FP6 Project: COLL-CT-2006-030338

ADOPTIC

Additive Optimisation for Improved Ceramics

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Activity area: **Horizontal Research Activities Involving SMEs**

WP 11 – Project Management
Publishable Final activity report

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Project coordinator organisation name: *CERAM Research*

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RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	X

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Diffusion list

Consortium and the EC

Approvals

	Name	Company	Date	Visa
WP Leader	P. Jackson	CERAM	22-12-2009	Approved
Coordinator	P. Jackson	CERAM	22-12-2009	Approved

The report was circulated also to the IAGs for validation.

Documents history

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1. Project execution

Project Identity Card

Acronym	**ADOPTIC**	
Title of the project	Additive Optimisation for Improved Ceramics	
Proposal number	**COLL-CT-2006**	
Contract number	**030338**	
Starting date / End date	01/09/2006	31/08/2009
Duration	3 years	
Total Budget / Total Manpower	1 836 899,27 €	301.29 PM
Community Financial Contribution	1 316 782,60 €	
Project Officer	**Annabelle ASCHER** European Commission – Research DG	

Contractors involved

N°	Name	N°	Partner
1	CERAM	15	HYBNER
2	FEDERCER	16	SD
3	BCC	17	VULCAN
4	APICER	18	PSR
5	AIDA	19	TENMAT
6	GRAF	20	CC
7	INCO	21	CNR-ISTEC
8	NOEMI	22	UAVR
9	EUROCOAT	23	AGH-UST
10	CERINVEST	24	UNIMORE
11	PASTCERAM	25	CERAMICOLOR
12	AGORAMAT	26	Internation Syalons
13	DOMINO	27	SOFC Power
14	MANUFAKTURA	28	CONFCER
		29	CTCV
Caption	RTD	IAG	SME

Work packages structure

Type of activities	WorkPackage	WP leader
Research activities - Dissemination and exploitation activities (dissemination and exploitation)	**WP1** : Industrial specifications: **WP2** : Production of rheology measurement protocols relevant to the three generic ceramic shaping routes (each RTD **WP3** : Study of the effects of additives on current pressing-related processing **WP4** : Study of the effects of additives on current plastic forming processing **WP5**: Study of the effects of additives on current suspension-based processing **WP6**: Study of the effects of additives on emerging and nano-ceramics processing **WP7**: Creation and update of the Knowledge-Based System **WP8**: Industrial validation of the additive optimization **WP9**: Dissemination and exploitation activities, WorkPackage	APICER ISTEC UNIMO UAVR AGH ISTEC CERAM AGH BCC
Training activities	**WP10**: Training activities , WorkPackage	AIDA
Consortium management activities	**WP11**: Project management, WorkPackage	CERAM

Introduction

The work packages indicated above can be grouped as follows:

WP1 was all about gathering existing information based on both partner experience and what was availabe in the literature. This information formed the basis of the KS developed in WP7 and the rheology protocols developed in WP2.

WP3 to WP6 were all about augmenting the existing knowledge from WP1 by carrying out experimental work associated with additive use in the three main ceramic processing routes:

- Via fluid suspensions that can be cast into shaoes,
- via powders that can be pressed into shapes,
- via plastic ceramics that can be extruded, moulded into shapes.

WP6 covered novel processing that deviated from the classic routes in WP3-5. WP3-6 also allowed the consortium to test the viability of approaches with potential to help SMEs with their processing issues in WP8.

Thus, ultimately WP1 though WP6 generated information for the Knowledge System (KS) development in **WP7**.

WP8 applied the KS to solving real industrial problems. The problems were specific to each SME partner and work was conducted on a 1:1 basis in that RTDs worked with each SME. In reality, information from WP1-6 led to solutions being explored in WP8 much earlier that envisaged.

WP9 and WP10 helped re-inforce the message of careful additive selection and trialling to both partner and external SMEs. It also generated useful feedback to WP7, allowing a final version of the web-based KS to be created by the project end. WP9 also defined post-project actions for exploitation.

The **two main general objectives** of this project asa whole were:

1. **To improve final ceramic products and raise yields by 1 to 15% depending on the product/process category** thanks to an appropriate selection and dosage of additives

2. **To help SMEs to integrate emerging technologies, thus, maintaining the competitiveness.**

More specifically, this objective had **three sub-objectives**:

2.1 To develop rheology protocols in order to determine how to measure the rheology with respect to the application for each main family of process (in order to homogenise the language between the whole ceramic sector).
2.2 To compare the additives, to determine the best mixture for the targeted applications proposed by the core group SMEs, as well as to adjust the mixture depending on the processing conditions.
2.3 To create a database able to provide the information on additives to manufacturers of ceramic products.

In terms of the first objective (additive optimisation to raise yields, product performance etc.), WP8 represented the ultimate delivery point. In WP8, SMEs worked on a 1:1 basis with RTDs to address specific processing problems. In carrying out this work, use of rheology protocols created in WP2 and the Knowledge System (WP7, created using WP1-6 information) was paramount. A measure of success against this can be gained from the following comments:

Of 17 production problems explored with SMEs, 7 produced either no benefit or SMEs felt it was too early to quantify benefits because they either
(a) needed to do more in-house work or
(b) develop markets for the encouraging results seen.
In one case (Vulcan Refractories) an improved additive solution in terms of cleaner burn-out was found but rejected by the company as too expensive. However, this stimulated further work on retaining the current binder but identifying faster (lower energy) schedules in which binder additive burn-out was still achieved.

Total annual benefits from WP8 work was quantified at €784K. However of the 9 companies providing quantification only 5 felt the benefits could be realised immediately – the others (especially Polish companies) gave benefits based on what could be realised after the recession or once a new market had been developed. **The annual benefit to the 5 companies able to run immediately with the improved processing now was €535K**.

Whilst at the start of the project yield improvements were thought to be the most likely output, **discussions with SMEs indicated that there were a wider range of "requirements" from additive optimisation**. In some cases, there were dual benefits.

The benefits (and total number of scenarios where they were relevant) were:

- **Yield** – 6 scenarios
- **Energy Savings** (less fuel use in drying firing ceramics) – 4 scenarios
- **Improvements to intermediate** (processing efficiency gains) **and / or end product quality** (via better microstructure) – 5 scenarios
- **A desire to use recycled materials** and so improve the companies "green" credentials – 3 scenarios
- **Embracing new forming techniques** – 3 scenarios
- **Development of new products** – 2 scenarios

Those looking to raise yields (6 companies) reported that improvements of 4-20% could potentially be made as a result of WP8 work.

As regards objective 2 (SMEs embracing new technologies to become more competitive), this was achieved in a number of ways:

- The KS (WP7) contains information on emerging ceramic shaping technologies. All SMEs are free to read this to stimulate ideas.
- Some rheological tests proposed and investigated were "new" to some SME partners
- The importance of strictly using of a protocol against each rheology test was accepted by all SMEs and can certainly be considered as embracing new technology. SMEs not involved in the project (but reached through dissemination) were also honest about not always sticking to protocols – this almost always resulted in SMEs never getting to grips with issues around poor yields etc.
- SMEs became exposed to novel quality control tests outside of rheology (e.g. fired strength tests) by working with RTDs in WP8. In addition they gained skills on how to develop a series of trials to check how different additives impacted on intermediate and final product properties. It is highly likely that SMEs involved in Adoptic will be more likely to seek external help from RTDs in future. This will help cut out any protracted and ineffective trial and error trials conducted in-house by SMEs.

Instrumental to achieving the second objective was:
1) the successful creation of a web based Knowledge System (KS) in WP7 (now available at www.adoptic.eu) containing a wealth of information on additives.

The ability to look for additives within the KS via 3 routes:
- following factory process routes;
- looking at tree diagrams showing families / specific additive chemistries;
- viewing pictures of fault and learning about how additives can help)

was an important step forward – this recognised different levels of awareness of additives across the SME community. During the project, the consortium constantly battled with what information / how much information should be included. There was not always 100% agreement on this, with CERAM making final decisions having listened to feedback at the 6-month meetings. It was decided to restrict entries on additives to a the "Top 60" most common chemistries. Ultimately, there were gaps on the final KS, but it should be emphasized that (a) the KS as it exists is a useful resource and (b) the KS was always seen as a "work in motion" with opportunities to expand the content likely to occur well after the project concluded.

2) The creation of protocols for fluid ceramic powder suspensions, based on three simple, low-cost pieces of apparatus. In addition, tests and protocols for powders and "plastic" ceramics (i.e. intermediate products formed from fluid suspensions) were also delivered and embraced by relevant partners.

3) The creation (and delivery of) training programmes around rheology testing and case studies. This helped to re-inforce to SME partners the importance of using rheology when assessing new additives. The case studies featured actual data on how % yields were increased, material was not waste etc. and how this translated to €K savings per year. Again, this helped to convince SMEs of the benefits they could realise to raise profitability, safe-guard jobs etc.

The majority of companies wanted assistance with existing processing, although GRAF (Ink Jet Printing), INCO (coloured pigments for novel pressing technologies) and SOFC Power (screening tape casting of nano-materials for solid-oxide fuel cells) can be described as needing assistance with break-through processing / products. In addition, although International Syalons were working on pressing of products, WP8 work gave them the confidence to take on work involving more demanding shapes and the use of post-pressing machining.

WP1: Industrial specifications

Original target time-scale: Month 1 to Month 3
Actual time-scale: Month 1 to Month 12

The specific objectives of this WP 1 were to collect information about the three mainsubjects of the Project:
(i) the additives used in the ceramic sector;
(ii) the rheological procedures applied to evaluate the effects of such additives;
(iii) the processes and the products where the additives are involved.

Therefore, the WP was divided in three Tasks:
- Task 1.1: Collation of data on additives
- Task 1.2: Industrial procedures, rheological measurement protocols, industrial practices
- Task 1.3: Industrial specifications on industrial processes and products

Results / Conclusions

Overall, WP 1 went smoothly, with encouraging engagement by SMEs who were keen to share information of their production process routes, additives typically used and aspects of production they were unhappy with / wanted to improve. As the project entered year 2, on-going activities such as introducing new additives naturally became part of WP7 (KS development).

