Theme: BRICKS **Axis:** Processes **Project code:** B/P/2

Title: Technology of non-conventional processes with glasses, metals and composites materials

Summary: Accounting for localized multiphysics involving an extremely large number of process parameters for describing complex and optimal process trajectories.

Leader: Jean-Yves Hascoët (PU)

Participants: A. Poitou (PU/Gem), C. Binetruy (PU/Gem), G. Racineux (PU/Gem), T. Rouxel (PU/LARMAUR), P. Mognol (PU/IRCCyN), M. Rauch (MC/IRCCyN), A. Barasinski (Scientist), S. Comas (Scientist), J-L Siedlis (Engineer), Didier Priem (Engineer), JM Lebrun (Ass. Engineer), F. Pasco (Ass. Engineer), G. Carabin (Engineer), T. Broquin (Ass. Engineer)

Foreign collaborations: E. Boila (EPFL), I. Stroud (EPFL), SH Suh (Postech, Korea), P. Bartelo (Leiria), S.Advani (Delaware), R. Akerman (Twente), R. Riedel (Darmstadt)

Context:
New technologies are enabling us to design, build, distribute, and support new and improved products with speed and quality not achievable just a few years ago. Clearly, innovations in processes, equipment, and systems will play a lead role in driving major transformations of the manufacturing base over the next few decades. Beyond design, simulation tools can greatly help improve the efficiency of manufacturing processes. Manufacturing is changing rapidly around the world. Coincidentally, recent advances in information systems, business practices, engineering techniques, and manufacturing science now enable companies to produce new and better products quickly and at a much lower cost than ever before.

Research project:
The project does not focus on *one* process or *another one*, but will focus on a generic approach for the choice of the best process, or the best processes. The concept of hybrid manufacturing, or multiprocesses will be developed (*for example, incremental forming of basic material as substrat for noble materials in Direct Manufacturing, or fiber placement associated with the induction welding*). The bedplate of the approach is based on the study of the generations of complex trajectories in the space under constraints of the operating parameters inherent to each process.

The processes that are proposed for study in this project have **four main common features**: (i) **They are still emerging** or at least currently not well understood enough to be widely used in varying situations. The purpose is therefore not to optimize one process, but really to develop new ones. (ii) **They act on the material locally on a small subset of the part**: in opposition to classical forging, stamping or injection molding processes,… which act on the bulk material. (iii) As a consequence of the previous statement, the development of the processes requires that a **large number, or even an infinite numbers, of degrees of freedom** be chosen. *In an incremental forming or FSW process for example, without any reference to the tool geometry, the whole tool trajectories, which means "quasi infinite" different possibilities, has to be fixed.* This cannot be done with purely empirical method like experimental design. (iv)The degrees of freedom of the process are fixed through controlled systems. Thus, the tool involves so-called **dynamic errors** in the process (*due for instance to tool deflections, or more generally thermo-mechanical interactions between the tool and the material*). Reducing dynamic errors is essential in order to improve the quality and accuracy of the processed part.

Each process is specific but the interaction of the tool with the materials requires the understanding of the **complex multiphysics** involving the behavior of the material within the process. The discrepancy between specified and actually experienced tool trajectories (dynamic errors) need to be compensated. To do it with a closed loop controlled system a real-time simulation of the process would be a prior interest. The process modifies the materials so that the in-service durability of the part cannot be studied without a reference to the process.

The processes that are proposed for study: (i) Composite fiber placement, (ii) Thermoplastic composite welding processes (ultrasonic, induction, laser, high frequency …), (iii) Direct

manufacturing (powder sintering / Clad for FGM/Functionally Graded Materials Metal/Metal, Glass/Glass, Metal/glass, Metal/composite), (iv) Friction Stir Welding, (v) Incremental forming.

This study could be made only with a strong interaction between the Materials and Simulations Bricks, to take into account all the constraints of all the manufacturing chain. Furthermore, this allows to federate multiple knowhow (often isolated), what also presents another challenge of this project.

For more details and extra references please refer to www.irccyn.ec-nantes.fr www.gem.ec-nantes.fr http://www.larmaur.univ-rennes1.fr/