Publishable Executive Summary

Project details

Project Title:	Monitoring, Optimisation and Control of Liquid Composite Moulding Processes	
Project Logo	Project web site (public area)	Coordinator's Details
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Project summary

The main limitation of the currently existing Liquid Composite Moulding manufacturing technologies in the fabrication of high quality, affordable and highly integrated aerospace structures lies in their inability to combine the available information (accurate simulations, measurements, experience and knowledge) that deals with the **integrated** process (resin flow and cure) into a **global** control system.

To circumvent this limitation, the COMPROME project proposes not just the refinement and integration of existing control approaches, but the development of a revolutionary control system applicable to the production of composite materials through a wide range of LCM methods. It employs the dielectric signal for sensing resin flow and cure processes and consists of:

- an integrated, durable and tool-mounted dielectric **sensor** ;
- modular **monitoring system** with embedded knowledge;
- a process **control strategy**;
- a global **integrated process control** (IPC) system;
- the manufacturing aerospace components with **cost-effectiveness** and **improved quality**

The proposed novel **global IPC scheme** brings full benefit from the use of monitoring devices and the utilisation of the existing process knowledge. The benefits to aerospace manufacturers include the manufacturing cost-effectiveness, while the global nature of the control scheme allows the fabrication of large and complex components (free of joints and bonds), thus contributing to increased safety and weight saving in the aircraft. The system promotes closed mould processing techniques, which possess significant environmental benefits due to reduced emissions in the production area.

The main **innovations** reside in:

(a) an integrated, durable and tool-mounted dielectric sensor cluster
(b) the multi-sensor real-time monitoring system;
(c) the interface between composites process simulation tools, process actuators and composites process monitoring tools.
(d) the intelligent guidance of the manufacturing stage along a predefined path of global process conditions towards a given final state.

Duration

From 01 February 2004 to 31 July 2007

Key objectives

The principal and measurable objectives of the project are summarised in the following table. The benchmarking of the COMPROME system and its components will address the attainment of these objectives.

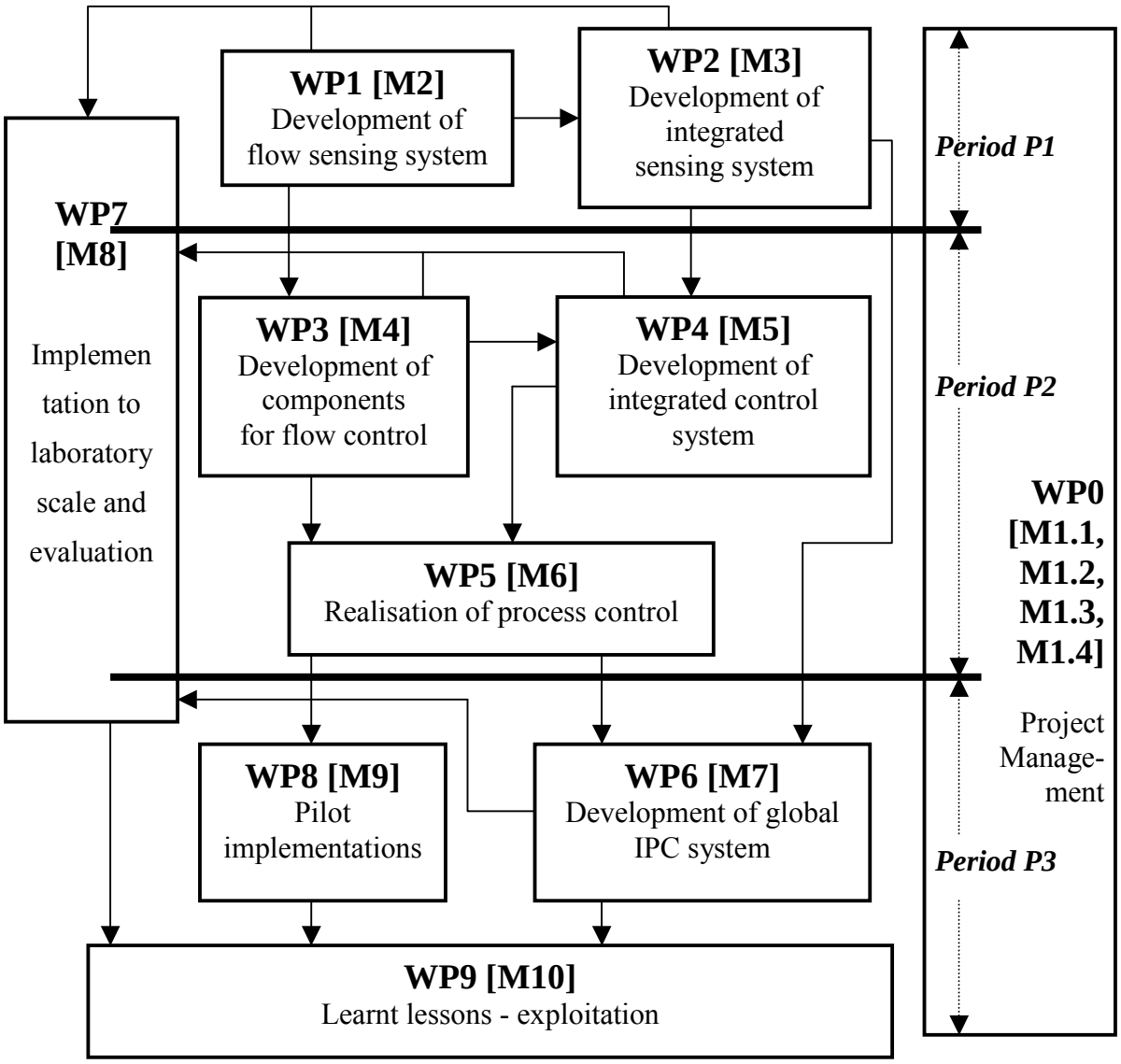
Scientific research objectives	Technical and technological research objectives
Design and prototype fabrication of a robust and durable (tool-mounted) **integrated dielectric sensor cluster** capable of characterising accurately and reproducibly local flow (speed, direction, depth) and cure progress (material properties evolution)	**Integration** of process simulation tools with process monitoring and injection control equipment capable of reducing LCM production development costs by 40%
Development of **process monitoring strategy and guidance** with high speed signal analysis and interpretation assistant features	The **guidance of a composites manufacturing process** through an optimal path to the attainment of prescribed material properties, capable of reducing the overall process cycle by at least 50%
Development of intelligent **on-line flow control** validated on the mould filling of high temperature curing composite materials	**Integrated process monitoring system** with embedded knowledge and established links to actuators capable of reducing scrap by at least 30% in the short term and by 90% in the long term
	Fabrication of structural components using the **global IPC (integrated process control) system**

