Kompetenzzentrum
Niedersachsen · Netzwerk
Nachwachsende Rohstoffe e.V.
www.3-n.info

Production of 3D Filaments made of Natural Fibre/Biopolymer Granules using a CMS Compounder

Development of a new compounder system for long natural fibres with biopolymers.

- **State of the art and tasks:**
  With the previous method, the introduction of long natural fibres (cellulose fibres) or cellulose staple fibres was difficult. Compounding via screw extruders or heating-cooling mixers often results in thermal degradation of natural fibres. Industry demands with respect to odour and colour cannot be achieved with these products. In addition, from a material point of view, bast fibre reinforced thermoplastics have low impact properties, which preclude their use in many consumer goods. Shortcomings also exist with respect to the flexibility and achievable properties of natural fibre reinforced thermoplastics. Moreover, the potential that lies in natural fibres often could not be exploited. The products on the market are made of wood particles or free-flowing fibres a few millimetres long, which have higher quality requirements and inadequate mechanical properties.

- **Approach and implementation:**
  Based on preliminary tests and intensive R&D discussions with industry partners, a new principle for NFK compounding has been implemented. At the Werlte Climate Centre the necessary technical equipment was set up for experimental procedures. At this plant experiments were conducted with different fibres and polymers. The preliminary results are summarised below.

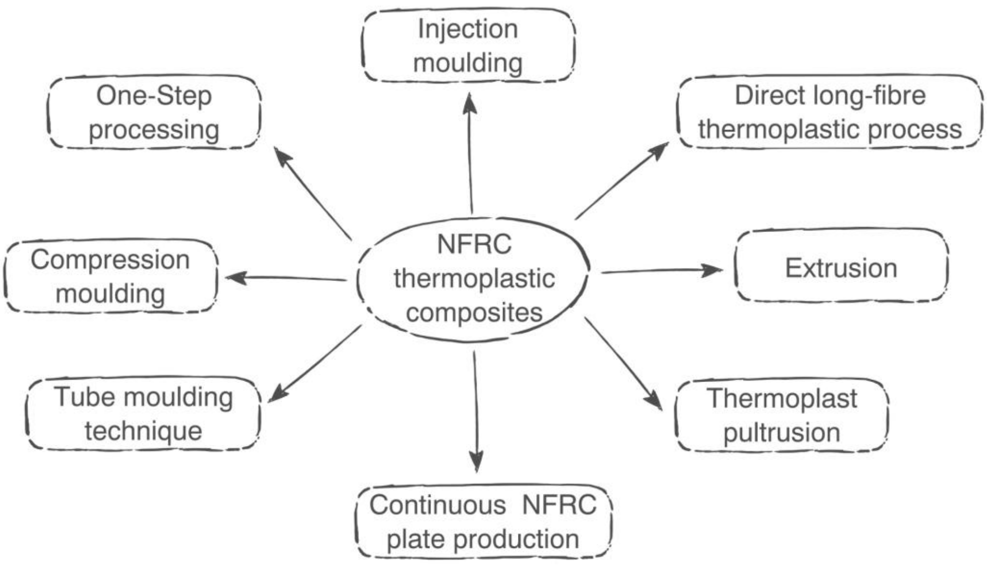

Fig. 1: Benefits of the new CMS compounding process (Müssig and Wieland, 2014)

Table 1: Matrix polymers and adhesion promoters used

Polymer	Description	Manufacturer
PP	Moplen EP 500V	LyondellBasell, Frankfurt (DE)
	Ducor 2600 M (previously: Domolen 2600M)	Ducor Petrochemicals BV, Rotterdam (NL)
	Y101	Rabigh Refining & Petrochemical Co. Rabigh (SA)
	AdstifHA840R	LyondellBasell, Frankfurt (DE)
PLA	PLA3251D	NatureWorks LLC, Minnetonka (USA)
	PLA4043D	NatureWorks LLC, Minnetonka (USA)
	Naturegran 11bz10091 (compound with main component from PLA)	Linotech GmbH & Co.KG, Forst (DE)
Bonding agent	Scona TPPP 8112 GA	BYK-Chemie GmbH, Wesel (DE)

