PROJECT NO: FP6-513182

THERMOFIT

THE DEVELOPMENT OF A THERMAL IMAGING BASED PART INSPECTION TOOL FOR INJECTION MOULDING

Co-operative Research (Craft)

Horizontal Research Activities Involving SMEs

Publishable Final Activity Report

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Project Information

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TITLE OF PROJECT:	THERMOFIT – The Development of a Thermal Imaging Based Part Inspection Tool For Injection Moulding
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SME EXPLOITATION MANAGER:	Micotron A/S

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3 Contura
4 Automation Technology
5 Sciteq Hammel
9 Gimplast

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6 Engel

RTD PERFORMER CONTRACTORS:

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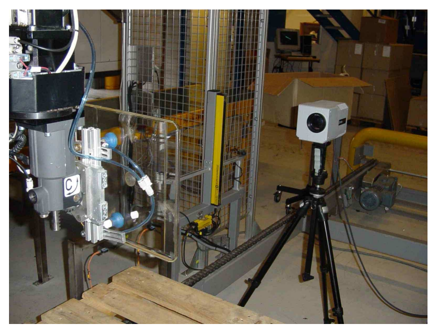
Executive summary

This report covers the work carried out in the final reporting period of the THERMOFIT project. The main body of this report is a précised overview. However, more detailed appendices are attached to cover the technical work programme.

The Thermofit project proposes to develop a new low cost Thermal Imaging based Part Inspection System that allows injection-moulders to rapidly identify parts that are faulty or likely to develop failures.

This proposal aims to improve the EU Plastic competitiveness by enabling plastic processors to rapidly and effectively identify failure in their production process which will reduce their operational costs.



The technical objective plans to use infrared technology combine with a pattern recognition system to look for faults in produced plastic parts which will reduce the waste by adjusting the process parameter of the injection moulding machine and then before getting severe fault.

The technical work over the second 15-month period (1st December 2005 – 31st March 2007) has been spread over the tasks in Work Packages 1, 2, 3 & 4:

WP 1:	Enhanced Scientific Understanding of Polymer Thermal Profiles after Demoulding
WP 2:	Fault Inspection Module
WP 3:	2nd Order Part Inspection Module
WP 4:	Integration and Industrial Trials

There have also been a number of successful project and technical meetings hosted by various partners reviewing and carrying out trials for their relevant tasks.

These tasks cover the completion of a fault inspection platform capable of learning to recognise faults and integrated in a production environment.

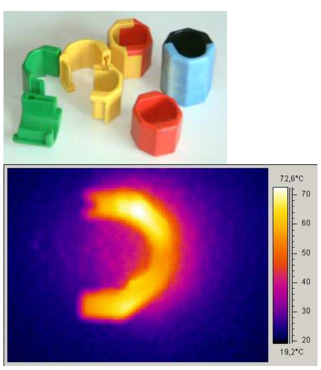
Approach

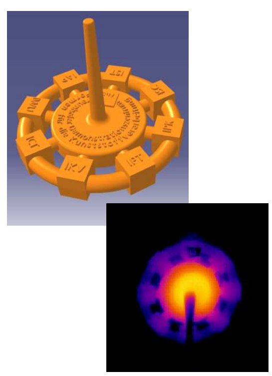
Project management co-ordination, clustering, dissemination & implementation have been on-going throughout the life of the project. The 'Kick-off' meeting was held at Pera Denmark on 13th January 2005, where the project goals, work plan and initial actions were successfully presented and agreed upon. 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.

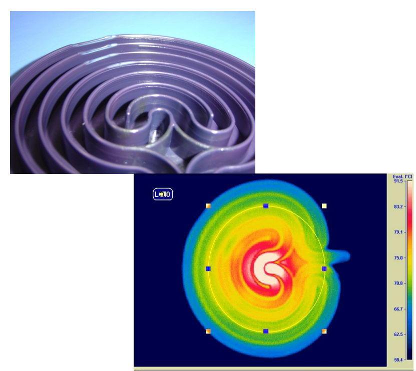
One result of first meetings was that the inspection system must be applicable to any part, this being regardless of fault, geometry and material, this poses a challenge regarding the software because no static variables can be used, as these might not work on certain faults, geometries or materials. Hence all variables should be dynamic, meaning they will be calculated based on the given dataset. For each type of fault Thermofit will need to detect, a specific module will have to be developed.

