PROJECT NO: FP6-513205

POLYDRY

THE DEVELOPMENT OF AN IN-LINE ENERGY EFFICIENT POLYMER MICROWAVE BASED MOISTURE MEASUREMENT AND DRYING SYSTEM

Co-operative Research (Craft)

Horizontal Research Activities Involving SMEs

Publishable Final Activity Report

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Start Date: 1st October 2004 Duration: 27 Months

Lead Contractor: Wittmann Skandinavien ApS Version 01

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Project Information

PROJECT NO: FP6-513205

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TITLE OF PROJECT*:* THE DEVELOPMENT OF AN IN-LINE ENERGY EFFICIENT POLYMER MICROWAVE BASED MOISTURE MEASUREMENT AND DRYING SYSTEM - POLYDRY

COORDINATOR: Wittmann Skandinavien ApS

SME EXPLOITATION MANAGER: Wittmann Skandinavien ApS

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3 Gisip AB
4 ITS-Plastics Ltd

OTHER ENTERPRISE / END USER CONTRACTORS**:**

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Executive summary

This report covers the work carried out in the EC FP6 CRAFT project POLYDRY. The overall industrial objective of the project is to develop a new low cost, rapid, energy efficient microwave based moisture measurement and drying system. This will enable in-line, accurate, real-time microwave moisture measurements to control the drying process, integrated with a low cost microwave based drying system that can dry a diverse range of polymer types. These will be joined together by an intelligent control module to enable closed loop control of the continuous measure-dry process and integration with the downstream process.

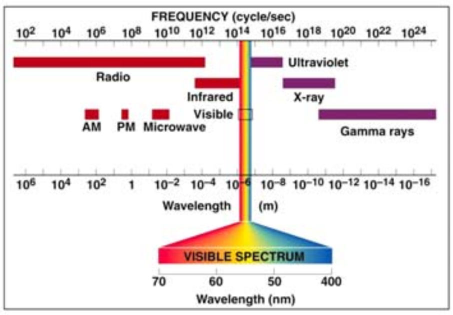
This proposal aims to improve the quality of life of all EU citizens by enabling plastic processors to rapidly and effectively identify and control polymer moisture levels thereby dramatically reducing scrap and rejected products which will reduce the amount of material to be granulated thereby reducing the time operators are exposed to the dangers of granulators reducing fatal and major injuries in the plastics processing sector.

The technical objective plans to reduce energy requirement of the drying phase of polymer processing, increased productivity through savings in drying time and reduced waste by eliminating faults related to residual moisture as a consequence of inadequate drying. The result of this innovation will be a more competitively priced service & supply of plastic products from EU plastic processors competing in a global market.

The technical work over the reporting period (1st October 2004 – 31st December 2006) has been spread over the tasks in Work Packages 1, 2, 3, & 4:

WP 1;	Enhanced Scientific Understanding of Polymer and Microwave Interaction
WP 2:	Moisture Content Sensing Development
WP 3:	Microwave Drying Development
WP 4:	Integration and Industrial Trials

Project management co-ordination, clustering, dissemination & implementation have been on-going throughout the life of the project. The 'Kick-off' meeting was held at Wittmann Skandinavien ApS on 10th November 2004, where the project goals, work plan and initial actions were successfully presented and agreed upon. During the duration of the project meetings were held approximately every 3 months hosted by various partners reviewing and carrying out trials for their relevant tasks

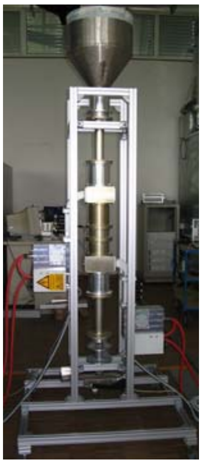


The theory of micro-waving was investigated and compared with conventional thermal processing and it has been determined that microwaves belong to the portion of the electromagnetic spectrum with wavelengths from 1mm to 1m with corresponding frequencies between 300MHz and 300GHz. The two most commonly used frequencies are 0.915 and 2.45 GHz. The theory also shows that the two main mechanisms by which microwaves produce heat in dielectric materials are ionic polarization and dipole rotation and microwavability of thermoplastic polymers mainly depends on the dielectric constant and the tangent loss of the materials.

The material properties and chemical structure of polymers were investigated with regard to the transportation of water and their dielectric properties. Trials concerning the microwave absorption have been carried out and recommendations on microwave system requirements for moisture measurement and removal have been developed. Initial trials to prove that water molecules are bound to polymer have been carried out on a number of selected polymers. The drying techniques used were: Microwave Drying, Conventional Oven Drying and Traditional Dehumidifying Drying. All the results were plotted and the results clearly prove that micro waving polymers helps in moisture loss. Also the percentage weight was found to show some linearity with respect to time of micro waving.

Two sensor types were identified as most suitable for further development: a so called open resonance technique and a cylindrical resonance pipe. The first type is very easy to assemble; the second could achieve a better accuracy. The contact with the manufacturer TEWS/Germany was intensified who agreed to develop conjointly a system with improved accuracy so that it would fit with the projects demands.