Table 2: Reinforcing fibres and fillers used

Fibres	Description	Manufacturer
Hemp	BAFA Short Fibre (< 0.5 mm)	BaVe Badische Faserveredelung GmbH, Malsch (DE)
	HempAge Cut Fibre (cutting length approx. 5 mm)	HempAge, Adelsdorf (DE)
	Hanf KGE-02 (fibre length > 20 mm)	NAFGO GmbH, Dötlingen-Neersted (DE)
Regenerated cellulose	Cordenka (CR244dtex f 1350 TO; cutting length: 2mm)	Cordenka GmbH & Co. KG, Obernburg (DE)
	Danufil (3.3 dtex / cutting length: 5 & 8 mm; 9.0 dtex / cutting length 3mm)	Kelheim Fibres GmbH, Kelheim (DE)
Wood fibres	Arbocel C 750 (length: 40 – 70 µm)	J. Rettenmaier & Söhne GmbH & Co. KG, Rosenberg (DE)
Agricultural residues	Paprika fibres	Millvision, Raamsdonk (NL)
	Pea fibres	Emsland-Stärke GmbH; Emlichheim (DE)
	Grass fibres	Linotech GmbH & Co.KG, Forst (DE)
Paper fibres	Paper fibres	Standard-Druckerpapier (80 g/m²)

- **Summary of Findings:**

Table 3 shows the mechanical properties (tensile strength, elastic modulus and Charpy impact strength, unnotched) for unreinforced PP and PLA matrices, as well as the compounds from pilot tests (Müssig and Graupner, 2013) and granules produced at the new facility.

Table 3: Examining CMS Compounds – Mechanical Properties

	Probe	Zugfestigkeit in MPa	Zug-E-Modul in MPa	Ungekerbte Charpy Schlagzähigkeit	Faserart	Polymer
Neue Versuchs-reihen	**PP- Y101**	26.0 ± 0.3	1630 ± 281	NB	-	PP- Y101
	30% Hemp Age/PP + 3,5% Haftvermittler	31.6 ± 0.2	3205 ± 474	16.7 ± 1.4	Hemp Age Kardenband, Schnittfasern	PP- Y101
	40% Hemp Age/PP + 3% Haftvermittler	34.8 ± 0.8	3940 ± 959	16.6 ± 1.6	Hemp Age Kardenband, Schnittfasern	PP- Y101
	50% Hemp Age/PP + 2.5% Haftvermittler	34.5 ± 1.2	4842 ± 993	12.7 ± 1.5	Hemp Age Kardenband, Schnittfasern	PP- Y101
	PP - Adstif HA840R	33.4 ± 0.2	2117 ± 345	70.4 ± 5.4	-	PP - Adstif HA840R
	30% Danufil/PP + 3,5% Haftvermittler	40.5 ± 0.5	2707 ± 687	29.5 ± 3.8	Danufil 3.3 dtex	PP - Adstif HA840R
	PLA 3251D	53.8 ± 0.2	3286 ± 661	18.5 ± 3.7	-	PLA 3251D
	30% Hanf/PLA	61.5 ± 0.9	6672 ± 1670	11.7 ± 2.6	BAFA Kurzfaserhanf	PLA 3251D
Vorversuche	**PLA 6202D**	48.6 ± 0.5	3056 ± 137	10.8 ± 0.8	-	PLA 6202D
	30% Hanf KGE-02/PLA	55.8 ± 1.7	6196 ± 124	9.4 ± 0.8	Hanf KGE-02 (> 20 mm)	PLA 6202D
	30% Hemp Age/PLA	69.9 ± 1.8	6618 ± 805	11.6 ± 0.7	Hemp Age Kardenband, Schnittfasern	PLA 6202D
	PP - Moplen EP 600V + 5% Haftvermittler	28.4 ± 1.1	1844 ± 72	30.3 ± 8.4	-	PP - Moplen EP 600V
	30% Hemp Age/PP + 5% Haftvermittler	44.2 ± 1.3	3934 ± 285	18.8 ± 1.5	Hemp Age Kardenband, Schnittfasern	PP - Moplen EP 600V

- Long natural fibres can be compounded with the CMS compounder without another processing step (pelletising or cutting)
- Compounds with fibre mass of up to 50% could be produced as injection-mouldable granules and successfully moulded to tensile bars
- Strengthening with natural fibres leads to an increase in the tensile strength and moduli as compared to pure PP and PLA
- An increase in the fibre mass fraction of 30% to 40% and 50% significantly increased elasticity modulus
- The impact of the 30% Danufil/PP sample with regenerated cellulose that is ductile and more weakly bonded to the matrix is almost twice as high as the 30% hemp/PP sample