Further information on how the WP progressed is provided below:

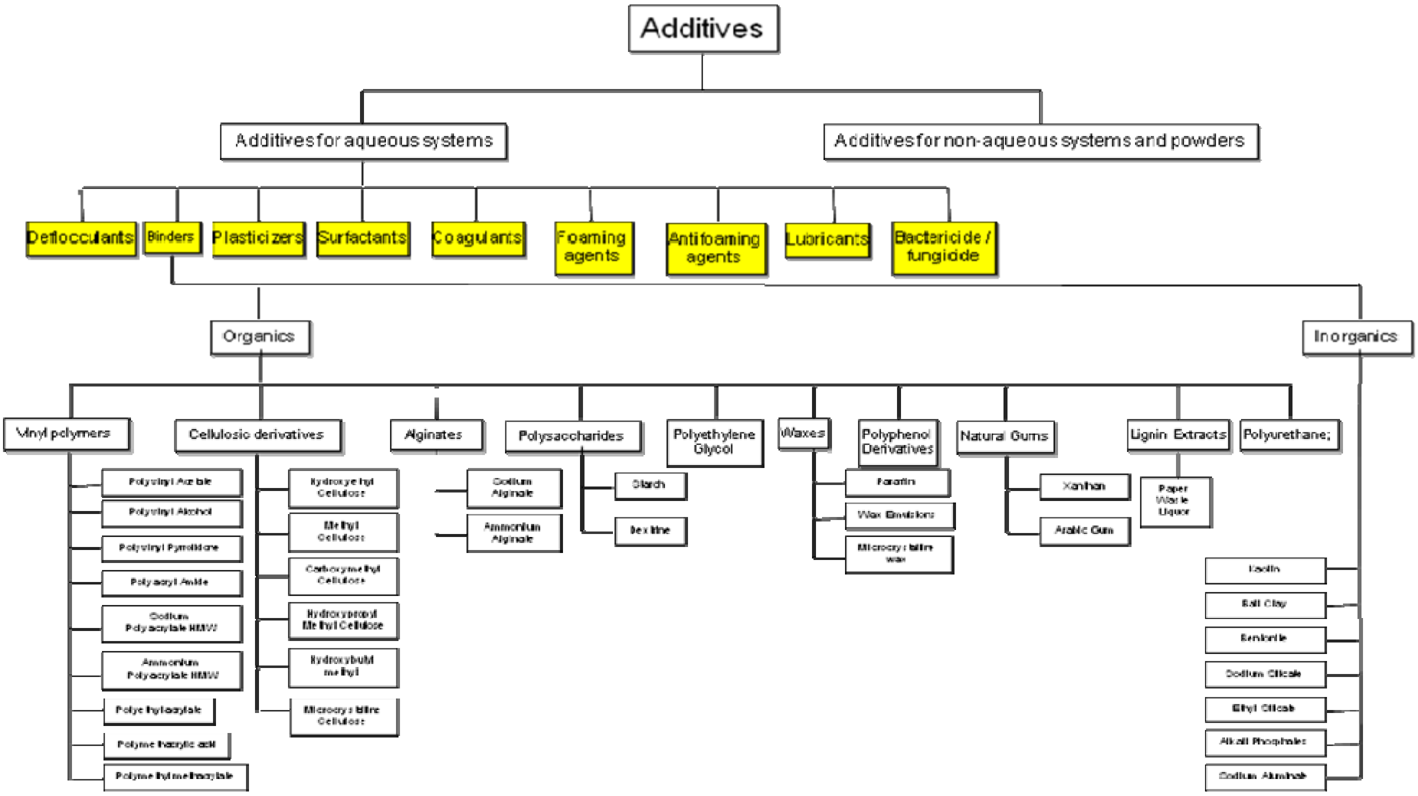
- **Task 1.1. Collation of data on additives There were several sub-activities to this task.**

Task 1.1.1 Firstly, feedback from the SME partners was sought. In particular, RTDs asked about:

A) How should additives be listed (by commercial name, by chemical formula, or by main action developed)?
B) What additive types did SMEs typically use?
C) The difficulties arising when an additive is no longer available in the market;
D) The need of more complete technical information of the commercial products;
E) The effect of the application of new regulations (REACH) on the availability of the additives.

This feedback led to some important decisions regarding the KS:

* It was decided to organize the additive database as a tree diagram, branched, first, by the additive role (a deflocculant, a binder, etc) and, second, by the chemical composition (polyacrylate, cellulose etc.). The concept can be appreciated from the diagram below:



* The KS would contain information on a short-list of 60 additives only. A one-page template containing key information was devised and the RTDs shared repsonsibility for finding / completing the information.
Task 1.1.2 Collation of additive information

It was felt that existing additives knowledge could be gained 70% from RTD expertise and 30% from a literature review and / or RTD discussions with additive suppliers

Based on this information, additional laboratory work was defined and conducted (see WP3 to WP6) to fill in any gaps.

- **Task 1.2: Industrial procedures, rheological measurement protocols, industrial practices**

A state of the art of the rheological instruments, tests and practices currently used by the technicians of the ceramic SMEs was carried out via a detailed questionnaire. It showed that there is a great variability of procedures because each factory has adapted the procedure to its fluid ceramic suspension process route. It was clear that the absence of common standardized practices, along with the use of empiric viscometers, made it impossible to sensibly compare the results of the measurements performed in different factories.
However, RTD partner CNR-ISTEC was able to define an approach to developing simple, reproducible rheology tests (WP2). Partners agreed that sophisticated tests should only be used if the simple ones fail to solve a production problem. Details of the techniques, together with contact information for research groups that can carry out sophisticated rheology tests, would be provided in the Knowledge-Based System

- **Task 1.3: Industrial specifications on industrial processes and products**

Another questionnaire was sent to the SMEs to obtain information on their current processes. IAGs were requested to collaborate to collect information from their SMEs members about processes/products.

In this Task the SMEs helped RTD performers in:

(a) describing in details their processes (this helped CERAM in WP7 to include generic process routes within the KS)
(b) defining the problems, faults, losses that can risk in production (also critical to offering SMEs another way on interrogating the KS)
(c) ensuring that the Knowledge-Based System asks questions that are pertinent to factory production.

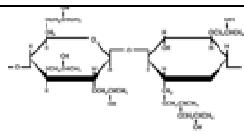
A final questionnaire was sent to the SMEs to know which technical information relating to additives were useful for them. It was organised as electronic form and distributed online for the filling. Encouragingly, all the SMEs answered and this provided good feedback as summarised below:

Number of SMEs that have answered	17	
	Percentage of request	
pH	87,88%	
Sodium content	51,52%	
Molecular weight	39,39%	
Aspect	12,12%	
Chemical formula	25,76%	
Total solids(%)	78,79%	
Glass Transition Temperature(°C)	27,27%	
Density	37,88%	
Viscosity	92,42%	
Residue after firing in air (%)	43,94%	
Applications	60,61%	
Material safety data sheet	80,30%	
Other	1,52%	

Based on this feedback a template for summarising the properties of additives was created. The figure below shows the template, completed for a cellulose additive. This information now resides in the KS.

Hydroxypropyl Methyl Cellulose

Chemical composition
$C_{56}H_{108}O_{30}$ (not well specified)   Source: http://www.omri.org/HPMC.pdf

Chemical and Physical characteristics:	Average value
Molecular weight (atomic unit)	80.000÷1.200.000
Appearance at 20°C	Powder, odourless, white powder
Density (g/l)	
Average active content (%wt.)	------
Residue after firing (% (as Na_2O)	------
Viscosity Brookfield RVT (rpm)	------
Tg (°C)	------
Chemical formula	 (1)
pH (2% in water)	5-8

(1) Source http://www.herc.com/aqualon/food/food_prod_data/food_klucel.html

Properties and application
Common ingredients in the recipe of engobes and glaze slips. • Binder. • Water retentive. • Thickener. • Rheological modifier. • Adhesive. • Drying controller Besides the HMC is not harmful for the health and the environment. It gives limpid and viscous water solutions without generating foam. Normally anhydrous HMCs are resistant to bacterial degradation, but if they have to be kept for a long time either in a glaze or in a mother solution it is suggested the addition of a preservative agent.

Instruction for use
It may be added directly into the mill at the beginning of grinding or during the final stages of milling; alternatively it can be added prior the application of the glaze.

Dosage
The dosage may vary approximately from 0,1 % up to (very rarely) 1,0 % with respect to the solid content, according to the composition of solids and liquid. Put attention to an excess of additives that can make worse the rheology of the suspension.

Handling, storage and packaging
HMCs are generally stable to prolonged storage under condition where extreme moistures do not occur. The shelf life is at least twelve months if this condition is observed.

Safety
• Caution: hazardous in case of eye (irritant) and ingestion (irritant), skin contact (irritant) and of inhalation (irritant). • First aid measures Skin contact Flush skin with plenty of water for at least 15 minutes. Cold water and disinfectant soap may be used. Remove contaminated clothing and shoes. Get medical attention immediately. Eye contact Flush eyes with plenty of water for at least 15 minutes. Cold water may be used. Get medical attention immediately. Inhalation: Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention immediately. • May be combustible at high temperature. • Material in powder form, capable of creating a dust explosion. • Keep away from heat. Keep away from sources of ignition.

Suppliers
• Chimicolor industria chimica srl • Dow Wolff Cellulosics • Hercules

WP2: Production of rheology measurement protocols relevant to the three generic ceramic shaping routes

Original target time-scale: Month 2 to Month 16
Actual time-scale: Month 2 to Month 19 (minor adjustment thereafter)

The specific objective of this WP was the development of standard rheological protocols for the characterization of ceramic systems prior to the shaping stage. The main shaping routes involve ceramic systems in three different physical states: **powders, plastic bodies and suspensions**.
Therefore, for each class, devoted rheological protocols were proposed. This will permit to make comparisons between systems (of the same class) differing for the formulation (in particular for the different amount / nature of the additives) and to individuate the effects of the additives themselves. In carrying out this work, the impact of novel ceramic processing was considered, with the idea to propose alternative rheological tests / protocols if appopriate.

First, some guidelines were defined for the development of the rheological measurements:

1. Definition of the relevant rheological variables to be measured (e.g. as viscosity or thixotropy for the suspensions) depending on the need (a) to know the performance of the systems in the subsequent processing conditions or (b) to study the influence of compositional modifications on the rheological behaviour. In the first case the system should be submitted to a rheological history as similar as possible to the real industrial process, while in both cases the rheological analysis will need to be correlated to the results of tests carried out later in production (as visual or mechanical inspection of the green, dried or fired bodies).
2. If possible, the rheological variables should be measured with the simpler instruments most used on SME ceramic factories. Only when those instruments fail to deliver correct, reproducible, and useful rheological data, should more sophisticated and expensive instruments be proposed.
3. The protocols must be as simple and user friendly as possible.
4. The data analysis should made simple and the transfer to modifications to process parameters as easy as possible.

