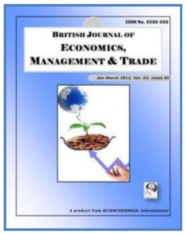

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Improving the Competitiveness of the SME's using Trade Knowledge and Simulation Based Design

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Many SMEs are manufacturing sub-contractors, leaving their purchaser manage the design phase. Even those using CAD systems do it in a very basic way. They face technical and methodological problems when they try to evolve to functional design which is mandatory in the globalized world, for instance to use numerical simulation before manufacturing. Simulation is mainly used to verify the specification, all along the design process. Many SMEs follow well known stages: Modelling the object using CAD system, simulation under given condition of the behaviour of the model, modification of the CAD model. Some limitations or drawbacks of this kind of process are obvious: the designer does not manage the multi-criteria aspects of the problem and by using the constructive approach of CAD systems, he cannot express the overall objectives.

In order to be more efficient, intensive simulations, based on trade knowledge, should be done before the design itself.

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After an introduction presenting the context of the research, we detail in chapter 2 the evolution of the process from the traditional process to the XFD (X For Design) one.
In order to verify the interest of XFD, we have chosen to process industrial, mainly on industrial (SMEs) cases. This work has been then a central work of the research centre DINCCS theme for last five years as an inductive research. About fifty industrial cases have been studied. About twenty of them are significant for the object of this paper.
In order to illustrate the diversity of the industrial cases we detail (not technically) some examples. We present some important results, considering three cases, based on the technology point of view:

- The integration in a specific tool of the numerical simulation and CAD system.
- The use of numerical optimization before design
- The specific use of trade knowledge in a dedicated system

Then, we discuss the strategy point of view, illustrated by six main cases.
The industrial examples confirm that this new approach can provide a quantifiable competitive advantage for most manufacturing SMEs. This is very important for SMEs, particularly manufacturing ones. Using numerical simulation (optimization) intensively, before defining the CAD model, they can get unexpected gains (mass, quality, better use of the means of manufacture).

Keywords: SMEs; design; simulation; competitiveness.

1. INTRODUCTION

We consider SMEs (Small and Medium Enterprises) whose core business is to manufacture products.

The behaviour of the product in a given number of circumstances is the basis of the design process. SMEs, including subcontractors or OEMs are usually in one of the following cases:

- They have to manufacture using a CAD model which was not designed taking into account the company's manufacturing processes. So, they must adapt the initial design to their own specification (in condition even the instructing party to accept the modifications).
- They receive a functional specification, including the targeted behaviours. The sub-contractor can then process its own design (directly or in collaboration with the customer), taking into account its trade knowledge.

We have already studied the first case [1], by a collaborative work based on appropriate procedures. This is, as expressed above, not the most effective method, and it should be used only in cases where it is impossible to stand in the second case.

In this paper, we are interested in the second case.

The company's performance can be hugely improved by using better the tools, giving it an advantage compared to its competitors. This can be done only by defining methodologies for the use of numerical engineering software, for example, to facilitate the design, simulation, or manufacturing phases.

Numerical simulation and optimization must be in the design loop [2,3]. The CAD (at least in the general sense ascribed today) will be only a complementary tool certainly fundamental, especially to complete forms, but whose use should be guided by functions (parameters, design methodologies, tree of construction).

The main points which should be considered are:

-the quality of the models (especially for the simulation): This quality is generally verified by physical tests.
-the variety of parameters (physical quantities, materials, form...) influencing the design and describing the behaviours. It should be noted that certain behaviours are described in the specification, but that the SMEs - ETI should include their own behaviours, including manufacturing processes used (but not only).

The 'traditional' design on a CAD system, due to the CAD technology itself, is constructive and non-synthetic. It faces the complexity of design that is due to several factors:

- There are many free variables of different kinds

- The objectives to sustain are often conflicting
- The constraints, as the objectives, are contradictory
- Many problems are non linear.