Several polymers of different families were dried, prepared and trialled. Conventional moisture detection was carried out with these samples by Karl-Fischer-Titration and an ABONI-system to calibrate the microwave data. Some of the trials could not identify a clear relation between moisture content and microwave signal. TEWS/Germany could calibrate their systems to deliver a reasonable signal. Several tests with two systems and three types of polymer at different drying stages were carried out. At the moment an accuracy of 0.03 % moisture content can be achieved but at a very low signal level.



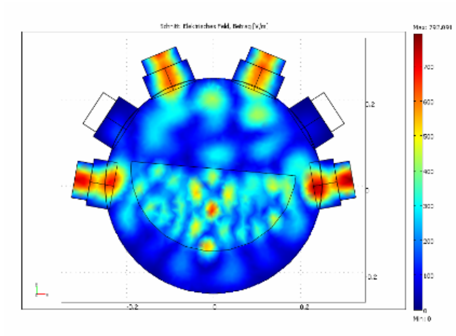
For a continuous inline drying process that means there will have to be several sections with separated power sources and their microwave field inside the dryer should also be separated from each other. A cylindrical waveguide system was developed with sections of different diameters and additional wave traps. The polymer runs through the cylindrical pipe and the output is controlled by a vibrating transport unit.

The development of the moisture measurement software and the drying software a Software Requirement Specification (SRS) document has been created to describe the two first steps “Requirement Analysis” and “High Level Design” of the V-cycle model which has been chosen to develop the software as this is a standard and a recognised approach to develop software. The SRS document has been used to enumerate the feature requirements of the moisture measurement and drying software, regarding the description of work and input from the partners. Preliminary graphical interfaces (GUI) have been built based on the features list, in order to give an idea of what the software should look like to the future end user. The SRS describes also the external requirements for the moisture measurement and drying software. Regarding the moisture measurement and dying devices, the external requirements need to be defined according to the hardware types that will be chosen. Regarding the database that would be used to save moisture measurement setup and drying setup, preliminary tests have been performed to connect a database (Postgres) using the ODBC interface.

A number of extensive moisture measurement trials were carried out on several polymer families, however it was concluded that the necessary accuracy would not be achievable with a microwave based system. The consortium agreed to concentrate the work on the drying system and to use a new offline solution which was tested and resulted with the required moisture measurement accuracy, and the results are reproducible and stable.

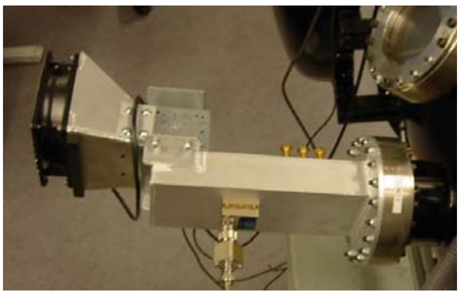
The PC control software for the POLYDRY 'pilot' microwave drying system will be able to sense the temperature of the plastics material and control the magnetrons involved in the drying, thus allowing the user to dry plastics material before using it in production. The user is able to interact with the drying system through a Graphical User Interface (GUI). The notion of context will be used in the User Interface (UI) to describe a specific software setup for each material to be dried. The software will also be able to use a database for saving and retrieving data. The user will be able to monitor and control the system from different GUIs.

The microwave drying process needs a variation of microwave power vs. time. The microwave radiation is generated by a Magnetron (MW-Source). From the Magnetron the microwave radiation is guided through a waveguide circulator which can be tuned by the Autotuner/Impedance analyzer that optimizes the impedance of the waveguide. The power requirement can be reached by a combined number of magnetron heads. Using COMSOL-simulation software the field pattern in the 3D model concept design of the 'pilot' microwave drying system can be simulated which depends on the incident angles of the waveguides beaming into the cylindrical cavity.



Initial trials successfully dried different raw materials in a 'lab based' Micro Wave system and determined that the plastic granulate should be dried using Micro Waves to heat up the moisture in the plastic granulate but it should be done under vacuum and with a IR sensor temperature control build into the process to provide continuous measurement of the temperature in the plastic raw material.

Design ideas for the 'pilot' microwave drying system were produced and an outer chamber and inner drum concept were successfully reviewed and a 3D concept model developed. The positioning of the magnetrons was critical for good distribution of the microwave field pattern. The spacing of the magnetrons and their individual alignment to the chamber was determined by using simulation software to analysis of the microwave field in the prototype 3D Model. This also defined the design parameters of the waveguide components to be made. The POLYDRY 'pilot' microwave drying system was successfully built, assembled and initial vacuum Tests were carried out before shipping to Sonderborg Plast where the waveguides, magnetrons, power supply was fitted and control system integrated together. The waveguides were fine tuned and initial checks performed before validation trials phase.



A detailed costing spreadsheet was produced which calculated that the overall estimated cost for the build of the POLYDRY prototype system was acceptable, however this cost will be significantly reduced when the system is designed for manufacture and volume production set-up.

Initial validation trials concentrated on the functionality tests for the systems components and fine tuning of the system that reduced the reflected power to < 2% and achieved an efficiency of 80% with each magnetron. Water load tests were carried out which concluded that the functionality of the microwave components had been successfully demonstrated. Further system trials with vacuum and plasma are now planned for springtime 2007.