Secondly, the main steps constituting any protocols (independently on the process to which it refers) were identified:

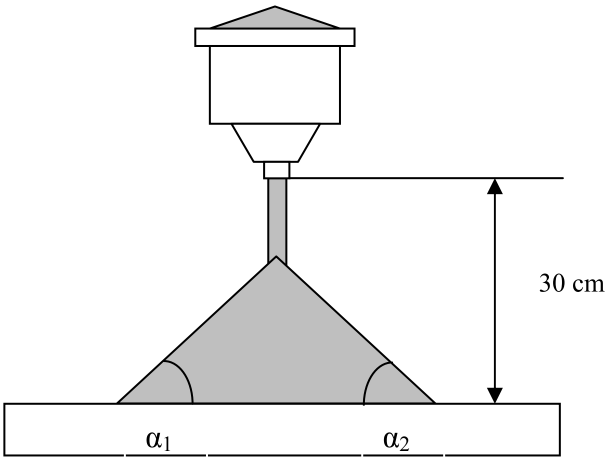
a) Sampling (i.e. collecting a representative sample)
b) Rheological pre-treatment (i.e. the work necessary to cancel the rheological history of the sample);
c) Loading (i.e. putting the material in the instrument)
d) The procedure of rheological measurement;
e) Guidance on the interpretation of the data.

Final decisions concerning rheological tests were are summarised below. Deliverables report for WP2 at Months 12, 18 and 24 provide further details and all tests / protocols were included in the final KS (WP7):

- Task 2.1 **Fluid suspension rheology**. Two simple, low cost instruments, (Ford Cup and Gallenkamp Viscometer), and a more sophisticated instrument (Brookfield viscometer) were purchased in order to replicate in the RTDs' laboratories the same tests carried on in the factories and to evaluate the results in the light of those obtained with more sophisticated viscometers. Based on this data, clear protocols were developed for viscosity measurement.

The literature on existing industrial tests was surveyed and protocols were designed, tested and approved: Two protocols for Ford Cup, Two protocols for Gallenkamp viscometer and four protocols for Brookfield viscometer were suggested. The Brookfield has the advantage of being able to introduce shear behaviour (i.e. conditions than mimic processes like glazing, spray drying). The four (as opposed to two) protocols for the Brookfield reflect this versatility.

- Task 2.2 **Powder rheology**. The measuring methods selected after consideration were: **Angle of Repose, Flow Through an Orefice and Hausner Ratio**. They are a good compromise between cost and efficiency. Angle of Repose has been selected as the overall preferred test. This technique has been utilized in several industrial and scientific sectors to characterize the powder flowability. Angle of Repose is defined as the angle of the conical surface of a pile of powder dropped from a set height onto a horizontal plane.

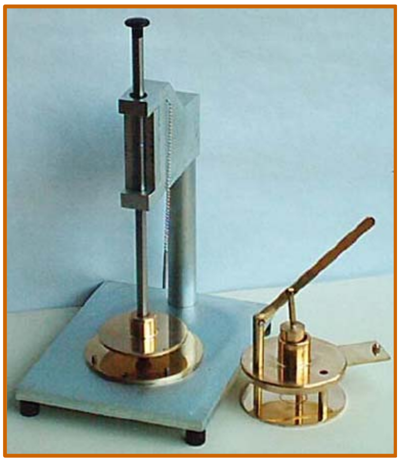


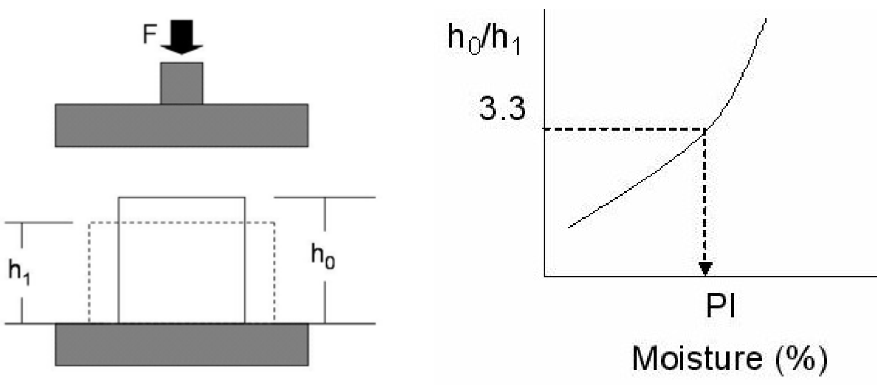
- Task 2.3:**Development of protocols for plastic-forming processing**. Plasticity can be defined as the property of a moistened material to be deformed under the application of pressure, with the deformed shape being retained when the deforming pressure is removed. This property is fundamental for processing of ceramic pastes by plastic forming method. Generally speaking, the more plastic a paste, the more water content it will tolerate without becoming a fluid.

  Although Atterberg, Stress-Strain and penetrometer methods were considered, **the Pfefferkorn method was ultimately selected as the preferred test** and a protocol developed. There was also interest in the CERAM "Melt Flow Index" technology whereby time to extrude a set length of material under a fixed load is measured. However, "MFI" was not deemed a low cost apparatus widely available to SMEs.

In the Pfefferkorn method, a plate having a defined weight of 1192 g is dropped from a height of 186 mm, onto a measurement cylinder having a height (h_0) of 40 mm and a diameter of 33 mm, whereby compression to height h_1 occurs. The water content at which the compression ratio $h_0:h_1 = 3.3:1$ is considered to be the plasticity number according to the Pfefferkorn method. The water content at which a compression ratio $h_0:h_1 = 2.5:1$ is reached is referred to as the make-up water requirement.

1. Take a sample of dry paste and mix some amount of water from the plastic squeeze bottle.
2. Prepare a cylinder of paste using the mould of Pfefferkorn apparatus.
3. Locate paste cylinder over the marked circle in the Pfefferkorn apparatus.
4. Release the plate of apparatus over the testing sample.
5. Measure the height after test (h_1).
6. Repeat the test using pastes with different water amount (moisture).
7. Plot values in the graph $h_0:h_1$ against paste moisture (in weight percentage).





- Task 2.4: **Development of best practices for characterization of emerging and nano-ceramic suspension-based processing.** As new process technologies potentially require a more thorough control of the rheological parameters this aspect needed to be considered carefully. Substantially, it was found that **novel emerging processes can be assimilated to the traditional powder, plastic or suspension-based rheology tests mentioned in tasks 2.1 – 2.3** . The main differences lie in the particle-size distribution (from micro to nanosized), fluid dynamic conditions (e.g., in ink jet printing, *in-situ* consolidation) and cost of the raw material (till to hundreds of euro / kg). The same protocols can be in principle applied to the novel processes, but critical issues to consider are the availability of only small sample volumes, the different operative ranges, the possibility to carry on tests during the changing chemico-physical state of the sample.

Although most WP2 work was carried out in years 1 and 2, some additional checks on the protocols were made in year 3. This work related to flowability of glaze and pigment powders, plus an assessment of both fluid and powder (granulate) rheology in gres porcellenato tiles (and how this linked to tile properties). In addition, a document concerning the definition of procedures for the optimization of deflocculants using DOE and Artificial Neural Network was prepared. DOE and the Artificial Neural Network approaches (and their benefits in terms of understanding interactions between additives present in a given ceramic system) are described with examples. As these approaches require apposite software in order to reduce time and errors, related links on the web for both freeware and commercial softwares were mentioned. The former can be freely downloaded and used for normal work or for evaluating the proposed techniques. The latter, often more comprehensive and efficient, can be tested in demo versions. Both types of software can be downloaded via Internet (ADOPTIC_D.3.1 & D3.2 _ UNIMORE_Final.doc).

Results / Conclusions

Suitable tests (using low cost, easy-to-use apparatus) were selected from a wider range of possible tests. This was done to ensure SME engagement and achieved for fluid suspensions, powders and plastic ceramic bodies – thus covering ALL possible ceramic process routes. For each test 1-4 protocols were created and assessed by SMEs. The protocols cover important processing aspects, especially for fluid suspensions – not just viscosity but factors such as thixotrpoy (critical for processing speeds and quality of final microstructure). The SMEs approved the final tests / protocols which were used during WP8 as well as being logged permanently within the KS (WP7) for SMEs to access at will.

WP3: Study of the effects of additives on current pressing-related processing

Original target time-scale: Month 4 to Month 21
Actual time-scale: Month 9 to Month 30

The specific objectives of this WP were:

- Measurement of the additives' effects on rheology of aqueous slurries; spray-dried; granulated; dry glazes and pigments. Their effect on green (unfired) and fired properties for pressing related processing (mainly isostatic and die processes).
- Influence on the aesthetical quality of the application of glazes and pigments: Aesthetical quality is a very important industrial parameter in the production of ceramic. High quality is obtained with the glazing (aesthetical and technical improvement). Glaze can be applied as suspension (in the main cases) or in dry form, with the latter of interest to (for example) SME partner INCO. Pigments are added to spray-dried and granulate aggregates as syroup or as dry powder (technique of the future). Both are important in the production where the knowledge is low both in scientific and technical fields.

The work of WP 3 was originally distributed between tasks studying the effects of additives on isostatic and uniaxial pressing. Since additives are typically added at the slurry stage (even though the slurry is spray-dried into a granulate that is pressed) rheology measurements at the slurry and powder stage had to be correlated and linked to pressed properties like strength. It was these correlations (rather than the role of iso-static versus uniaxial pressing) that were found to be important

The rheological effects of the additives present in the additive tree (WP1, WP7) on two typical aqueous suspensions for porcelain stoneware and wall tiles were measured using the procedures and instruments proposed in WP2 (see **D2.3-M12**).

Data on the influence of some binder additives on mechanical characteristic of the pressed dried powder were then tested. The results were in agreement with the expected ones, on the basis of their placement in the additive tree. No significant problems in the rheological procedures were observed.

One interesting finding concerning the rheology of dry powders was the efficiency that dry silica powder provided to the flowability of some pigments used in ceramic industry (see **D3.2-M24**). The effect changed according to the characteristics of the pigment. This is important for dry processing of colours in tile production.

<u>Results / Conclusions</u>

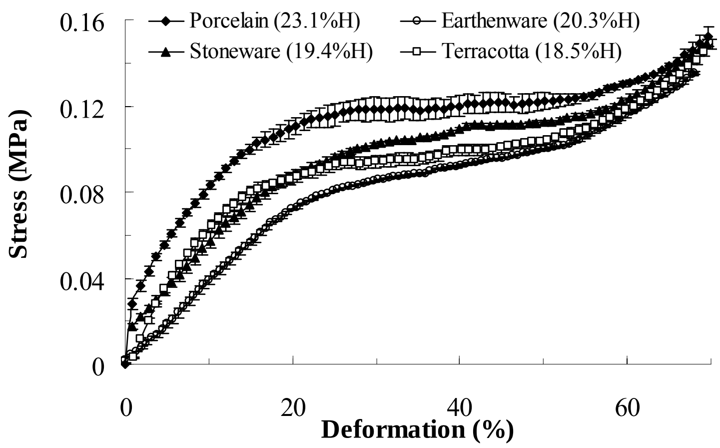
Studies in WP3 tended to support existing thoughts on how additives like binders, deflocculants influence ceramic powder pressing.