In most case, this complexity cannot be taken into account by the designer. Even using parameter design, which gives a certain flexibility of amendment, it is illusory to believe that it is possible to determine the parameters of the most suitable design, except in special cases, at the beginning of the use of the CAD.

The objective is thus to find 'better' design parameters for a given project by studying the influence of these parameters on the behaviour of the product. The most common method is to evolve the value of these parameters and submit the model to an experiment (be it virtual simulation or whether by a physical test). It is of course inconceivable, except in special cases (discrete sizes with a relatively small space), to hope to test all possible cases.

Plans of experiments are a solution in determining and ordering tests to identify the effects of the parameters, with a synthetic approach (of the "General" settings to retail settings) on the response of the product.

2. FROM DFX (DESIGN FOR X) TO XFD (X FOR DESIGN)

Most SMEs usually follow a traditional process of design using a CAD system, simulating the result under the circumstances modifying the CAD model and thus of follow to arrive at a satisfactory model. There is, however, an approach, known in large corporations and subject of numerous publications: DFX (design For X).

The second approach described below SFD (Simulation for Design) is at the heart of most industrial applications presented in this paper. XFX (here mostly XFD - X for Design) is a new direction that is still the subject of research projects.

We do not enter into technical details, but give the main elements for a manager to understand the challenges of technological choices.

2.1 Traditional Approach in SMEs

The « try / error » methodology is, in general used to optimize the design. This approach lead to test prototypes whose design is based on the experience of the engineer. It is based on the following classic stages [4]:

- CAD models are made using the experience of engineer trying to respect functional specifications, and the general environment of the structure.
- Some calculation models (static, vibration, dynamic etc.) are processed
- Several iterations (design loop) are used to change the design in order to meet the specifications and optimize the structure.

This manual approach should be unimaginable today, because of costs and the many iterations it can cause.

The disadvantages of the traditional design (CAD-simulation loop) method can be partially addressed by the use of concepts as DFX (Design for X), design for example taking into account of the simulation (CAD4SIM), by setting procedures in CAD which ensure that the model is adapted to the finite element modelling and easily changeable for a parametric simulation.

The acronym DFX (Design For X) refers to the work, studies or methodologies regarding the design taking into account a later phase of the life cycle of the product. The X can thus refer to manufacturing, recycling, assembly, maintenance [5,6].

But this methodology faces (each action design tries to take account of the constraints related to subsequent phases) new possibilities of the software, including numerical simulation.

In most cases, the notion of DFX applies to phases of the lifecycle of the product as the manufacturing, the maintenance, the end of life... However, in the current context the numerical simulation takes a very important role in the development of a product. The CAD-CAE link becomes a key element in order to ensure the quality of the entire process. Many works and research strive to improve this passage in focussing primarily on a good understanding of the continuous model from CAD for the finite element discretization. These works are therefore mainly applied when the CAD model is frozen and does not take into account the trade aspect (preparation of the CAD model for calculation, identifying functional area).

One of the goal of the projects of DINCCS is to define a general approach to manage the CAD-CAE link, in order to avoid discontinuities. This process is structured according to an architecture based on the work of the P4LM project [7] and associated rules of good practice to integrate knowledge related to geometry and context to prepare as soon as possible in design, best CAD model. The inductive approach of the research centre DINCCS helped inter alia to establish and test the processes and good practices on industrial cases. These rules were established as part of a doctorate work [8].

However, this approach is very difficult to use, due to the multiplicity of X: Well design to simulate, to manufacture, to maintain.

2.2 SFD: Simulation for Design

The numerical optimization becomes a particular activity of the numerical simulation. On the basis of constraints and objectives, it provides a number of solutions to a problem. The implemented algorithms give the user the opportunity to share innovative solutions. Research projects are mainly interested in improving optimization algorithms or find new ones.

