Valuing Knowledge Management impact on engineering design activities

Mickaël Gardoni, Aurélie Dudézert

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MICKAEL GARDONI, AURELIE DUDEZERT

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1 Introduction and objectives

Knowledge Management Systems (KMS) have been developed in Engineering Design activities in order to improve the productivity of these activities. Nevertheless it is still very difficult to identify the impact of such Systems on the Engineering Design Performance.

In this paper our goal is to present why valuing Knowledge Management Impact on Engineering Design is today a challenge. In a first part we aim at presenting how and why Knowledge Management has been introduced in Engineering Design Activities. By a review of the literature from a span of disciplines we will next focus on the different ways to value the impact of Knowledge Management Systems on firm activities. At least we will propose a method to monitor the impact of Knowledge Management Systems on Engineering Design Activities.

2 Knowledge Management and Engineering Design Activities

In the context of our work, we consider that knowledge is in peoples' mind, so it is tacit. If it is explicit, we consider it as being information. Brohm [1] argues that the notion of "explicit knowledge" is another expression for information which can be interpreted by receivers by using their expertise. We agree with this argumentation and therefore consider explicit knowledge as information as long as it possible to interpret this information.

These two processes play an important role for the knowledge management models and for knowledge creation processes based on information. However, in order to be able to transform information into knowledge, people need a certain expertise and need to know the context of the information. For each transformation, the human being brings in his own interpretation of the knowledge or information. Therefore, the information and knowledge can have different meanings for different human beings.

Research/design activity implies the management of information and knowledge and could be considered as a knowledge production process. Indeed, the process of assembling knowledge involves the combination of knowledge to create new knowledge that could be reused within another combination. In this context, the only object that we are able to manipulate is information in order to improve the design/research process but this is not implying the improvement of the research/design product. So the valuing Knowledge Management is primordial.

3 Different ways to value Knowledge Management on Firm Activities

A brief state-of-the-art on Knowledge and Knowledge Management Evaluation immediately shows a large variety of ways to value Knowledge Management Impact on Firm Activities. In particular Knowledge Management can have financial impact, strategic impact or operational impact. A lot of works have already been devoted to value the financial impact of Knowledge and Knowledge Management on Firm Activities [2] [3]. Therefore we will mainly focus on the valuing of Knowledge Management strategic and operational impacts which have been less described in previous studies.

3.1 Financial impact of Knowledge Management

A state-of-the-art on Knowledge and Knowledge Management Evaluation shows that there are a lot of researches on financial value of Knowledge. Often inspired by trademarks or licences accounting methods, those Methods which demonstrate the impact of Knowledge and Knowledge Management on company financial ratios have been developed since a long time ago. Knowledge is seen as an asset which can be valued and accounted likewise a tangible asset. The difficulty is to make financially valuable such an intangible asset. Therefore, in order to value Knowledge and Knowledge Management, those methods account the financial value of documents, licences and trademarks of the company. The most these documents, licences and trademarks are financially valuable; the most Knowledge Management has a positive impact on the Firm Activities.

Methods such Intellectual Capital of Strassmann [4] [5] [6], DOW's Knowledge Evaluation Method [7] or Tobin's Ratio are often quoted as such Evaluation Methods.

Such methods aren't very useful to Knowledge Managers. They do not value the direct impact of Knowledge Management on the Firm Activities. They value an indirect impact of this Knowledge Management. Such methods are global indicators of the Knowledge Management efficiency for Engineering Design Activities. They are not able to characterize precisely how to improve the Knowledge Management.

3.2 Strategic impact of Knowledge Management

Studies on strategic value of Knowledge and Knowledge Management are more recent. They have been developping since the Resource and Knowledge-Based View theories (Penrose and Wernefelt, Prahalad and Hamel) are considered like a dominant paradigm in the Strategic Management Research Community. Knowledge has strategic value because it helps companies to gain a competitive advantage. In fact these RBV and KBV theories show that efficient Knowledge Management provides firms with competitive advantage.

Evaluation Methods like Balanced ScoreCard [8], Intangible Assets Monitor [9], Intellectual Capital Statement [10] or ICdVal [11] are influenced by these theories. These Evaluation Methods may be used to value which kind of Knowledge is strategic in a company and/or whether Knowledge is efficiently managed in a company in order to obtain a competitive advantage.

Nevertheless the above-cited methods do not take into account the point-of-view of operational actors of the company (e.g. workers; Knowledge workers…) on the strategic value of Knowledge. They define the way Knowledge is strategic within a macro-organizational point-of-view of the company. It's probably one of the reasons why such methods are not often used in Engineering Design Activities.

3.3 Operational impact of Knowledge Management

Some quite more recent works aim at valuing Knowledge and Knowledge Management in an operational way. This way to value Knowledge Management is probably the most appropriate to value the impact of Knowledge Management on Engineering Design Activities. The operational way to value Knowledge Management intends indeed to value the impact of Knowledge and Knowledge Management on operational activities and processes.

This category of approaches and methods gathers works inspired by researches and methods on the operational processes of companies (more particularly Quality approach) and works inspired by researches and methods on Information Systems.

<u>The processual approach of the performance of Knowledge Management</u>

The first approach of this category is the "processual" approach of the performance of Knowledge Management. In this approach, Knowledge Management is considered as a specific operational process. To study the KM Performance, this approach aims at valuing the impact of the KM process on the operational processes and the activities of an entity (department, business unit …). The goal is to optimize the management and the performance of this entity.