WP4: Study of the effects of additives on current plastic forming processing

Original target time-scale: Month 4 to Month 21

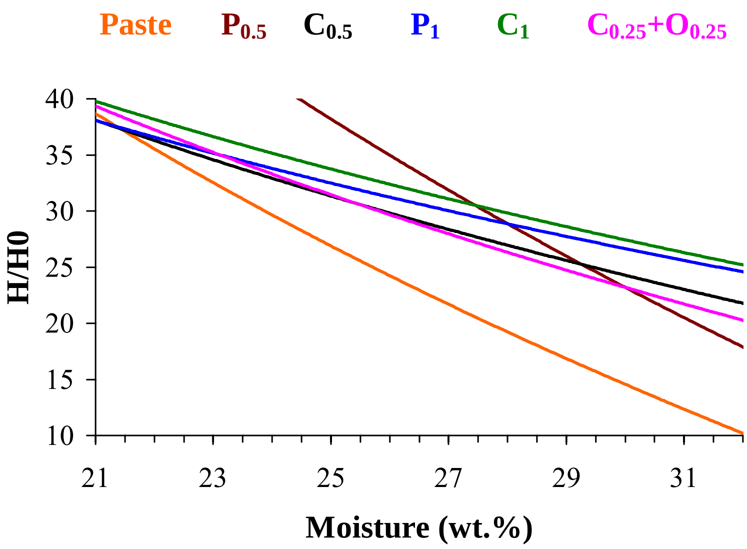
Actual time-scale: Month 9 to Month 27

During this WP, UAVR played a key role. UAVR were able to use more sophisticated analytical techniques that those proposed in WP2 as a means of better understanding additive behaviour. One of these techniques is a form of capillary rheometer, giving stress / strain data as shown below. These curves indicate efficiency of different clay bodies with respect to extrusion (an important shaping technique for ceramics).



As an example, work with PASTCERAM and others on plastic materials used to make roof tiles and whitewares showed the value of a cellulose-based binder called Zusoplast. For example, it improved extrudability of compositions that are normally difficult to work with (for example bodies making us of aluminium waste or aesthetically pleasing white bodies containing added kaolin). The work also showed that moisture content of the ceramic body was critical and needs to be considered in conjunction with an optimised wt% of the additive selected. The importance of using supplementary lubricant additives was also assessed. UAVR were keen to demonstrate to the meeting how the impact of additives on properties right along the process route should be considered – for example, good extrudability can ensure good particle packing and so low porosity / higher density in the final sintered item.

Work under WP4 also confirmed that the chosen “SME” quality control test (Pfefferkorn) did give consistently reliable and useful data that correlated to other techniques (a very good agrement with Atterberg’s test was seen). In the diagram below the changes in H/Ho (original height of plastic cylinder versus “pressed” cylinder height) vs moisture content for different additives, clearly show that this simple test gives good differentiation.



The mixing of additives to plastic pastes revealed some difficulties due to the swelling behaviour and the low solubility of plasticizers in water. Adding polymeric additives at the suspension stage (prior to filter pressing / pugging) can help although this can result in blinding of the filter press cloths. Conversely, adding a powder additive directly to a plastic body results in poor distribution of the additive. If a solution of the additive is added to the plastic material, the moisture content can become high and ideal plasticity performance is lost. Overall the work has shown to SMEs how these different needs in plastic material need to be accommodated / compromised according to the processes used on factory.

Results / Conclusions

As for WP 3, 5 and 6, the work in WP4 helped to enhance understanding of how additives capable of enhancing plastic forming processes need to be optimised. Pitfalls in terms of unwanted impact on other properties were identified. Gaps in knowledge relating to key binder, lubricant performance were plugged.

WP5: Study of the effects of additives on current suspension-based processing

Original target time-scale: Month 4 to Month 21
Actual time-scale: Month 9 to Month 27

The specific objectives of this WP were:

a. Measurement of the effect of additives on rheology and on green (unfired) and fired properties for suspension-based processing.
b. New rheology measurement protocols developed in WP 2 for suspension based processing appropriated to be used by the SME's

The work of this WP is distributed between tasks:

- Task 5.1 Study of the effects of additives on slip casting.
- Task 5.2 Study of the effects of additives on pressure casting
- Task 5.3 Study of the effects of additives on tape casting
- Task 5.4 Study of the effects of additives on direct milling
- Task 5.5 Study of the effects of additives on spraying

Most literature data had been collected prior to M18, with complimentary laboratory evaluation to fill the gaps occuring between M12 and 30.

In task 5.1, some 30 additives were assessed for their impact on rheological behaviour (using Torsion Viscometer and other tests defined in WP2

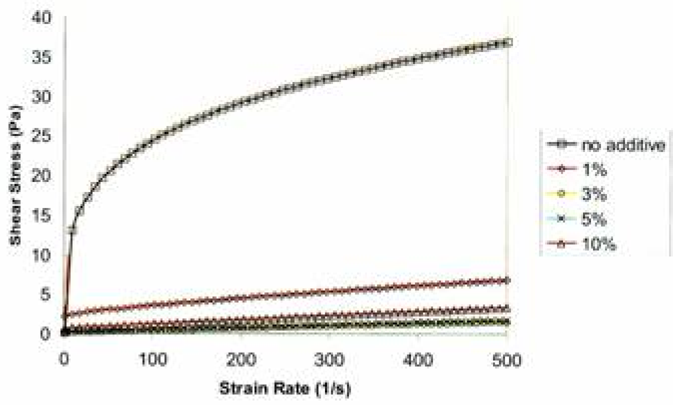
For task 5.2 the role of binder additives (to raise green strength, whilst not adversely affecting casting times at different pressures) was evaluated.

For task 5.3, there was a focus on AQUEOUS tape casting systems (traditionally tape casting has been non-aqueous) with two polymeric additives assessed. Although an alternative QC test, zeta potential measurements of zirconia were seen to be important for controlling rheology,

Where milling is required (**task 5.4**), it is important that polymeric additives (introduced prior to milling to provide binding action in subsequent shaped items) are not adversely affected (polymer chains broken down). PVA and polymethacrylate emulsions were amongst additives assessed for their impact on rheology before and after milling.

In task 5.5. the impact of dispersants and binders on glaze suspension rheology was assessed. It is important that a rheology of the glaze suitable for dipping or spraying is retained, whilst a balance is achieved in terms of binding action (glaze is not accidently brushed off during handling before firing) and quality of glaze powder lay-down against the ceramic substrate (to avoid faults in the final glaze).

Within this section, AGH focussed efforts on the impact of maltodextrin-type polysaccharides on fluid suspension behaviour. Such materials can have a combination of dispersant (lowering suspension viscosity), binder and stabilizing properties. The following figures shows, by way of example, the viscosity reduction attainable in advanced ceramic alumina slurries



These additives were shown to burn-out before 300C during ceramic firing and not generate any toxic gases.

<u>Results / Conclusions</u>

This section of work also generated no surprises. Control of suspensions is critical, since ALL ceramic processing tends to go through a fluid suspension stage (usually at the start of the production process). As such WP5 assumed a greater importance that WP3,4, and 6, with much work needed to check that the rheology tests from WP2 were robust. Fortunately, there is a sigificant level of literature on fluid suspension behaviour which made this WP easier to manage.

WP6: Study of the effects of additives on emerging and nano-ceramics processing

Original target time-scale: Month 4 to Month 25

Actual time-scale: Month 9 to Month 30

The specific objective of this WP was to study the effects of additives on emerging and nano-ceramic processing. Analysis of the rheological responses of some ceramic systems (assumed as reference) by varying the additives (as nature and/or type) was performed.

The work of this WP is distributed between tasks:

- Task 6.1: Study of the effects of additives on emerging pressing-related processing
- Task 6.2: Study of the effects of additives on emerging plastic forming processing
- Task 6.3: Study of the effects of additives on emerging suspension-based processing:

Highlights from this work included raising understanding of:

- How to create hydroxy apatite (HA) and Tri-calcium phosphate (TCP) nano-particles with smaller particle sizes through precipitation in water containing a polycarbonate surfactant. Additives and pH can control particle SHAPE and % CRYSTALLINITY too. This was relevant to the partner Agoromat who are involved with plasma HA coating of metal implants.
- In addition to the above use of surfactants, use of ultrasonics, evaporation and ageing can help raise wt% solids loadings of nano-powder suspensions without causing an unwanted rise in viscosity. This is important for both conventional and novel (e.g. Gel or Direct Coagulation Casting) processing.

Work carried out on this project investigated gel an hydrolysis assisted solidification for alumina / zirconia mixes as employed in hip replacements. Longevity of ceramic inserts due to a high quality micro- / nano-structure could play a critical role in assisting the ageing population to retain mobility for longer.

- HA, TCP peformance in high solids, plastic slurries suitable for robocasting (laying down thin strips from a 50 micron nozzle)
- A study of the additives on the rheology of high solids alumina ceramic suspensions for rotomoulding was carried out by UNIMORE jointly with CERAM. Rotomoulding is a technique used in the forming of polymers that could be used also in the ceramic field.

Two different allumina powders: P152SB (Alcan) and A17 (Almist) were studied in a system that can solidify (gel cast) after creating a hollow shape. The suspensions were prepared adding the aluminas to an aqueous mixtures of: Methacrylamide (MAM), N,N'-Methylenebisacrylamide (MBAM); N,N,N',N'-Tetramethylethylenediamine (TEMED), Ammonium persulfate (APS) produced by Sigma Aldrich. Dispex A40, a commercial polyacrylate, was utilised as dispersant to increase the flowability of the suspension before curing. Size distribution of alumina and reaction kinetics with respect to the percentage of APS and TEMED was linked to with rheological measurements.

- Cement slurries used to confer low electrical conductivity after being heat-treated to cure them. Inorganic binders (as opposed to more conventional organic versions) were trialled. The work showed the need for anti-foaming additives to retard bubble formation.
- Screening of electrode / electrolyte layers in solid oxide fuel systems. The use of Laric Acid was seen to offset unwanted segregation in slurries. This helped improve shelf-life.
- Rapid Prototyping & Manufacturing techniques; digital printing (Ink Jet Printing etc.) Literature searches / discussions with contacts helped identify the various sub-sectors

within these section and the role additives can / might play. This provided useful data for KS development in WP7.