The use of numerical optimization within the design process is recent and there is currently no work on the implementation of such tools in SMEs. Even within large groups, developing their own methodologies, the integration of optimization is still at its beginning, even if offices have always faced the problem of continuous improvement of the performance of their structures to predict from the earliest stages of design forms and optimal structures of these.

SMEs would achieve a better manufacturing quality at better prices, if they were able to integrate their parameters trades, particularly those related to the manufacturing process, as soon as possible. The numerical simulation is an integral part of any process of industrial design. It allows to verify or validate certain concepts in a virtual manner.

It is well known that the upstream phases of design occupies 5% of the design process, but commit more than 75% of the overall cost of the product. This fact is even more critical when you consider that they can lead to deadlocks that are detected in the phases of manufacturing for example. To ensure that these decisions are the most appropriate, one can implement the design processes relying on methodologies, as discussed in this paper, but also provide a human organization (project structure with experts according to trades…).

2.3 XFD (X for Design)

In General, a DFX methodology leads to multi-criteria problems. Reverse the binding by simulating to better design seems relatively obvious. It comes then to generalize this approach by simulating the different significant life cycle phases of the product, including the 'real' phases, such as manufacturing or maintenance and "virtual", such as simulation of mechanical structure. This trend is present, even if it is often poorly formulated in LCA (life cycle analysis) in the heart of eco-design.

The multi-criteria problem aspect is inherent to a majority of problems. However, it seems more natural and no doubt better to term to proceed in this direction. XFD is naturally easier to implement, as seen above, to take into account the optimization of forms for example. LCA (Life-Cycle Analysis) is clearly categorized as XFD (analysis of the lifecycle to better design).

Certain phases (manufacturing, maintenance, etc) pose complicated problems to enter the framework of the XFD. This is a wide field of research to which we will return... Some approaches make it possible for SMEs to optimize their product, e.g. a topological simulation before the phase of CAD. However, these optimizations are typically mono objectives and can lead to disastrous results (for example by optimizing the mass of a piece, but by making its manufacture costly, if not impossible).

2.4 Trade Knowledge

DFX, SFD and XFD can only run if trade rules are described.

If you consider the manufacture of the product (DFM: Design for Manufacturing), knowledge relates to:

- The product, mainly its characteristics: For instance, its form may have a strong influence on the costs of manufacture according to processes ("easy" to make forms are not the same in NC machining and additive manufacturing.), material,

tolerances. Generally, it is impossible to take into account all the knowledge.
- The manufacturing proceed, for instance the available resources: Machines (machines for additive manufacturing, machine tools with numerical control, robot Assembly, furnaces, injection moulding machines, means of transport), tools, operators; etc. The design of products must, as far as possible, take account of these resources, or, at least, detect both easy and difficult to manufacture, the types of design that will require or not tools, those that involve outsourcing.
- The process-related characteristics, which, of course, also strongly influence the design insofar as they impose characteristics of forms (for example, the spoils in forging).

Some factors, not related to manufacturing technology factors are also taken into account, including the costs and deadlines.

So, defining numerical optimization according to the trade lead to methodologies to use the best optimization algorithms depending on the circumstances (represented in the form of process methodologies). Trades identified in the work of DINCCS include stamping, forging, foundry, plastics and additive manufacturing [1,5,9-13].

Integrating trade knowledge, objectives and constraints is the only way to use numerical simulation (optimization). In general, the results of the simulation (optimization) is also an approximation which must be reworked by the designer.

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 Industrial Cases

3.1.1 Experiments

The gains that can be achieved by a questioning of the design process (including simulation) are phenomenal, especially for the SMEs, subcontractors or not. These gains affecting a large part of the industry (manufacturing) should not be overlooked. However, it is very difficult to convince SMEs without some experiments.

