling processes are necessary. The recycling of thermoplastic composites is in this case much easier than a second life procedure of thermoset composites.

Another project was started to optimize the injection process with thermoset resin in Resin Transfer Moulding (RTM). Therefore a new batcher system and a new tool concept for RTM will designed.

Lightweight structures are not necessarily made out of composites. Thermoplastic foams can also fulfill the requirements on lightweight structures at even lower material and processing costs. Therefore the TCKT also investigated thermoplastic foams in extrusion and injection molding applications on the one hand, and with a complete new processing technology on the other hand. With this new processing technology a mono-material sandwich structure out of polypropylene was developed together with a company partner.

Recycling

Due to the public discussions of waste disposal and availability of crude oil recycling of polymers gets more and more important for our society, policy and therefore for research. Recycling of polymers, thermoplastics or thermosets is one of the important topics in the future. In some European countries the recycling of plastic waste is well organized and statutory by law. But predominantly the reuse of polymer goods after lifetime is not regulated. Even when recycling systems exist, the main amount of plastic waste is incinerated. Mechanical recycling of polymers is well known but not sufficiently investigated. Polymer recycling is in its infancy and a lot of problems need to be solved.



Therefore, different research projects were started at TCKT. In one of these projects TCKT is searching for methods to improve the recycling of mixed material streams out of thermoplastic polymers. When recycling collected polymer waste it is not able to get neat polymer types. It's impossible to avoid impurities. Hence, you have always to deal with mixed material streams. If the different materials are incompatible, immiscible multiphase systems will exist. So, the compatibility of mixed materials is investigated and improved to get better performance of the recycled material.

More complicated, is the recycling of composite materials – all the more if they are based on thermosets. Carbon fibers in carbon fiber reinforced Polymers (CFRP) for example, are valuable materials in the polymer industries. Therefore the recovery of the fibers is worthwhile. At TCKT we are looking for different ways to recover the fibers and find new implementations.

Interface

Many of our topics for research like compounding, WPC, CFRP or recycling, are dealing with multi material systems. So it's self-evident to investigate the interface of these composites. Our most recent field of research is engaged in the investigations on interfaces in composite materials, no matter if they are in interaction with mineral fibers, natural fibers, thermoplastic fibers or polymer blends as a multiphase system, because the interface behavior is one of the most important properties for an optimized material behavior. The field of interfaces is very wide, so the first step is to identify the most important combinations of materials. The next step is to find the combinations with poor compatibility and improve the compatibility with suitable compatibilizer. It is important in this case to understand the mode of effects in interfaces. The effectiveness of compatibilisation is checked with mechanical tests and microscopic analysis.

Even though this field of research is the most recent, we already conduct several research projects at TCKT in this sector.

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