- In year 3 and related to task 6.3, GEL CASTING was deemed an important area to investigate for micro- as well as nano-powder processing. The relevant rheological properties necessary to investigate the effect of additives on ceramic systems for selected applications was measured. Solids loadings of 50-60 vol% are needed for gel catsing and surfactants were shown to have a key role to play in achieving this.

The dynamics of the properties during the processing, due, *e.g.*, to the temperature-induced transformation of chemico-physical state or to the high rate of application, were followed with rheological measurements in order to define the better additives needed for the processes. Solidification has been realized by immobilizing the medium (water) and ceramic powder inside the hydrogel structure. Because in this process there is no filtration (removal of medium), shape forming has more potential to deliver defect-free components . In the "gel from slurries" approach, the heart of the technology is the use of organic monomers mixed with ceramic powders. Water is the preferred solvent. This composition can be polymerized to form a strong crosslinked polymer-solvent gel, which immobilizes ceramics powder in semi-fabricated products of the desired shape.

<u>Results / Conclusions</u>

In addition to assisting several SME partners already embracing novel processing (SOFC Power, Agoromat etc.), some general information for populating the KS (WP7) was attained. Such information will at least inform SMEs about new process routes they might consider and some of the QC issues likely to arise. More (post-project) work is needed to further populate the KS, since there are many novel emerging process routes and it was not envisaged that this project would cover all of these.

WP7: Web-based platform creation and update

Original target time-scale: Month 13 to Month 36
Actual time-scale: Month 1 to Month 33

The specific objectives of this WP are:

- To collate the data gathered in WPs 1-6 and create a Knowledge Based System (KS) which users can interrogate to identify potential additive solutions to process issues
- To revise the KBS against feedback from SME ceramic producers

The specific deliverables for this WP are:

- D7.1 Initial KS package in CD-Rom format (a fully functioning tool) by M24
- D7.2 Revised KS package in CD-Rom format and as a web-based tool M36
- D7.3 Report from an investigation into the feasibility of extending the functionality of the KBS by integrating a tool capable of handling variable inputs/enquiries and automatically interrogating *combinations* of desirable properties from a data-base

For D 7.1, year 1 saw the creation of "pencil on paper" diagrams in a bid to capture (a) generic process route information for all sub-sectors except building materials and (b) additive family trees. For (b) a decision was made to only provide "one-page" data for the top 60 additive chemistries within the diagram. Information on faults was generated by RTDs

(50% completed at end of year 1; 75% at end of year 2; further inputs - specially photos of faults - received right up to M33).

Suitable software was found by M18. Also in year 2, domain name was registered (www.adoptic.eu) and suitable space on a web server secured to host the KBS for the term of the project (and beyond). During year 2 the decision to offer THREE routes to interrogate the KS ("faults" "additive tree" and "process routes" was made. Ultimately, at M24, the key structure of the KS was approximately 80% complete with the remaining 20% of structure added ultimately by M36 (original target was M30). It was also estimated that 40-50% of the planned information had been input. This was sufficient allow training on the KS use at the M24 meeting in Modena. The online KS enabled the project team to observe its incremental development during M24and provide feedback on design, content, structure and operability.

Task 7.2: During the majority of year 3, the Adotpic site was password protected (single password to reduce costs) to ensure that only project partners could gain access as the KS developed. Towards the end of the project, it was clear (WP9) that ALL ceramic producers would be allowed access to the site. Given that, by M33, the site was deemed sufficiently advanced the password protection was removed. It was still not possible to find www.adoptic.eu via a google search however.

Also in year 3 further KS refinements/updates included: Addition for further additive datasheets; interlinks; terminology references; photographs; and, illustrations. Specific scientific data created in WP3-6 was selected by way of demonstrating typical trends arising from the use of certain additives and how intermediate or final product properties are altered. A glossary of technical terminology was included to aid understanding and usefulness of the KBS. An illustrated guide to the use of the KBS was then compiled (also as part of WP10, Training) and printed for distribution to RTD's and SME's to support the familiarization process. The guide uses 'screen-shots' of the actual KBS to describe its structure and to enable the end-user interact with the tool online and identify the principles of navigating quickly to the desired information. This guide was subsequently translated (by the RTD's) into Italian, Portuguese, and Polish, to improve it's relevance in the respective countries.

Milestone 7.3 dealt with receiving and acting on SME feedback regarding the information contained within the KBS. The main points receied were:

- Some sections provided excellent information beyond that originally envisaged, e.g. process maps, rheology protocols.
- The additive datasheets and fault examples highlighted the on-going nature of the KBS. Although the information provided was to the agreed format, and in virtually all cases provided useful information, there was an ongoing need to include more information.
- Provide 'real' examples of additive usage within the datasheets
- Linking the generic additive information to Trade Names was highlighted as important for SME's.
- Providing a 'SEARCH' facility within the KBS
- Deal with REACH and how it could affect additive availability

Feedback from outside the consortium (Milestone 7.4) was gathered largely from additive suppliers who were not represented in the ADOPTIC project. Interest was expressed in having (and possibly paying for) a presence on the KS. The feedback helped shape the post-project exploitation plan for the KS (WP9). Of note was the fact mineral and analytical equiment suppliers (as well as additive supplier) expressed interest.

For 7.3. it was recognised that the main scope of the project encompassed a tool to select an additive as a processing aid. In the first instance the query / search procedure is being encoded as a simple decision tree in a set of web pages. This approach provides a positive decision (the user navigates a definite route through the decision tree) based on a fixed knowledge base (the knowledge is coded into the structure of the web pages).
In order to expand on this approach, a method is required that allows degrees of uncertainty/confidence in the users input and allows for “near” matches to be presented as alternative/combined solutions. Such a method can no longer rely on a system in which the knowledge is encoded as part of the program (or in this case html). Instead abstraction is required in order to split the decision making method (decision tree, fuzzy logic, expert system etc) from the knowledge (set of rules, database etc). This allows a system that can dynamically utilise/combine knowledge based on a user input that is incomplete has degrees of uncertainty or indeed matches more than one base case within the knowledge base.
Several alternative decisions making systems were reviewed but implementation is now deemed as a long way off – immediate (1-2 year time-scale) improvements to the KS need to focus on imputting further data within the current structure.

Results / Conclusions

In the end, it was decided that there was no point in creating a CD-ROM, since the information within the KS was constantly evolving and regular visits to the web-site (www.adoptic.eu) would provide more up-to-date and so meaningful feedback. An initial KS was available as planned at M24 (D7.1) and feedback was received from all partners during year 3 to ensure a final package (D7.2) was delivered at M36. D7.3 was a minor work package, with effort concentrated on delivering a useful initial KS without worrying too much about how this could be expanded to allow the software to automatically calculate how well a given additive met the users requirements. This will be a major future under-taking if embraced.

WP8: Industrial validation of the additives optimisation

Original target time-scale: Month 25 to Month 36
Actual time-scale: Month 9 to Month 36

The specific objectives of this WP are:
- Satisfy the needs of the SMEs in terms of optimisation of the additives in the relevant processing steps;
- Industrial validation of the additives optimisation supported by RTD performers in order to implement the identified solutions and give guidance from the results obtained in the previous Work Packages.
- Industrial validation of additives for the 3 processing routes. All RTD’s will cooperate with SME’s to implement solutions identified in WP 3,4,5,6. Implementation of the results achieved will allow SME to out-run their competition on the world market.

Potentially, scope existed for 4 sub-tasks (8.1 to 8.4, dealing with factory issues concerning powders, plastic ceramics, suspensions and nano / novel ceramic processing. this was dependant on what the SME partners needed help with.

Task 8.5 dealt with quantification (actual and / or potential) of benefits arising from work in tasks 8.1 - 8.4.

The work / benefits obtained from each SME is briefly summarised below:

8.1 Powders
Star dust was able to work with AGH to optimise suspensions prior to spray drying, such that the dry granulate possessed better flow into dies and better pressed performance. The use of 0.05 – 0.1 % starch additives improved pressed granulate appearance. Domino had a similar issue, wanting to improve granulate for pressing tiles. Working with UAVR, they used sodium silicate / polyacrylate dispersants to raise solids content in the suspension prior to spray drying. This saved 8% of spray drying energy costs and gave a superior granulate

International Syalons (IS) were in need of a binder / deflocculant, having had their usual additive withdrawn from the market due to REACH regulations. Employing suspension and powder flow rheology tests from WP2 and RTD recommendations for alternative additives, IS were able to create improved Si-Al-O-N granulates, so much so that they gained confidence in pressing more challenging shapes and saving energy by not needing and intermediate firing to give strength to pressed shapes. The final components are used in applications such as temperature probe sheaths for molten glass, metal where thermal shock and chemical resistance is paramount.

Vulcan refractories worked with CERAM to source a more environmentally binder to pre-empt future emissions legislation. Although solutions were found they were 10x more expensive and “shelved” until legislation comes in. However, by studying Differential Thermal Analysis traces, Vulcan were able to identify lower energy firing schedules that would accommodate burn-out of their current binder. These schedules were introduced during the Adoptic project and gradually optimised. ~€100K savings per annum have been predicted.

INCO learnt via work with UNIMORE how additives can improve (a) granulate pigment flow into dies and (b) the pressed microstructure in gres porcellenato tiles. In addition problems associated with pneumatic conveyance of piment granulate (namely contamination via abrasion of conveying pipework) were also solved, with QC tests introduced.

Agoromat were able to identify a much cheaper binder compared with their former PVP material. Cellulose binders were found to be acceptable and the wt% loading was optimised in work with UAVR. In addition to material savings, Agoromat were able to generate spray-dried calcium phosphate granulate (end application – medical implants) with improved properties

8.2 Plastic formulations
UAVR helped Pastceram (a) find Zusoplast binder additives for ceramic pastes and then (b) identify the best way of introducing it into the ceramic body. Adding Zusoplast in a powder form and then adding water was the most successful method. The pastes were tested at the following non-parter SME Portuguese customer companies: Vasicol (metallic moulds) and Ceriart (plaster moulds). By adding 0.5 wt% Zusoplast binder, faults were reduced on these

factories by 4-28%. The main impact was that the binder added strength to unfired shaped ware such that it wasn't distorted during handling. This work represented welcome extra dissemination outside the consortium.

Commercial Clay worked with CERAM to show that washing waste powder glass removes soluble ions that become unwanted additives. The washed glass could then be added (at 5wt%) to lower the firing temperature of clay bodies, without the plasticity of the "pugged" body changing with time. Commercial Clay further worked with adding nylon fibre additives to clay bodies to improve strength in dried (unfired) clay items as made by students in schools. Strength data (3-point bend) picked up only minor strength improvements although the material "felt" stronger.