The competitiveness of sub-contractors is a key parameter to take into account the competitiveness of the whole chain. Due to the strategy of big firms (for instance in automobile, manufacturing is outsourced up to 80%), it becomes paramount. Whatever the context, the objectives of subcontractors are the same as most companies in terms of quality, price and customer satisfaction, inevitable in such sectors as aeronautics and automotive. Indeed, these requirements are imposed by the prime contractors seeking more and more, for less and less expensive products. In response, many SMEs have obtained certifications and have improved their productivity. They are adapted to relocations, sometimes "suggested" solutions by the prime contractors for a portion of their production. It is far more difficult to change their design culture.

In order to prove the industrial interest of our approach and to use real cases to improve it (inductive research), about fifty industrial cases have been treated these past five years. Some of them (about a half) were not directly related to an improvement of the design, but were essentially concerned by the validation of the functional specification (without automatic modification of the design). The others were concerned by an optimization (mass, delay).

All the concerned firms are SMEs (or function as SMEs belonging to a group) in the east of France.

The main domains of applications belong to the design of mechanical parts, using traditional manufacturing methods (foundry, forging, NC) or new additive methods.

The P4LM methodology was used, giving the firm the expected results. So, the position we take in this paper is based on real industrial cases, not just experimental examples. Even if most of the cases are confidential, they provide the essential figures usable for this paper.

Comparing the gains is almost impossible, knowing that some of them, for example obtaining a contract, are not easily quantifiable.

In order to illustrate the diversity of the industrial cases we detail (not technically) some examples. We give some significant results, considering three cases, based on the technology point of view:

- The integration in a specific tool of the numerical simulation and CAD system.

- The use of numerical optimization before design
- The specific use of trade knowledge in a dedicated system

3.1.2 Case 1: Integration of CAD-simulation tools

Example 1: Study of a rear shelf of automobile.
This case is interesting because it shows a full integration CAD-simulation with manual intervention. In such a case, virtual experiments plans integrate many simulations to achieve the best result, instead of letting the operator the difficult task of determining the 'interesting' ones. The simulation of a case can be processed in less than 10 minutes instead of 2 days before. A very important advantage is that the designer is ensured of the manufacturing feasibility. In order to lead to the "best" (in fact a "good") design, it is mandatory to process about twenty or thirty experiments.

Example 2: It's the design of the filling system in foundry (which is used to fill the moulds of parts).

Knowledge is well controlled in this area and known by experts. However, an automatic system, including trade and physical knowledge to model the system and numerical simulation to validate it, will allow to reduce design more than half time and yields to results in terms of "lost" material better than those of a human expert by a factor of 40%. In some cases, it leads to absolutely new designs (in fact, designs that the human operator would have never found).

The other processed examples show earnings of the same order of magnitude in different fields (mechanics, building). With a very low investment (some engineers days), the gain are important in terms of delay, but also quality of the design.

3.1.3 Case 2: Optimization, showing an important gain in mass important, playing on a few parameters

Example 1: It is to optimize a lifting hook.

In addition to the mechanical parameters, a numerical optimization to obtain the same functions with a mass of 5 kg instead of 8 kg.

Example 2: This is to reduce the mass of a set of wheelhouse in the railway field.

Gains are also significant: reduced mass of 13% of the connector (i.e. 1200g) and reduction of the mass of 10% of each lever (i.e. 300 g).

Example 3: This is to optimize the mass of a rod. The original part has a mass of 817 g. The virtual one, optimized by computer simulation, has a mass of 656 g. To take into account manufacturing methods, the mass of the final part is 662 g, which leads to a gain of 155 g (19%). this example illustrate the necessity of optimizing taking into account, not only the structure behavior, but also the manufacturing process.

Example 4: This is to standardize the variations in the thickness of food trays and reduce the thickness of the trays (material gain).

In addition to harmonization and reduction of the thickness of the plates while maintaining the aspect, the methodology yields a gain of 27% on consumption material (measure after 10,000 injected trays) and average gain of 44% on the injection cycle time.

All the processed cases lead to at least a gain in mass of 10% when mass is not the primary parameter, to 40% when the gain in mass is a primary parameter.