Construction of a production chain for granulation on filament production and 3D printing to the finished product

3D printing is one of the top technology trends (Rivera, 2014). This is because numerous companies are purchasing systems for prototyping and other applications – i.e. companies are upgrading to 3D printing. They increasingly recognise the potential of the technology. 3D printing technology offers greater flexibility in design, reduces the use of raw materials and provides the opportunity for tailor-made and customised solutions. As a result, 3D printing will be increasingly used to achieve more efficient production in the space, aeronautics, orthopaedics, jewellery making, dental technology, education, architecture, medicine and automotive industries.

According to a recent forecast, sales of 3D printers, 3D printing accessories and services is expected to reach 16.2 billion US dollars by 2018 (Canalys, 2014). This figure is based on an estimated annual average growth of 45.7 per cent. In 2014, the turnover in the 3D printing industry amounted to 2.5 billion US dollars. The industry will grow strongly in the coming years, according to market researchers. A 2013 study (Steel, 2013), which dealt with the environmental impact of 3D printing, shows positive effects as a result of lower resource consumption, reduced inventory, lower transportation costs and less packaging waste. Also, the overall market of the seven most important materials averages about 800 million US dollars and will increase tenfold by 2025 to more than 8 billion US dollars. The catalogue of available 3D printing materials is growing steadily.

Development Work at 3N

An innovative market segment involves printer wires from natural fibre reinforced biopolymers. In addition to pellet production, process chains have been further developed. For the first time it was possible to produce thermoplastic wires from the special granules for 3D printing. The next step is to optimise the filaments and the adjustment of the printing technology to the new material.

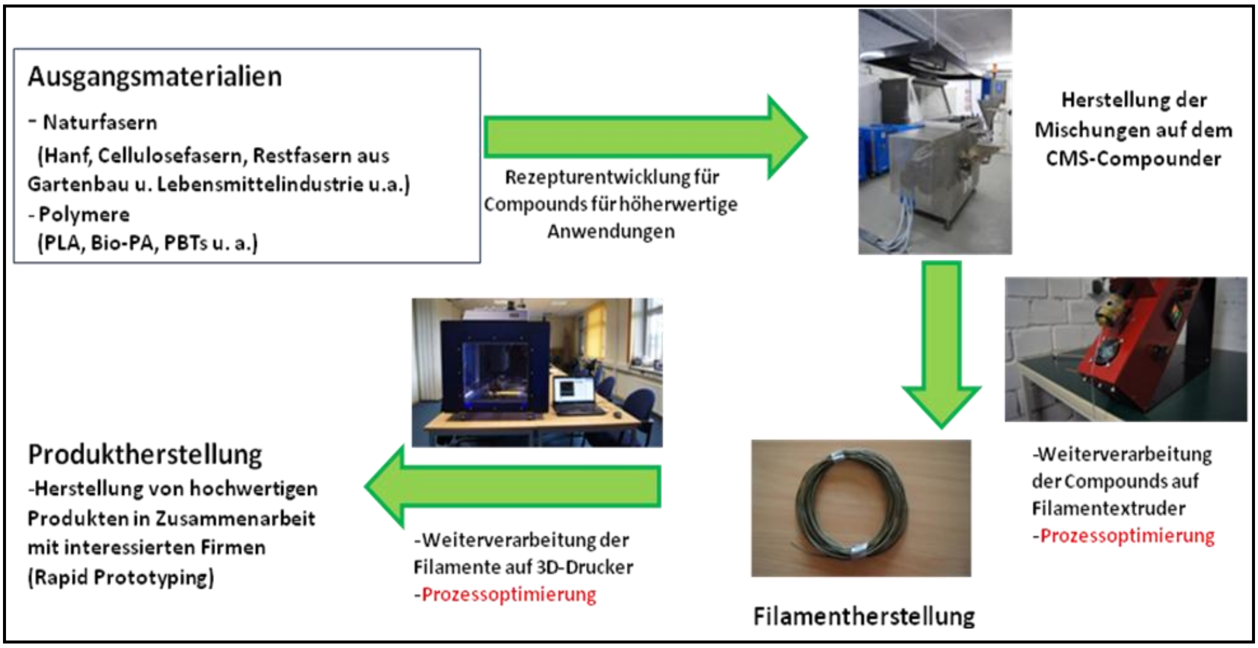

Fig. 2: Process chain for the production of NFK products via 3D printing

Previously produced filaments made of grass fibres/PLA, wood fibres/PLA and Danufil fibres/PLA (10% fibre by weight) are currently being optimised and tested for the 3D printing process.