8.3 Suspensions

CERINVEST tested additive improvements suggested by CNR-ISTEC into their production process (e.g., the use of different thermal cycles for the consolidation of the cements). Final product quality was enhanced.

Hyber was assisted by AGH in finding an additive to minimise pyroplastic deformation of sanitaryware. A solution was found in waste materials (scrap porcelain for example) as an additive.

Pastceram discovered, via UAVR, that an arabic gum binder used in a glaze, gave the unfired glaze layer a rigidity, such that it could be handled prior to firing without introducing defects that showed in the final piece.

Parkinson Spencer (PSR) reduced batch to batch variations by working with RTDs to create an optimisied "order of addition". This took into account the zeta potential and particle size of fine and coarse alumina / zirconia additions. The levels of surfactants (and order of addition) was also altered to adjust zeta potentials of individual components. Small-scale trials then showed good consistency, with PSR committed to larger-scale implentation, post project.

Manufaktura were able to avoid faults in fired glazed ware through additive selection. In addition, work was carried out using a powerful flux (lithium-containing Spodumene) to lower firing temperatures.

8.4 Nano / Novel processing

The effect of some additives on the rheological behaviour of aqueous suspension suitable for digital printing system (e.g. Ink Jet printing) for ceramic tiles developed by GRAF was carried out. Problems with the printability of four basic colour inks (basically too high a viscosity, sedimentation, agglomeration) have been solved. Of note is the fact GRAF took o board the Design of Experiment (DoE) approach highlighted by UNIMORE.

SOFC Power worked with CNR-ISTEC on two novel processing issues:

1) tape casting of <u>aqueous</u> suspensions (for the production of anode layers for SOFCs)
2) screen printing (for the production of cathode layers for SOFCs).

The aim was to check: 1) Confidence in scaling-up to industrial scale and 2) The capability of rheology tests to supply useful information able to discriminate the effects of different additives. Industrial validation was ultimately achieved with suitable Quality Control methods set up to ensure / increase quality of the ceramic products and the yield of the processes. SOFC Power were able to fully study the effects of the addition of:

- different amounts of dispersant to the tape casting suspensions
- a binder to the tape casting suspensions;
- lauric acid (as dispersant) to the LSM screen printing inks;
- four different fatty acids (as dispersants) to the LSM/YSZ screen printing inks.
-

All the above work led to a reduced number of defects and higher mechanical strength - improved by 50%). Such benefits increased the yield from the 70% to a value higher than 90% with an estimated savings at full scale production of about 300 k€ per year. **This represented perhaps the most successful WP8 case study**

UNIMORE also investigated the influence of additives on the rheological characteristics of a suspension of nano-Al_2O_3 and the ultimate impact this had on the properties of High- velocity suspension flame sprayed (HVSFS) alumina coatings. HVSFS is a technique to spray micron, submicron or nanoparticles with hypersonic speed with the aim to form thin and dense coating layers. The powder is dispersed in aqueous or organic solvent and fed into a combustion chamber of a spray torch. The final characteristics of the coating are strongly influenced by the rheological characteristics of the suspension containing the powder. In particular high deposition efficiency was obtained with less agglomerated suspensions. A low porosity, measured by image analysis, was obtained optimizing the choice and amount of additives. Protocols developed in WP2 were utilized to characterize rheologically the suspensions.

8.5 Economic benefits

Deliverable report D8.7 shows the benefits estimated by each SME from WP8 work.

The summary table is reproduced here:

SME company	Country	Brief description of additive issued explored with company	Estimated benefits (€K)	By when?
Vulcan Refractories	UK	Binder with cleaner burn-out found - rejected as too expensive	0	
Vulcan Refractories	UK	Use of TGA / DTA curves to allow clean binder additive burn-out but on faster (lower energy) firings	100	From now
Commercial Clay	UK	Hydrocyclone cleaning of glass powder (removes "leachable" additives) to give stable clay+glass body		Estimated market will emerge within next 1-2 years
Commercial Clay	UK	Use of nylon fibre to strengthen clay in unfired state (demand from schools)	45	R&D performed has raised CC confidence with processing and led to enquires (no firm orders yet) that suggest 100-200+ T per year sales
International Syalons	UK	Source binders to give green strength and so avoid a firing before machining	30	

SME company	Country	Brief description of additive issued explored with company	Estimated benefits (€K)	By when?
International Syalons	UK	Source binder to give green strength and so allow pressing of more challenging shapes	30	
PSR	UK	Reduce losses & reduced surfactant costs in casting of very high solids refractory mix. Via: order of mixing fine powders & surfactants; cleaning of alumina prior to creating a suspension		PSR have implented a new mixing protocol when making slips. Cat quality appears better but need 3+ months of production to quantify improvements via higher yields etc. NOTE: washing alumina had a detrimental effect and has been dropped as an approach
HYBNER	PL	possibility to produce large size ceramic product without defects and deformations (decreasing cost of production). 5% yield rise. Also waste material (3%) can be recycled	11	per annum. Estimate, from point when production returns to normal levels after recession
MANUFAKTURA	PL	decreasing of firing temperature (50 C) by adding spodumene (more expensive , increase whitness of glaze (better quality of product)	23	per annum. Estimate, from point when production returns to normal levels after recession
STAR DUST	PL	better ability to consolidate powder (better quality of tiles). 5% rise in yields BUT with more expensive binder. Net savings shown	170	per annum. Estimate, from point when production returns to normal levels after recession
SOFC Power	IT	Increased yield (70-90%)of SOFC anode tape production by optimizing the amount of deflocculant & using WP2 rheology protocols	300	Per year, from now
Cerinvest	IT	Improved quality (electrical insulation) in thermally treated cements thanks to additive selection (e.g. anti-foamers)	0	Too early to quantify or estimate
INCO	IT	Additives to reduce abrasion from pigments transported pneumatically (Steel pipe-work can lead to contamination of pigments). UNIMORE developed a new test for quantifying wall friction	0	Too early to quantify or estimate
GRAF	IT	Ceramic ink development for IJP. Additives needed to kepp ink viscosity low and to reduce sedimentation / agglomeration.	0	Too early to quantify or estimate
DOMINO	PT	Investigation of deflocculants to raise solids loading in spray dried suspensions and so (a) lower energy consumption and (b) improve granulate quality	75	From now. Equates to 10-12% saving in energy costs
AGORAMAT	PT	Lower dispersant costs (95% reduction via cheaper chemistries, lower levels used) leading to calcium phosphate granulate that flows better	0	Too early to quantify or estimate
PASTCERAM	PT	UAVR helped PASTCERAM improve the plasticity of their clay feedstock using 0.5% additions of Zusoplast additive. In subsequent trials where PASTCERAM	0	Definite benefits seen, but non-partner companies trialling improved PASTCERAM material could / would not quantify the

SME company	Country	Brief description of additive issued explored with company	Estimated benefits (€K)	By when?
		material "with" and "without" additive was shaped into tableware / cookware at a non-partner factory, yield increases of 4-20+% were seen. The main fault avoided was distortion of shape after making items with the feedstock material		savings
		TOTAL SAVINGS / INCREASED INCOME:	784	

Data taken from the web-site of CERAME-UNIE (the umbrella organization for all ceramic IAGs in Europe, currently having national IAG representation in 23 of the EU states) indicates that, in 2003 the turnover for the European ceramics industry was 26.2B€. This is split down according to the various ceramic sub-sectors (tableware, tiles etc.).

Because the Adoptic Knowledge System does not currently contain information of use to the brick / roof-tile / clay pipe sub-sectors, we can subtract a total of 7.1B€ from the above figure. This results in a turnover of 19.1B€ for European ceramics producers that the Adoptic Knowledge System can realistically reach and help.

The total turnover for the Adoptic SME partners at the start of the project was ~€70.53M. This amounts to less than 0.4% of the 19.1B€ market mentioned above.

The sum of the estimated quantifiable benefits for SMEs working on WP8 is 784K€ per annum (see table of results). If we then apply a pro rata calculation is applied based on:

(a) The fact this project has reached an estimated 0.4% of relevant European ceramic producers and
(b) A conservative estimate that just 10% of European ceramic producers access and use the Knowledge System

We can estimate that savings or increased income generation of (10 / 0.4) x 784 K€ or 19.6M€ per annum might be realized.

The potential impact on jobs can also be gained from the CERAM-UNIE site. In 2003, some 222,000 people were employed by the industry. Subtracting out data for the brick / roof-tile / clay pipe sub-sectors reduces this figure to 169,000. If we assume a pro rata link between any savings / increased income and number of staff employed, as many as 173 additional jobs might arise from the Knowledge System (calculation: 19.6M€ benefits divided by19100M€ turnover multiplied by 169,000 jobs = 173 jobs).

Results / Conclusions

Each SME partner bought one or more factory problems to the project. RTDs helped demonstrate improvements in most cases and there was a value in SMEs watching how RTDs approached a problem in terms of what should be measured in addition to rheology to establish correlations.

Encouragingly, RTDs from different countries worked together on some problems. For example, UAVR visited the UK SME Parkinson Spencer in the UK to jointly advise on order of additions of materials / additives in a refractort formulation.

WP9: Dissemination and exploitation activities

Original target time-scale: Month 7 to Month 36
Actual time-scale: Month 7 to Month 36

The specific objectives of this WP were to manage the dissemination and define the way in which the overall project deliverables can be exploited.

The work is thus distributed between tasks:
Task 9.1 Dissemination activities beyond the consortium
Task 9.2 Exploitation of the results

<u>Dissemination</u>
A table containing target dissemination activities (number of oral, written presentations etc.) was created and placed on the Alma project management platform "Myndsphere". This was shown and updated at each 6 month project meeting. The final version is reproduced below in Section 2 “Dissemination & Use” below.

The IAGs introduced a procedure for alerting other partners to dissemination opportunities and to ensure material intended for publication was first vetted. In short the procedure called for:

- *The leader of WP9 should be made aware by any member of an intention to present a paper, etc. no later than 8 weeks before the intended date.*

- *A transcript of the paper, etc. should be forwarded to all IAG representatives no later than 45 days before the intended date.*

- *IAG representatives must confirm their acceptance or requests for change to the leader of WP9 within 21 days.*

- *The WP9 leader must confirm to the originator the acceptability of the intended paper or the areas where change is necessary 21 days before the intended publication date.*

- *If this acceptability is conditional on any change in the proposed document, the original member should confirm to the leader of WP9 that the change is accepted and has been made, within 2 working days.*

An important milestone, M9.2 looked to achieve dissemination to 33%+ of the European ceramic community. A figure of 90%+ is claimed based on oral presentations (accompanied by a written paper or abstract handed out to delegates) at key ceramic conferences such as ECERS 2009. Delegate information for ECERS suggest that 90% + of the 27 European states were represented.