3.1.4 Case 3: Specific use of trade knowledge, showing an important gain in term of delay

Example 1: It is to optimize the management of client requests in real time with automatic production of documents (specifications, technical specifications,...) in the field of wooden building.

Processing of customer applications with automatic production of the site plans, construction, nomenclatures, good production, good commands, 3D visualization and implementation for building, permit information to treat the entire folder in minutes instead of several days.

Example 2: It's a rim mould semi-automatic design.

This kind of application must solve some geometrical problems. The result leads to a reduction of half of the design time.

Example 3: This is the optimization of the process of machining of parts of aeronautical structures.

The formalization of domain knowledge and consultation of different experts (cutting tools, machining...) led to gains of 25% in the production time. In addition, the standardization of this process ensures a constant quality during the production. The earnings in term of implementation of the process are significant: 15% in the realization of the production range (due to possibility to build on past experiences and from a standard range or range of a similar product). 40% in the costs quoting estimation.

3.1.5 Comparison

It is impossible to compare industrial cases between them. They are too different, as well in term of application, than in terms of firm culture, objectives...

However, it is clear that the methodology leads to significant gains in all cases treated. The lower earnings relate to gains of 10% in mass, the strongest gains are observed not only on weight gain (40%), but also on deadlines in design and manufacturing. We found no case which did not lead to a significant gain (mass, delay, quality).

When it comes to optimize direct gains that can be achieved in the quotation service (including not costly solutions, with simple tools of type 'good practices' or base of known cases), the following results were obtained:

- At least 40% (up to 95%) in time of realization of the quotation
- Direct gain in terms of cost of the solution over the solution which seemed correct for designers to at least 20% (for instance due to the possibility to analyze many cases).

The indirect gains (obtaining the contract, quality of the solution) are impossible to quantify. In some cases, a comparison with competing products was made in terms of quality of the product. They all have shown a major competitive advantage.

The gains obtained in a quote akin to the gains that can be obtained on a new design. In fact, implemented processes are similar, in the way it comes in both cases to design a product based on a specification.

These gains offer a considerable competitive advantage, either for the placing on the market of a new product, either for the quality and timeliness of a response to a call for tenders. They confirm experimental, often confidential, data obtained for example in the automotive field:

- 50% of cost and more developing does erosion of profit that 3 or 4%
- 10% additional cost in material gives an erosion of profit by about 25%
- a 6-month delay in the delivery of a new product means an erosion of profit of almost 1/3 or the complete loss of a market.

These General and experimental data in SMEs strongly suggest that investing in design is a priority.

They are comparable to those obtained with more or less similar approaches (design guided by simulation) in the field of crash for example. In [14], the authors claims that in results of their experiment, it is estimated that using simulation/design integration and knowledge management in configuration allows saving 50% time in the design process than classical approach.

Get the same result (about 50%) in aircraft components [15].

In [16] it is demonstrated that in the case of a stamping die (a typical case in our studies) topology optimization result has shown that 28.1% mass reduction was achieved with a slight difference of the die structure performance and blank forming quality.

There are also other areas of the optimizations that do not only concern gains in mass. For example in the design of a golf club [17], a similar process allowed the quick evaluation of important design trade-offs associated with golf driver design, leading to a 25% decrease in aerodynamic drag when comparing optimized and non optimized parts. Player tests further validated the effect of aerodynamic drag by demonstrating a 0.34 m/s (0.75 mph) increase in average swing speed.

It is important to notice that the methodology also guarantees that the company will be able to manufacture in the best conditions.

3.2 Discussion

3.2.1 Invest in design

The experiments we conducted show that it is very interesting to go from 'banal' design to engineering assisted by knowledge of the company and/or the numerical simulation. Indeed, it is to use technology at best, including trying to optimize products and processes.

Two additional opportunities available to the company: Master the skills and simulate. Knowledge management through a mastery of it, with different approaches, and must facilitate long-term innovation. Digital simulation, in various forms, must be a help to the design and tender towards optimizing the establishment of appropriate procedures. These are new opportunities of development, optimization and innovation for leaders able to understand and master these technologies.