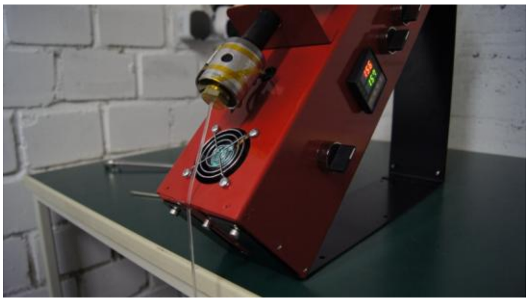

Fig 3: Filament Extruder (Noztek Pro ABS and PLA Filament Extruder for 3D Printers, Noztek, London, UK) in the laboratory in Werlte (Climate Centre)

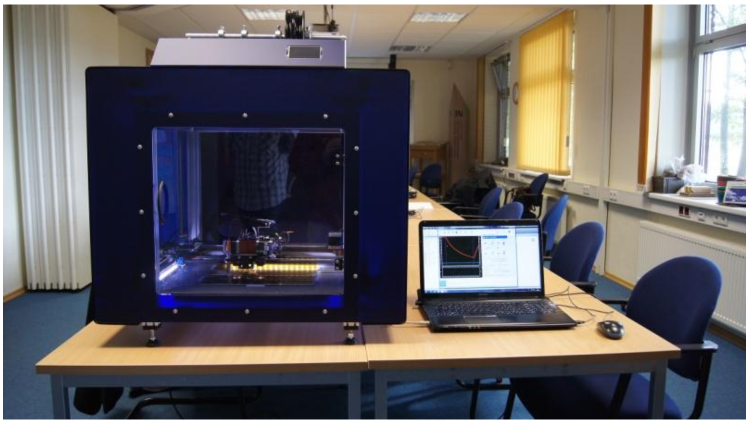

Fig 4: Special 3D Printer in Werlte

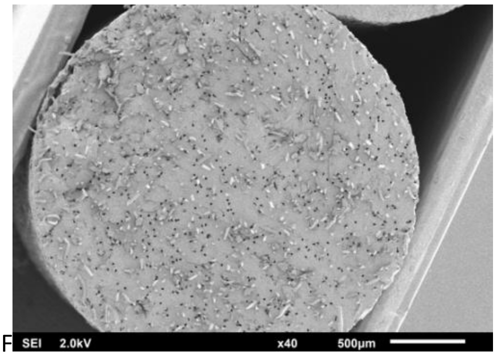

Fig 5: SEM image of a fracture surface of an extruded 3D printing-wire with 10% Danufil and 90% PLA (PLA 3251D); recording of complete wire cross section; the incorporated fibres exhibit a uniform distribution in wire.

These developments were carried out in collaboration with the University of Bremen. There is close cooperation among companies in the field of 3D printing.

We offer:

- Development of NFK granules for special applications (characterisation of the required properties of the materials to be used)
- Production of 3D printing filaments of different materials, also NFK granules
- Test application for 3D printing filaments (printability)
- Manufacture of products by means of 3D printing (printing room size: 300x300x300 mm, 3 printheads for use of up to 3 colours or 3 different materials)
- Quality tests in conjunction with the university

Contact us!

Further Information:

Kompetenzzentrum
Niedersachsen · Netzwerk
Nachwachsende Rohstoffe e.V.
www.3-n.info

3N Kompetenzzentrum Niedersachsen Netzwerk Nachwachsende Rohstoffe e. V.
Kompaniestrasse 1
49757 Werlte

Hansjörg Wieland
Tel.: 05951-9893-13
Email: wieland@3-n.info

Dr. Marie-Luise Rottmann-Meyer
Tel.: 05951-9893-12
Email: rottmann@3-n.info

Unterstützt durch /
Mede mogelijk gemaakt door:

INTERREG Deutschland Nederland · EDR · Ministerie van Economische Zaken · Niedersächsische Staatskanzlei · provincie Drenthe · Provincie Noord-Brabant · provinsje fryslân provincie fryslân · provincie groningen · provincie Gelderland · provincie Overijssel · Provincie Flevoland