Exploitation

A summary of post-project exploitation opportunities and the associated plan is listed below. In addition to this, all 1:1 work carried out as part of WP8 is also a "result". Details of these results has been provided in the section summarising WP8 and will not be repeated here. It is not anticipated that further actions are required to allow the SMEs to exploit the 1:1 work they carried out in WP8 – Each SME now have the know-how to exploit alone, although it is accepted that (a) in some cases they will need to market new products before achieving sales or (b) there may be a delay before implentation until markets pick up.

	Result	Who owns it?	Future Milestone
1	**Knowledge System**	IAGs, acting on behalf of the SMEs. N.B. SMEs have waived any royalty payment associated with the KS, asking for FREE access to all ceramic producers but payments (to allow KS upkeep) from additive, raw material and rheology equipment suppliers.	Jan 2010: IAGs to decide which RTD(s) are to run the KS for the first year of operation post-project. This is likely to be the RTD Unimore, possibly working in conjunction with Keywork Design, a company with expertise in KS lay-out, software.
			Feb 2010: RTD appointed above to make list of proposed KS advances and improvements for delivery by end of 2010. RTD to carry out this work at own expense.
			Apr 2010: To have added to KS, details for 10+ additive suppliers engaged to add additional information - initially for free. Each supplier to have a page summarising their offerings and links to their web-page. This will improve the attractiveness of KS.
			Jun 2010 & Dec 2010 RTD to provide interim reports on progress to exploitation manager (IAG).
			By March 2011, to have secured €30K+ per annum via suppliers wishing to continue to have a presence on the KS.
			Between Dec 2010 and March 2011, IAGs (led by BCC) to define a on-going agreement whereby additive supplier fees are allocated against an agreed annual plan for KS development.
2	**Rheology protocols** (a) For fluid suspensions (b) For plastic ceramic materials (c) For Dry ceramic powders	IAGs on behalf of SMEs. It has been decided that ALL partners have a free licence to use the protocols. SMEs have and will continue to use the protocols as part of their production . RTDs and IAGs may well wish to use the protocols as part of both commercial and not for profit training courses	Protocols available for Ford Cup, Gallenkamp and Brookfield testing of fluid powder suspensions in particular could have a value in helping to shape future EC standards. ACTION: 1) IAGs to send protocols to CERAM-Unie to gain their feedback on the possibility to employ them in European standards. 2) CNR-ISTEC to keep a watching brief on developing standards for ceramics and offer the tests / protocols as and when opportunities arise. The creation of a PAS (Publically Available Specification) would be a sensible first step IF an opportunity arises.
3	**Training Material** - Case studies showing the value of judicious additive selection. This includes a PowerPoint presentation produced by UAVR as part of WP10 (Training) and "Quads" from other RTD partners	IAGs on behalf of SMEs. Once again, it has been decided to offer a free licence to all project partners. It is likely that RTDs and IAGs are most likely to use this result, picking and choosing from the case studies available to create in-house (university) and external training courses.	Sep 2010, RTD partners developed training packages on "use of additives" for use within their own Member State. These are now available for future use e.g. as course material within the under graduate courses. A free licence is granted to all RTDs, SMEs, IAGs to use in training activities, with or without commercial gain.

Results /Conclusions

The IAG BCC took on responsibility for managing dissemination and (despite an initial lead from Confindustria) was ultimately responsible for the final exploitation report. This arose due to pressures and problems experienced by Confidustria outside of the ADOPTIC.

Ultimately, dissemination targets were hit and a clear plan for exploiting the main deliverable (the KS) put in place. Each SME was granted a free licence to use (a) the rheology protocols and (b) any advice generated by the RTDs / SMEs in WP8 to enhance factory production. Other exploitable results are the rheology protocols and rheology / case study training material - in this instance, IAGs grant all partners a free licence to use such material to create training seminars (whether for commercial gain or not-for-profit events).

WP10: Training activities

Original target time-scale: Month 12 to Month 36
Actual time-scale: Month 12 to Month 36

The specific objectives of this WP are:

- To develop training packages that inform SMEs about (a) rheological characterisation to support use of additives (b) how to use the Knowledge System (KS) and (c) case studies involving additives (to inspire SMEs to optimise their processes)
- To deliver (at a national level, IAG/RTD to SME) the training packages defined above

The work of this WP is distributed between tasks:

Task 10.1 – Collation of training needs / materials
Task 10.2 – RTD to RTD training
Task 10.3 – RTD training to Core SMEs (done at a national level)
Task 10.4 – RTD training to the wider SME community (IAG members)
Task 10.5 – Additional RTD to RTD training (largely CERAM on the knowledge system – KS to account for changes as KS development proceeds).

Task 10.1 was completed before M24 and recognised the need to split training into three types: KS, "case study" and hands-on rheology. Tasks 10.2 and 10.3 were largely conducted at the M24 in Modena (focus on KS training) and M30 meetings (Stoke-on-Trent, focus on rheology and case study training plus further KS training on a 1:1 as needed basis). Case studies relating to Portuguese SME work presented by UAVR at the M30 meeting were then augmented by RTDs / IAGs. Typically, when repeating case study presentations in the UK, Italy and Poland, national case studies were added. RTDs / IAGs were encouraged to use a "quad" format, whereby a single PowerPoint slide per scenario succinctly covered the need, work done, findings and €K beneit to the SME. Tasks 10.4 to 10.5 took place mainly in months 30 to 36. Task 10.5 proved a very useful exercise in terms of providing further feedback on what the KS should contain (i.e. it inadvertently informed D7.2). The Activity report for year 3 (D11.4_Year 3 _Periodic Activity Report) contains a table of all training performed but is too lengthy to reproduce here.

A feedback form was created for all training carried out with external companies. In some cases the form was completed by Adoptic parners too. Created in English initially, this was translated into Italian, Portuguese and Polish. A 100% figure for "overall training course satisfaction" was recorded by delegates although useful feedback on how to improve (more "hands on" work; more focus on rheology tests relevant to each delegate) was also received.

Results / Conclusions

Overall this was the WP that suffered greatest from slippage. This was partly due to AIDA withdrawing from the project. However, a great effort to recover the situation in year 3 saw all tasks completed.

Attendance at meetings held for task10.4 were sometime disappointing, despite efforts to secure larger audiences. The recession was at least partly to blame. Dissemination by AGH, UAVR and UNIMORE to their students represented a powerful way to get across important messsages on processing optimisation to candidates likely to be employed by the industry in a few years time. Case study, rheology and KS training will now form a part of lectures in future academic years.

WP11: Management

Carried out continuously during months 1-36 as planned

The work package included the carrying out the technical, administrative, financial and strategic coordination of the project and the animation of the consortium:

- Building up the ADOPTIC communication platform with administrative, financial, technical, communication and archive sections,
- Producing and updating the Project Quality Assurance Plan detailing, for example, practices and advancements of the project
- Collection and submission of activity, management and financial reports on due dates,
- Organisation of the periodic project meetings,
- Creation of the project logo as well as a brochure for external diffusion,
- Management of contract and Consortium Agreement amendments, …

The completion of the management tasks in WP11 strongly depended on the efficiency and reactivity of the consortium and also a good communication between partners. A well-scheduled and quality methods according to standard and efficient procedures and followed by all partners, made easier the full accomplishment of these activities.

End results achieved and perspectives

Communication by partners was satisfactory over the project, with e-mail supported by conference calls the preferred route. Again some issues have been experienced with RTDs proving difficult to contact for updates (due to overseas trips / other commitments) but all RTDs seemed to "own" actions agreed at the six-monthly meetings and so ultimately delivered. Any delays were therefore accommodated.

Partners leaving the project (AIDA, Tenmat at the start), Noemi (during the project) put great strains on the management team in terms of chasing contacts for paperwork and time spent finding alternative partners. A further strain arose from partners having to reduce their effort on aspects of the project due to pressures at the company (e.g. Confindustria, APICER). However, solutions were usually found.

Provision of financial and technical updates at the end of 6 month and one year periods has been quite good from CERAM's perspective when compared with previous EC projects. At the end of year 3 the use of RTDs to support their national SMEs in financial form-filling seems to have been particularly effective. A 45 day extension beyond the original 15th October 2009 reporting deadline has had to be requested, but at the start of December, properly completed audits that cross-check with form "C"s were only missing from two partners BCC and Domino. Even for these companies, Co-operation with Alma / CERAM has been good - misunderstandings around exactly what was required appear to have been the problem.

As regards technical reporting, this was all accomplished in a timely manner with the exception of the PDUK and the over-arching (year 1,2 & 3) activity report, which CERAM had over-looked.

All WPs and tasks have been concluded. The overall grant claimed is likely to be slightly below the ceiling agreed with the EC. This is partly due to fluctuating exchange rates (whereby, for example, UK and Polish contributions now amount to a smaller K€ value despite man month effort being delivered or even exceeded). Also, some SME and IAG partners delivered less CIK than expected due to production pressures. Conversely, other SMEs gained so many ideas for additive optimisation that they exceeded their CIK.

The Adoptic project has been successfully delivered within the 36 month time-frame from a technical viewpoint, although the time-scales for each Work Package did deviate from the original plan. Good co-operation at six-monthly meetings meant that slippage was carefully monitored and revised delivery targets set.The main deliverable, a KS available to all SME ceramic producers, provides good quality information that should assist users to overcome yield, product quality issues. However, managing the process of populating the KS has been difficult and it has to be conceded that additional information should be added as soon as possible to plug obvious gaps. However, given the budget / time-scales of this project adn the myriad of information that is available for inclusion, it is likely that any consortium would have arrived at the position this consortium finds itself in.

2. Dissemination and use

The below tables give some details on the already publishable results and non-confidential knowledge like publications available from the project.