It is clear that the use of the knowledge through a kind of simulation of cognitive processes, and numerical simulation is based on mathematical or empirical knowledge. It is a good integration of all means of simulation and modelling of knowledge which should be the goal of every business. The consequences on the subsequent phases, including manufacture, must be taken into account. Indeed, a piece must not be designed in the same way as it will be made by this or that method. The margins of gain for businesses, which could take into account this fact, are immense.

Of course, the choices are not only technological. Companies must fit in networks, clusters, or notions of co-sourcing.

3.2.2 Management of new technologies

It can be considered that many leaders have a monomorphic vision of their own business by focusing on very specific strategies, for example, 'reduce costs by hunting waste or in relocating', 'expand their market through the acquisition of other companies', neglecting more fundamental aspects related to their offer and the company's processes and by attaching not enough importance to marketing, research and development, and new modes of organization and communication. Searching for local optima can lead to decisions that go against a global optimum.

To these developments and the importance of knowledge, business or technology, it may be the return of leaders less technocratic and more «technology» which will be required.

Indeed, technological elements cannot be considered as simple black boxes. It is necessary to well understand the sensitivity of assistance to market entry conditions and their own operating tools. It is vital to rely on active management with regard to the possibilities and the limits of "new" technologies.

The traditional management, resulting often in SMEs in family traditions and "house" characteristics, is going to have to adapt to new types of personnel (engineers, modern design and simulation tools) and methods of different work (co-design, physical or virtual plateau, shares of information systems).

These new cultures, often poorly known by SME's managers, involve fundamental changes of organization and management of personnel. Training plays a key role in this new context. It is essential to develop appropriate training, in close contact with the industrial world, not only with large companies, but especially SMEs. The need for "skilled" technicians, still advocated in production, is also essential in design and simulation. Indeed, the constraints are higher still for subcontracting SMEs than for independent SMEs without any relationship with a customer. New trades emerge around the integration of numerical models, quality assurance of the digital model or models by finite elements.

The acquisition and management of knowledge can largely benefit from skills shared by all partners. In addition to a better response to the market at a given time, this progress should foster a genuine strategy on the part of subcontractors in playing on their strengths and, eventually, playing the role of prime contractor for poorly controlled aspects: They have to look for the highest possible value.

Indeed, SMEs which have only a one-time need of such or such technology cannot afford to recruit qualified personnel which, in any case, would lose their expertise, rarely using these tools advanced tools. It is therefore necessary to implement specialized technical centres.

3.3 SMEs must have a Clear Strategy

Collaborative numerical engineering is function of the situation and the strategy of the company, which can be summed up by cases types (based on the strategy of the enterprise, using one or several technology approach as presented before), such as:

Case 1: Obligation or willingness to lower costs in a manufacturing outsourcing relationship. It is SMEs that have a history based essentially on production from information (plans, models) frozen capacity. Without seeking to intervene in the design of the product itself, the goal is to optimize the manufacture. Knowledge modelling, including rules related to the manner of manufacture is in the heart of the choice. The collaboration will remain limited to the tools of communication and exchange of reliable data. The strategy should be quickly challenged to check that it places the company in a healthy situation or to consider the case type 2.

Case 2: Obligation or willingness to move from an outsourcing of manufacturing to a functional outsourcing. It is, as in the first case of SMEs who have a story based primarily on production capacity, but are considering a strong evolution. Two essential difficulties are to be taken into account: Put in place the tools and skills to be able to interact with the principals at the design stage, and give the ability to fit into a true collaborative project. A questioning of the process, tools and skills is essential.

Case 3: Obligation or willingness to quickly respond to invitations to tender. It is necessary to use the latest communication tools (portals, marketplaces) and to quickly interact with the order-givers.