Overview of Project Objective

The overall project objective is the development of a new low cost, In-line, rapid, energy efficient Polymer microwave based moisture measurement and drying system where the key requirements are:

- A real-time microwave moisture measurement system to control the drying process.
- An integrated low cost microwave based drying system that can dry a diverse range of polymer types.
- An intelligent control module to enable closed loop control of the continuous measure-dry process and integration with the downstream process.

The key operation targets to develop a prototype microwave drying system are outlined below:

- Provide a microwave generator capable of achieving the drying of polymer granules passing through a continuous feed system.
- Controlling a drying process of the specimen as a function of the changes of the monitored microwave energy.
- Provides relative and absolute moisture detection down to 0.01%, 10 times/second, for 95% of the polymer types on the market.
- Provides accurate drying for 95% of the polymer types on the market to moisture levels of 0.01%
- Provides sufficiently accurate process control of the moisture vaporisation process to avoid clumping of the polymer particles due to melting
- Provides drying of 100kg of polymer per hour at a maximum output rate of 1.6kg per minute.
- Achieves polymer drying with a 50% reduction in energy usage compared to conventional hot air drying systems.
- Provides a continuous drying facility, which meets safety requirements for microwave shielding to current safety standards.
- Provides continuous polymer drying facility, which can be, electronically and mechanically interfaced with existing industry standard materials handling equipment.
- Supports the data storage of material drying parameters for quality assurance systems and traceability requirements and has a built in reference database covering 50 of the most commonly used polymer types, while supporting the definition of a material traceability setting for 1 polymer type within 5 minutes.
- Has a total cost of less than €20,000 per unit to the SME plastic processors.

Relation to Current “State of the Art

State of Art for Drying of Plastics

Hot air drying is at present time the most commonly used method for drying polymers. The convection heating from hot air heat the granules and pass dehumidified air over them as moisture works its way to the surface. The air is dried with the use of a silica gel dehumidifier. Hot air heats the mass of the plastic granule as well as the moisture inside it and the surroundings of the system around the granule. As a consequence energy consumption is high and drying time is also high as a result of the time needed to heat the embedded moisture. This traditional way of drying plastic granules is not flexible, as it is necessary to begin the drying process 4 hours before the granule is used in production. The capacity of a portable large-scale hot air dryer is approx. 400 kg pr. hour. The consumption of energy at this capacity is 30kW/h. Energy consumption with a central drying and transportation unit is lower with energy consumption at only 0,27 kWh/kg plastic raw material. This is based on an average of 4 hours drying time at 80 degrees Celsius.

Other methods of drying polymer granules are:

- Vacuum Drying
  As with convectional heating it also has a high-energy consumption and is applicable primarily for bulk drying and is unsuited for in-line drying systems with a continuous flow of granules.
- Infrared (IR) Drying Systems
  The problem with infrared heat is similar to hot air drying. The infrared waves heat not only the embedded moisture, but also the mass of the raw material. As a consequence energy consumption is significantly higher compared to microwave drying systems and drying time is approximately the same as for hot air drying.

State of Art of Moisture Measurement

Many techniques for moisture measurement exist. These techniques can be broken down into offline and online categories.

Offline Methods

- Thermogravimetry
  The main problem with this procedure is that it has to be done offline. The major sources of error with the method lie in the standards of sample handling and the possibility of driving off volatiles other than water when looking at low levels of moisture.
- Karl Fischer Analysis
  Yet again, this method is an offline technique, but is very sensitive and capable of measuring moisture in the parts per million, range (0.01% = 100ppm). Indeed, the Karl Fischer test is aimed at measuring very low concentrations of water
- Calcium Carbide / Gas Pressure Meter
  . This method is not suitable as a control or quality assurance test as it is not adequately sensitive to very low concentrations of moisture and pressure variations due to temperature change may mask results.

Online Methods

- Neutron Probe

The obvious disadvantage is that its operation relies on hydrogen atoms, which are virtually always present in polymers as well as water. There are also the problems of working with isotopes and emission of radiation.

- Gamma Attenuation
  It has a number of shortcomings notwithstanding the need to work with a gamma radiation source, the technique is affected by bulk density variations and there is a strong possibility that irradiation of a polymer could cause crosslinking or degradation.
- Nuclear Magnetic Resonance
  The major disadvantage is that the processional frequency of nuclei is dependant on their chemical environment. The different ways in which water can be absorbed into polymers will result in different peaks having to be measured for different polymers. Unlike other online techniques, nuclear magnetic resonance will not produce results at the rate required of this task within the project
- Infrared / Near Infrared Reflectance
  The main drawback of this method is that it is a reflectance method and as such will not give a measure of moisture deeper than a few microns beneath the surface of a granule of polymer.
- Resistance / Capacitance Measurement
  Due to the insulating nature of many polymers these methods may be limited to the detection of surface moisture, with water held deep in granules being protected by the dry, insulating surface skin of the granules.

Final Plan for Using and Disseminating the Knowledge

See Deliverable M15: Dissemination and User Plan