For any inquiries (like for publications), please contact: Dr. Philip Jackson, phil.jackson@ceram.com, Ceram Research Limited (UK)

2.1. Main publishable results identified and their status

Result no	Description of knowledge
R1.1	**a web based Knowledge System (KS)** that allows eligible stakeholders to access the database in order to: - to look for a particular type of fault, - to research a particular additive, - or to enter via a particular type of process and to see what knowledge is available.
R2.1	**Rheology protocols** (a) For fluid suspensions (b) For plastic ceramic materials (c) For Dry ceramic powders
R3.1	**Training Material** - Case studies showing the value of judicious additive selection (including a PowerPoint presentation)

SME company	Country	Brief description of additive issued explored with company	Estimated benefits (€K)	By when?
Vulcan Refractories	UK	Binder with cleaner burn-out found - rejected as too expensive	0	
		Use of TGA / DTA curves to allow clean binder additive burn-out but on faster (lower energy) firings	100	From now
Commercial Clay	UK	Hydrocyclone cleaning of glass powder (removes "leachable" additives) to give stable clay+glass body		Estimated market will emerge within next 1-2 years
		Use of nylon fibre to strengthen clay in unfired state (demand from schools)	45	R&D performed has raised CC confidence with processing and led to enquires (no firm orders yet) that suggest 100-200+ T per year sales
International Syalons	UK	Source binders to give green strength and so avoid a firing before machining	30	
		Source binder to give green strength and so allow pressing of more challenging shapes	30	
PSR	UK	Reduce losses & reduced surfactant costs in casting of very high solids refractory mix. Via: order of mixing fine powders & surfactants; cleaning of alumina prior to creating a suspension	0	PSR have implented a new mixing protocol when making slips. Cat quality appears better but need 3+ months of production to quantify improvements via higher yields etc. NOTE: washing alumina had a detrimental effect and has been dropped as an approach

SME company	Country	Brief description of additive issued explored with company	Estimated benefits (€K)	By when?
HYBNER	PL	possibility to produce large size ceramic product without defects and deformations (decreasing cost of production). 5% yield rise. Also waste material (3%) can be recycled	11	per annum. Estimate, from point when production returns to normal levels after recession
MANUFAKTURA	PL	Decreasing of firing temperature (50C) by adding spodumene (more expensive , increase whitness of glaze (better quality of product)	23	per annum. Estimate, from point when production returns to normal levels after recession
STAR DUST	PL	better ability to consolidate powder (better quality of tiles). 5% rise in yields BUT with more expensive binder. Net savings shown	170	per annum. Estimate, from point when production returns to normal levels after recession
SOFC Power	IT	Increased yield (70-90%)of SOFC anode tape production by optimizing the amount of deflocculant & using WP2 rheology protocols	300	Per year, from now
Cerinvest	IT		0	Too early to quantify or estimate
INCO	IT	Additives to reduce abrasion from pigments transported pneumatically (Steel pipe-work causes contamination). UNIMORE developed a new test for quantifying wall friction	0	Too early to quantify or estimate
GRAF	IT	Ceramic ink development for IJP. Additives needed to keep ink viscosity low and to reduce sedimentation / agglomeration.	0	Too early to quantify or estimate
DOMINO	PT	Investigation of deflocculants to raise solids loading in spray dried suspensions and so (a) lower energy consumption and (b) improve granulate quality	75	From now. Equates to 10-12% saving in energy costs
AGORAMAT	PT	Lower dispersant costs (95% reduction via cheaper chemistries, lower levels used) leading to calcium phosphate granulate that flows better	0	Too early to quantify or estimate

SME company	Country	Brief description of additive issued explored with company	Estimated benefits (€K)	By when?
PASTCERAM	PT	UAVR helped PASTCERAM improve the plasticity of their clay feedstock using 0.5% additions of Zusoplast additive. In subsequent trials where PASTCERAM material "with" and "without" additive was shaped into tableware / cookware at a non-partner factory, yield increases of 4-20+% were seen. The main fault avoided was distortion of shape after making items with the feedstock material	0	Definite benefits seen, but non-partner companies trialling improved PASTCERAM material could / would not quantify the savings
		TOTAL SAVINGS / INCREASED INCOME:	784	

2.2. Main publications

	Type of disseminattion means	Target No.	Actual No.	Reference / Place / Date	Partner responsible / involved	Title / Subject
1	2 oral presentations each at national seminars	8	7	P - Polish Ceramic Society 14/16.09.07		
				PL-13th Conf Sociedad Portuguesa de Materiais Porto April 2007	UAVR	Development of Mg substituted apatite cement for clinical applications
				PL-13th Conf Sociedad Portuguesa de Materiais Porto April 2008	UAVR	Aqueous suspension of CuO particles
				I - Italian Society of Ceramics 14.11.07		
				UK - Powder Matrix annual event		
				I - Xth Italian National Congress on Rheology , 19-21 May 2008	CNR-ISTEC	
				PL- 11th Int. Conf. of Euro Ceramic Society Crakow June 2009	Unimore/AGH	

	Type of disseminattion means	Target No.	Actual No.	Reference / Place / Date	Partner responsible / involved	Title / Subject
2	3+ oral presentations total at European or international seminars	3+	9	PL- 5th Asian Ceramic Ware Symposium Korea 2007	UAVR	Major challenges that the traditional ceramic sector is facing
				PL- Indian Ceramic Society (CG & CRI) Kolkata 2008	UAVR	Aqueous Colloidal processing of Zr & Zr-alumina ceramics
				PL- 1st Int. Conf on Recycling & reuse of Materials - Kerala, India July 09	UAVR	Traditional ceramic compositions for a wide variety of industrial wastes to a sustainable development
				PL- 14th Int. Clay Conf. Castellaneta Jun 09	UAVR	The role of clayey materials in the ceramic industry
				PL- 14th Int. Clay Conf. Castellaneta Jun 09	UAVR	Effects of additives on plastic forming techniques of traditional ceramic products
				PL- 11th Int. Conf. of Euro Ceramic Society Crakow June 2009	UAVR	Zn & Sr substituted bone elements for clinical applications
				I - Tecnargilla Oct 2008	Unimore	
				PL- 10th International Conf. of European Ceramic Society Berlin June 09	UAVR	Advances in processing Aluminium Nitride in aqueous media
				UK - Euromat, Glasgow Sept 09	Ceram	The ADOPTIC Project
3	At least 40% (of 1+2) to be written up as technical papers	4	3	PL- Kerala July 09 to 'Waste & Biomass Valorisation'	UAVR	
				I - Xth Nat. Congress on Rheology (see in 1 above) 19-21 May 2008	CNR-ISTEC	
				PL- UAVR Castellaneta Jun 09 (Effects of Additives etc.) 'Applied Clay Science' 2009	UAVR	
4	3 general articles in ceramic or materials journals	3	3	I - Ceramica Informazione (Unimore) In Italian & English Apr 09	Unimore/Ceram	
				UK - Article in Materials World Jul/Aug 09	Ceram	
				I - International Ceramics Journal June 2009	Unimore	The Expert System ADOPTIC for the selection of the additives for ceramic processing

	Type of disseminattion means	Target No.	Actual No.	Reference / Place / Date	Partner responsible / involved	Title / Subject
5	3+ poster presentations at European or international seminars	3+	10	I - Tecnargilla Rimini 28 Sept - 2 Oct 2006	CNR-ISTEC	
				I - Tecnargilla Rimini 30 Sept - 4 Oct 2008	CNR-ISTEC	
				UK - Euromat 2007, Nuremberg 10 to 13 Sept	RTDs	
				UK - Loughborough Mar 08		
				I - Research to Business Bologna 5 - 6 June 2008	CNR-ISTEC	
				I - Fabrica di Roma - Rome 14th May 2009	Unimore	New opportunities for the development & production of Sanitaryware
				PL- 11th Int. Conf. of Euro Ceramic Society Crakow June 2009	UAVR	Green strength of gelcast Ni ferrite ceramics
				UK - 14th Int. Clay Conf. Castellaneta Jun 09	Ceram	
				I - 14th Int. Clay Conf. Castellaneta	Unimore	ADOPTIC project optimisation of chemical additives
				I - 14th Int. Clay Conf. Castellaneta 14 - 20 June 2009	CNR-ISTEC	
				PL - 14th Int. Clay Conf. Castellaneta Jun 09	UAVR	Importance of additives on emerging processing technologies of nano-ceramics
				P - 14th Int. Clay Conf. Castellaneta	AGH	
6	Web site each updated ADOPTIC comment every 6 months - record any non member contact			UK - live on Ceram web sept 08; 2240 hits 50%+ for ADOPTIC	Ceram	
				I - Link to brochure on Unimore web site	Unimore	www.reolab.unimore.it
				UK - Info on Ceram site updated with training progress		
				UK - Web site now available to view, password protected	Ceram	
				I - Link to ADOPTIC on ISTEC web site 15 Oct 2008	CNR-ISTEC	
7	Start up brochure			Completed	Ceram	
8	2 national workshops each to	8	8	I - Ceramicolor member meeting Modena 07.05.07	IAGs	
				I - Board & Technical meetings at Modena 09/10.05.07		
				I - Confindustria members meeting	Confindustria	

	Type of disseminattion means	Target No.	Actual No.	Reference / Place / Date	Partner responsible / involved	Title / Subject
	promote awareness			UK - Ceram presentation to Refractory members of BCC	Ceram	
				I - ISTEC/Unimore/Confindustria present to technicians non ADOPTICpartners 06.04.09	Unimore	
				UK- Technician training on test protocols	Ceram	
				UK- Training on Knowledge system 03.04.08	Ceram/BCC	
				I - Dissemination to sanitary technicians Civita Castellana - 13th May 2009	Unimore	The rheology of ceramic suspensions
9	1 workshop each to disseminate idea to non-members	4	7+	UK - Energy & Emission meeting	RTDs/IAGs	
				Refractory & Ind. Cer. group 16.05.07 & 23.07.08		
				I - meeting with Ceramicolor member		
				UK - See training in item 8	Ceram	
				I - Presentation to students at Unimore 15th May 2009	Unimore	Science and Technology of Ceramic Materials Course
				I - Meeting with Confindustria Ceramica associated (non-ADOPTIC members), Sassuolo 16 Jul 2009	CNR-ISTEC, CC, UNIMORE, Ceramicolor	Present the ADOPTIC project
				I - Meeting with Tile Technicians _ Sassuolo Italy 25th June 2009	Unimore	
10	4+ meetings with additive/equipment suppliers to promote database	4+	6	I - Modena meetings	RTDs/IAGs	
				UK - One to one meetings with Lubrizol & IMCT (2 meetings)	CERAM	
				UK - Suppliers (WBB & Ceraktiv) invited to KS training event Jul 09	CERAM	
				PL- Meeting with Lambertti Oct/Nov 2008	AGH	
				UK- Meeting with Ceradrop (France) Sept 2009	Ceram	
11	Brochure distribution			UK Brochures sent Mar 07 to BCC members in Refractory & Ind.	All	

	Type of disseminattion means	Target No.	Actual No.	Reference / Place / Date	Partner responsible / involved	Title / Subject
				Ceramic sectors		
				UK Brochures sent Apr 07 to BCC members in Whiteware sector		
				UK- 764 downloads of pdf on Ceram web site since Sept 08		
12	Special IAG Meeting			All IAGs - Sassuolo, Italy 19.11.07	IAGs	
13	Training			See ALMA list prepared for Faenza meeting 27/28 July 09	Ceram/BCC	
				I-Mezzolombardo c/o SOFC Power, 6 April 2009	CNR-ISTEC	