The user interface must be very simple and straightforward, as the end users are likely to have little or no experience regarding the setup of software or vision systems, and the solution of the problems will therefore be created requiring little or no user setup.

The software setup must also be very simple and fast to configure and use, as software with a complex configuration might not be used. If the machine operator does not understand what he is doing or finds it too time consuming compared to the traditional "trial and error" approach, the operator is likely not to use the software.



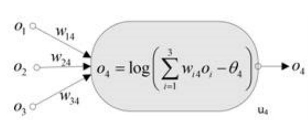




Furthermore the software must be fast to setup, and require as little training as possible, because a system requiring thousands of parts would provide little or no benefit to the average end user running small batches. To sum up the general requirements and the issues to address in this document:

1. **Adaptable** – No static variables concerning part and fault size, geometry and material
2. **Simple** – limited user configuration
3. **Fast** – fast training by a reduced amount of features.
4. **Accurate** – high rate of detection
5. **Robust** – Applicable to an industrial environment

Due to the high adaptability and the proven track record of **Neural networks** within classification and pattern recognition, a solution using neural networks for the fault identification module has been chosen.



Platform

To meet the objectives a test platform has been created for both the scientific investigations and the industrial trials.

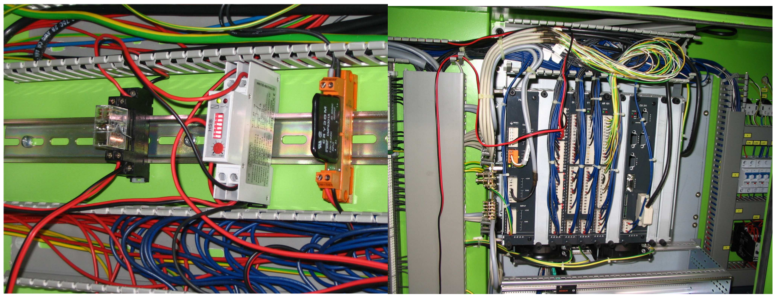
Elements of the test platform are given below:

Machinery at Fraunhofer ICT: Engel ES 200/60 HL ST

Gas injection unit: Maximator gas pressure control unit

FLIR IR-Thermacam SC 500

Trigger Equipment



Robot handling from Engel ER-HLi 31 VC

Pictures of the test platform

Results

Tests have been performed on different material: ABS, PP and PA6; and different type of moulds:

- Tests performed on GAIM parts (U-part, spin part) to produce incomplete filling part
- Tests performed on solid part (U-part, Porch part, Micotron mould, Gimplast and Micotron mould) to produced warpage and marks

Currently the accuracy of the system, depending on the test data set ranges from 98% to 100%. The majority of the performed tests yield very good results. The faulty with no access to the physical parts its extremely difficult to determine why the system detects bad parts as good, the injection moulding process is very difficult to micro manage and small deviations occur between shots, hence some parts may be borderline good and hence the system detects it.

Overview of Project Objective

The overall scientific project objectives are:

- Enhance the scientific understanding of the influence of part geometry and material on the temperature profile on polymer components as they are removed from the mould
- Enhance the scientific understanding of the relationship between variations in component surface temperature profile during a production run, and the part quality, both when it has cooled and when it is reheated during post-mould processing

The overall objective of our work is to develop a new low cost Thermal Imaging based Part Inspection System that allows injection-moulders to rapidly identify parts that are likely to develop failures, as a consequence of cooling or future expensive reprocessing and that has the ability to:

- Supports the storage of calibration settings for the emissivity of commonly used polymers and enables the calibration of the system to new polymer materials in less than 5 minutes.
- Support the analysis of temperature profiles of a moulded component in less than 2 seconds.
- Supports user-friendly polygon/freehand drawing and editing of area selections on part thermal images.
- Supports at least 4 different “fuzzy” temperature tolerance curves: Range, value, “less than” and “greater than” and attachment of a curve to a selection area.
- Supports storage of areas with tolerance curves attached.
- Supports easy drawing and editing of gradient linking (with e.g. arrows) of different areas.
- Supports tolerance curve attachment and storage of gradients.
- Supports the prediction of polymer part defects before the parts have cooled down and before reheating with an accuracy of 95% within 1 week of production.
- The system is applicable to 90% of the polymer types used

Relation to Current "State of the Art

Part Inspection

Post-mould quality analysis and part inspection is often used in addition to pre-process prediction and continuous data acquisition to ensure that no bad parts are shipped to the customer. These techniques currently include monitoring part weight, digital image analysis, laser measurement and touch probing.