Consortium

Participant Role	Partic. no.	Participant name	Participant short name	Country
Coordinator	1	INASCO Hellas	INA	Greece
Contractor	2	Technika Plastika SA	TPA	Greece
Contractor	3	Polyworx VOF	PWX	Netherlands
Contractor	4	ISOJET Equipements	IJT	France
Contractor	5	Israel Aircraft Industries	IAI	Israel
Contractor	6	INASMET Fundacion	INT	Spain
Contractor	7	KEMA Nederland b V	KEM	Netherlands
Contractor	8	National Technical University of Athens	NTU	Greece
Contractor	9	Bombardier Aerospace, Belfast	SHS	United Kingdom
Contractor	10	Kok & van Engelen Composite Structures bV	KVE	Netherlands
Contractor	11	Laser Zentrum Hannover	LZH	Germany

The consortium reflects the strong industrial interest due to the participation of 2 large aerospace companies, supported by 3 industrial research organisations, 5 SMEs and 1 Universitiy from 6 member states and 1 associated state, all those well experienced in manufacturing technology.

Project Workpackage interdependence



Work performed

In the third Year of the project, the technical work covered continued activities in all project WPs (WP1 to WP9).

The developed flow sensing technology was assessed in WP1 in terms of performance and comparison was made to other competing approaches on flow monitoring for closed mould processes.

The property grid (material state vs. dielectric signal vs. temperature) was developed for two resin systems allowing the real-time measurement of the degree of cure in composites processing (WP2). Additionally, the integrated (flow and cure) sensors were tested in RTM and infusion processes. The dielectric measurements standardisation issues were defined and addressed.

The development of flow control system was completed in terms of the use of flow simulation software as identification tool, the development of flow optimisation algorithm and the integration of the above tools to hardware (WP3).

The enhancement of existing cure control tools with a sophisticated monitoring strategy and fast/reliable cure optimisation tools was made in WP4. Also the integration of flow control to cure control has been implemented and supplied to the lab bench for testing.

The specifications of actuators for flow control have been compiled in WP5 and the virtual benchmarking of process control has been performed in terms of selected criteria and assessment.
The development of multi-channel monitoring system has been completed and the basic rules for sensors and actuators placement have been defined in WP6.
The flow and integrated control tools have been implemented in lab scale and their benchmarking has been completed in WP7.
The tests cases at IAI and Shorts in WP8 are defined and the integrated control tools have been installed. The test plan is in progress.

The plan for using and dissemination the knowledge is being updated. Conference presentations have been made and more are planned, while the first publication is in preparation.

Results achieved so far

The main output of the reporting period is the development of an integrated (flow and cure) process control system applicable in several Liquid Composite Moulding (LCM) applications. The operational components of the new system are: (i) the optimisation algorithm for the flow and cure control linked to flow simulation and cure modelling tools, (ii) the multi-channel monitoring system with capability to handle several flow and cure sensors, (iii) the rules for sensors and actuators placement in process toolings and (iv) the experience from the lab scale implementation of every component individually.

The integrated sensors are applicable to autoclave, RTM and infusion process environment. Tests show the robustness of sensor elements and the utility in providing quality control in composites processing.

Expected end results

The project aims to develop a revolutionary control system applicable to the production of composite materials through a wide range of LCM methods. The COMPROME system utilises the dielectric signal for sensing resin flow and cure processes and consists of: (i) an integrated, durable and tool-mounted dielectric sensor; (ii) modular monitoring system with embedded knowledge; (iii) a process control strategy; (iv) a global integrated process control (IPC) system; (v) the manufacturing aerospace components with cost-effectiveness and improved quality.

Intentions for use

A significant concern of the Consortium is to establish the path for the industrialisation of the COMPROME scheme, while ensuring that it is an operational method, and it would need further developments and investments to reach the productivity and profitability required from an industrial production unit. INA is the fundamental partner for this purpose, and assumed the positive results obtained with the pilot implementations, an industrialisation plan is foreseen to a fully industrialised scheme within two years after the end of the project. These plans include the full documentation of the scheme internal procedures for the certification and approval by the aviation authorities. The active involvement of all industrial partners is planned to provide the initial information and guidelines for this matter.

Impact

The project's technical development addresses significant problems related to the user groups:

- the aerospace composite material producers
- the manufacturers of process equipment and systems
- the measurement and testing equipment producers
- the developers and users of process monitoring sensors
- the research laboratories and process development sites.