Final Report: Advanced Multiphysics Simulation Technology (PIAP-GA-2012-323526-AMST)

This project was concerned with developing a novel and innovative simulation tool for multi-physics engineering applications that resulted in the paradigm of the Extended Discrete Element Method (XDEM). The activity was triggered by the fact that a large number of applications include at least two or more multi-physics phenomena that involves continuous and discrete phases. Problems that involve both a continuous and a discrete phase are important in applications as diverse as pharmaceutical industry e.g. drug production, agriculture food and processing industry, mining, construction and agricultural machinery, metals manufacturing, energy production and systems biology. Some predominant examples are coffee, corn flakes, nuts, coal, sand, renewable fuels e.g. biomass for energy production and fertilizer. In addition, Merrow [1] pointed out that particulate and multiphase processing rarely reach more than 60% of the design capacity because of inadequate understanding of the fundamentals. Therefore, any technological advance is bound to produce a mayor economic impact.

Having identified this technological gap, the AMST partners University of Luxembourg (Luxembourg) and inuTech GmbH (Germany) together with associate partners from industry and academia namely Paul Wurth (Luxembourg), FLSmidth (Denmark) and Lithuanian Energy Institute (Lithuania) were set to develop advanced multi-physics simulation technology. For this purpose, the software module of the Discrete Particle Method (DPM) available at the University of Luxembourg and representing the discrete phase was coupled to the Finite Element (FEM) or Finite Volume Method (FVM) representing the continuous phases by a generic interface during the lifetime of the project. A vast number of software relies on FEM and FVM as discretisation techniques for continuous domains such as Finite Element Analysis (FEA) and Computational Fluid Dynamics (CFD). In order to facilitate application of this tool, an appropriate graphical user interface (GUI) was developed. The GUI and these interfaces advanced significantly the predictive capabilities of the AMST tool and allowed to treat applications as diverse as powder metallurgy, material science, snow research, thermal conversion of biomass to promote renewable energy, iron making, material handling and its machinery and thus, have a achieved and exceed the objectives and anticipated applications areas of the project. Further documentation is found on the project's webpage: http://inutech.de/amst/

[1] E. W. Merrow. Linking R&D to problems experienced in solids processing. Chemical Engineering Progress, 81:14-22, 1985.

Secondment/Recruitment:

Secondments were carried according to plan and included Mr Sebastian Peetz and Mr Tobias Wittner seconded from inuTech to the University of Luxembourg and Mr Alvaro Esupinan, Mr Amir Mahmoudi, Mr Xavier Besseron and Mr Gabriele Pozzetti were seconded from University of Luxebourg to inuTech.

Transfer of Knowledge:

The inter-sectorial composition of the consortium reflects the character of the industry-academia partnership. The core team includes the University of Luxembourg as an academic partner and inuTech as a representative of industry and the associated partner as representatives of world-leading industries. The main part of transfer of knowledge took place between the core partners by arranging the schedules secondments between University of Luxembourg and inuTech. Hence, inuTech seconded researchers were trained to handle the XDEM software platform, while University seconded researchers learned to exploit the features of the graphical user interface (GUI). This transfer of knowledge resulted in an explanatory set of manuals and tutorials: Programmers manual, documentation of the source code, online manual of the GUI via mouse clicks, extended tutorial guide.

In particular the tutorial guide has been perceived as a valuable document, because it displays the predictive capabilities of the XDEM software framework and allows new users to find an easy entry to the software framework. Since tutorial include a complete case setup, they may be modified to

accommodate different requirements and geometries, so that these tutorials serve as a starting point for similar applications.
An initially workshop planned had to be cancelled due to a too low number of participants (only one), because a multi-physics conference took place at the same time organised by the renowned engineering society of NAFEMS (https://www.nafems.org/). Therefore, the above-mentioned workshop and the planned conference were merged into an internal workshop at the historic castle of Bacharach, taking place between the October 12th and October 14th, 2016 and announced on the AMST homepage. This workshop will be continued and organised by the University of Luxembourg beyond the duration of the AMST project due to the more than positive feedback starting autumn 2017.
A further activity of transfer of knowledge that exceeded the proposed actions in the proposal was training of PhD students inside and outside the European research area from the following institutions: University of Pisa, Italy, University of Milano, Italy, University of Monastir, Tunisia, IIT Bombay, India, IIT Madras, India.
In order to continue the contact with the above-mentioned researchers and institutions, a web portal has been created, to which the researchers are allowed uploading their input, starting the desired XDEM solver, downloading the results and finishing post-processing and analysis at their home office.

Communication, Dissemination, Outreach Activities:
The core partners, University of Luxembourg and inuTech, practised an active dissemination strategy throughout the lifetime of the project. As a first action a website for the project was set up and maintained as to be seen at: http://inutech.de/amst/ Main activities of dissemination included obviously publication of articles in peer-reviewed journals and conference proceedings as listed below. More dissemination activities again exceeding the actions in the proposal included Prof. Peters becoming the Luxembourg representative in the following COST actions:

- COST action MP1305: Flowing Matter
- COST action MP1106: Smart and Green Interfaces

Workshops/mini-symposia were organised by Prof. Peters at appropriate conferences:

- "First Multiscale-Multiphysics Approaches For Engineering Applications" at ICNAAM 2016
- "Second Multiscale-Multiphysics Approaches For Engineering Applications" at ICNAAM 2017
- "XDEM - A Software Platform for Advanced Multi-Physics Simulation Technology" at Particles 2017

Furthermore, invited keynotes/plenary lectures were delivered by Prof. Peters:

- European Centre for Emerging Materials and Processes, 2015: Multi-scale Modelling for Engineering Applications
- 26th International Symposium on Transport Phenomena, Leoben – Austria, 2015: The Extended Discrete Element Method (XDEM) as a Flexible and Advanced Tool in Multi-physics Applications
- SteelSim 2015, MODELLING and SIMULATION of METALLURGICAL PROCESSES in STEELMAKING: A Combined Experimental and Numerical Approach to a Discrete Description of Indirect Reduction of Iron Oxide

Outreach activities: Uni homepage + Faculty page, L'Essentiel, Paperjam, Chronicle, Innovation.public.lu, Social media: Twitter, Facebook Uni + Facebook FSTC, LinkedIn, http://radio.rtl.lu/emissiounen/10-bis-1/1752093.html

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