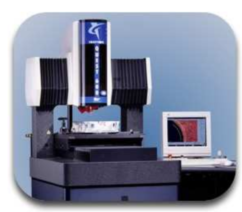
Measuring Part Weight

Part weights are compared to an average for the part, and monitored for changes, which indicate variations in the processing parameters. The limitations of this technique are that only the weight of the part can be monitored, and this gives no indication to the operator of any quality indicators other than the mass of material that has been pushed into the mould. Poor quality mouldings could pass undetected, and defects that would not appear until cooling is complete would not be observed at all.

Digital Image Analysis

Digital image analysis involves the acquisition, digitisation and algorithmic analysis of images of the moulded part to rapidly check for immediately visible faults that may have occurred despite tight machine parameter control. This image analysis can be performed on-line in a cycle time of 4 seconds per part [1] [2]. The limitations of this technique are that only defects that are visible at the time of analysis are able to be detected. This method cannot detect features that will only develop once the moulding has thoroughly cooled.

OGP Smartscope System



The OGP Smartscope system takes this one step further and combines video, laser and touch probe to check precise surface finish and dimensional form to an accuracy of 4 microns[3] [4]. The video performs digital image analysis, with the same limitations as previously described. The laser provides auto focusing for the video and measures surface profile[5] [6]. This allows slight changes from the desired surface to be detected, but cannot predict the change in geometry that can occur on cooling. The touch probe can be used in combination with non-contact video sequences to form a single measuring cycle with automatic reference and calibration to the same co-ordinate system[7]. Again, this cannot be used to predict what will occur once the part has completely cooled.

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1 Losner, L and Voloshin, A. S., Compact Disk Quality Control Using Digital Image Processing, NDT International, Vol 23, Issue 3, June 1990 pp.147-151

2 http://www.intego.de/download/Kunststoffe_PR_0103_e.pdf

3 http://www.qa-talk.com/news/ogp/ogp100.html

4 http://www.manufacturingtalk.com/news/ogp/ogp100.html

5 http://bcmac.com/OGP/DRSLaser.pdf

6 http://www.ogpmesstechnik.de/laserprobe.htm

7 http://www.qa-talk.com/news/ogp/ogp100.html

Thermal Imaging

Thermal imaging has been available for some years as one method of identifying defects. However, the relatively high costs of the cameras and their complexity have resulted in a situation where the cameras have remained in the hands of specialist thermographers8. However, new technology has lowered the cost hurdle of implementing a thermal imaging system. Current state-of-the-art thermal imaging cameras are capable of detecting temperature variations very accurately and can thus be used as a component of a system for detecting defects at an early stage of failure. In addition, thermal imaging cameras are able to provide real-time thermal images at adjustable speeds, which is essential for capturing the heat flow behaviour of a product9. Computer hardware with enhanced capabilities adds to such improvements. For instance, huge amount of data can be acquired, calibrated, processed and stored in real-time.

Because of the increased processing power of computers, dedicated software for thermal imaging offers new possibilities. For instance, thermal data for a given inspection process can be stored for VCR style playback, used for online process control or exported via serial or TCP/IP connection into a database for further analysis. Also thermal imaging software allows users to define key interest areas of the thermal image, which is a key interest in process control. Thermal imaging systems have been used for detecting defect cooling channels in the mould, however no thermal imaging systems are available today that can perform predictive quality control to detect part defects before the parts are cooling[10].

Although limited in scope research has been conducted at some of world's leading universities of combining thermal imaging and Image Analysis for industrial use. However, in most research and applications conducted to this date the technologies are used for validation purposes and not for predictive fault analysis and process control.

8 Infrared Thermography Advances Aid Proactive Maintenance, Jersey Infrared Consultants, 2002

9 Introduction to NDT by Active Infrared Thermography, Maldague, X., Université Laval, Canada, 2002

10 www.Innova.de

Final Plan for Using and Disseminating the Knowledge

See Deliverable D28: Dissemination and User Plan