Case 4: Willingness to share ways to progress. Several competing companies can work together to advance their market. Additional companies may also work to better respond to a market or create new products (networks of companies). All levels of collaboration can be considered simple informal communication to co-design. In addition to technical aspects, processes and mutual confidence, present in all cases, are very important.

Case 5: Willingness to play a role of row 1 in subcontracting (Integrator). Need to ensure the construction of a solution, as optimal as possible, with a set of selected companies.

Case 6: Willingness to play a role of instructing party: Many subcontractors must quickly evolve from the manufacture of products or sub-assemblies to co-design. This evolution strengthens with the need to respond to functions that require subsets modeling, or even the integration of several professions, for example for mechatronic systems. Integrating an extended company type or co-sourcing relationship is a condition imposed by the OEMs or tier 1 suppliers. The subcontractor may draw significant and lasting benefits.

Indeed, this gives him the opportunity to express its know-how, to share it (carefully) with the selling order-giver, grow faster and to establish relationships of trust bearing for the future. Of course, this sharing must be a fair and reasoned manner. In some cases, the instructing party will objectively help improve the performance of its subcontractor.

Subcontractors do not undertake without risk in a process whose expected benefits are difficult to assess, and it must be admitted that the implementation of new technologies in the past have not always been successful. However, the companies must meet these challenges to take or retain a place, as a subcontractor of functions, or even a system. Culture change is profound. The extended enterprise leads to an obligation to develop alliances, partnerships, trade to survive, internally or externally. Examples showing significant gains can help SMEs to engage in these new approaches.

Work habits are significantly challenged, in a context of competition and pressure. If short-term issues are well fit into a functional subcontracting in the context of extended enterprise, medium term need to be sufficiently efficient in his job and in the mastery of new technologies to anticipate the needs of the buyers.

Do not neglect, finally, the perverse effects of certain relocations, including in terms of loss of know-how. This finding, already known in big firms can be dramatic for SMEs. They must be able to rely on strong skills, taking into account developments, retaining a strong relationship in design offices and workshops. In our experiments, we found that even when a significant gain was obtained using trade knowledge or numerical simulation, the companies continued to manufacture in low-cost countries.

Although it is generally not in their culture, SMEs should consider their strategy in terms of business, technology, product, process and methods. They also have the duty of thinking at different levels. A regional level, to build networks with close and complementary companies; a national, European or global, to fit in projects advocating best practices and be able to compete with the world level. It is very interesting to rely on innovative projects allowing SMEs to acquire best practices.

4. CONCLUSION

Simulation is not yet intensively used in SMEs (an in many bigger firms). They process one or two simulations for performance reasons. If they wanted to do it, it would be also very difficult to express design of experiments (planning of simulations to perform). Moreover, the problem is, in general, multi-criteria and it is not easy to examine more than one or two parameters (for example the mass) and even more difficult to take into account manufacturing constraints at the design stage.

Even if you consider the case of unique parts (i.e. without Assembly or with simple assemblies), the method should allow incredible gains for SMEs.

We have experimented our approach on about 50 industrial cases. Each case implementation toke between 5 days to 60 days.

Even if it is not relevant from our point of view to carry a statistical analyses, the results of the industrial cases confirm that the intensive use of numerical simulation is essential for SMEs, while one might think that they could base their design on one or two simulations. Even for parts (without Assembly) designs or for new processes such as additive manufacturing, intensive simulation may prove to be very effective for businesses and lead to deep modification of the design-manufacturing process, particularly in SMEs.

The gains that we were able to examine, without yet using new developments (computational geometry) and automatic design of experiments are very encouraging.

The experiment show that it not only a technology point of view, but that management and strategy are the key of the success.

Our proposal should guide to a new design-simulation process that will be modeled by P4LM [6]. The relations of orders - subcontractors could be modified, giving more importance to the earliest stages of design in a collaborative scheme. This study leads also to an important change in trade culture, with technological and methodological changes which are the subject of an ongoing project in Dinccs.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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