C. Frank 's [12] and A. Jaime's [13] research works could be categorized in this processual approach of the KM performance. In both cases the objectives are to characterize the impact of the KM process to improve processes and activities in R&D entities or in Academic Laboratories. In order to succeed, these works focus mainly on the study of the impact of the support process to KM, i.e. the Information Sharing process, on the operational processes and activities. Moreover, these works characterize ways to improve research activities and Knowledge Management by supporting information artefacts (textual and graphical such as sketches). Thanks to new and ergonomic groupware prototypes working on PC networks they propose to control two kind of artefacts: (1) Semi Structured Information (e.g. reports, etc.) thanks to the ANITA functions, and (2) Non Structured Information (such as mail, dialogues, etc.), thanks to the MICA-Graph approach.

Evaluation Methods like MAGIC (Measuring and AccountinG Intellectual Capital) [14] or NIMMeasure [15] aim also at valuing Knowledge Management in such an operational way. Such methods consider there are only specific phases in the R&D process development where Knowledge and Knowledge Management have a particularly important impact. They focus on this R&D process development and identify the different phases where Knowledge and Knowledge Management have a real impact.

MAGIC (Measuring and AccountinG Intellectual Capital) is a method whose development was supported by the European Commission. It identifies factors that lead the R&D

Department to be efficient with Knowledge Management and compares this ideal situation to the actual situation. In this method Knowledge and Knowledge Management are not specifically related to the R&D process.

NIMMeasure's development was also supported by the European Commission. It aims at optimizing the management and development of Knowledge in R&D processes. Contrary to MAGIC this method considers Knowledge as intimately related to the Research Process. KM is a specific process but it is closely linked to the R&D process.

The systemic approach of the performance of Knowledge Management

A second approach in these « operational » approaches of the KM Performance focuses more specifically on the study of the performance of technological and organizational systems related to Knowledge Management. Such research works and methods are inspired by research works on Information Technologies (IT) and Information Systems (IS) Performance. A lot of KM Programs are today supported by Information Technologies and Information Systems. That is the reason why some of KM Performance evaluation methods are inspired by works on IT and IS Performance.

Such research works study more specially the performance of the Knowledge Management Systems (KMS). The KMS is defined as a technological and organizational structure that supports the Knowledge Management.

Such approaches are quite emergent. Nevertheless research works such as A. Lancini's Ph-D on the identification of successful factors of the KMS adoption in an organization [16] [17] could be put in this category. The impact of KM is defined by analyzing the impact of the implementation of the KMS on the operational activity of the Department. A. Lancini addresses this question by putting forward the hypothesis that the KMS is performing according to the use level of this KMS in the Department where it is implemented.

The eSmac Method [18] is inspired by such IS approaches of the KM Performance. This method identifies the performance of KM by analyzing how the implementation of the KMS in a Department allows fulfilling the strategical objectives of the Department. eSmac indeed aims at identifying the value-added by the KMS to the Knowledge of the Department and how this Knowledge could impact the operational process of this Department.

4 Ways to implement eSmac Method

In the context of the eSmac method, we intend to build measure means in order to asses roughly the amount of knowledge master by the firm and especially Engineering Design Activities or industrial research centres. Indeed, nowadays, industrial companies need to follow and control the acceleration of technological progress to be able to maintain the market position of their products and services and also to generate the opportunities required to become the market leader. As such, to improve their competitive advantage due to innovation, research activity should be rationalized and the efficiency of the Knowledge Management should be measured.

4.1 Research/Engineering Design Activities Specificities

Research activity implies the management of information and knowledge. Also, the research process could be considered as a knowledge production process [19]. As we wrote above, the research process could be considered as a knowledge production process. To improve this process, during the last few years, some research organizations have shown an interest in quality management. However, research activities present specificities in terms of goals, resources, practices and organization which make them very different from industrial activities, where quality management has been traditionally used, because the knowledge is less concrete than products, parts, etc.

This knowledge production activity, according to the results of research in science sociology [20] and reality observed over several months thanks to certain theses projects, is usually developed in the form of more or less structured research projects that make research activities difficult to harness which explains the interest of having support practices during the research process, of capitalising the scientific concepts. [21].

According to Dunbar [19] "many researchers have noted that an important component of science is the generation of new concepts and modifications of existing concepts." By scientific concepts the author means the constructions based on previous scientific knowledge and supporting data, that undergo an evaluation procedure to verify their ability to explore, explain, describe, predict or influence a phenomenon.

The bibliographical phase could be the main framework to this generation of scientific concepts. Indeed, the bibliographical work includes all activities: from the research of available knowledge in written documents (articles, thesis, etc.) or owned by other people, to the production of new knowledge with the writing of documents or by interaction with other people [22]. Results from research projects are already capitalised thanks to existing valorization mechanisms (articles, thesis, etc.), however all the knowledge produced throughout the research process and which form part of the construction of the final result is barely tracked. We are intended to think that the created scientific concepts could be considered as an elementary part of knowledge, and could be taking into account as an element of the immaterial capital.

To this end, supporting bibliographical work should not be restricted to the management of document references as objects and should embody the scientific concepts which are part of the bibliographical sources content. In fact, we consider that a scientific concept exist inside the firm when it is represented by an artefact (definition, etc.) and that someone in the firm has the competencies to interpret it. To keep track of this content, the artefact notion seems useful. Indeed, an artefact is an element having a material form (speed chart, paper-board, indicator on a data-processing screen or a measuring apparatus, etc.) or a virtual form (as it can exist in computer system) which can convey a part of the knowledge held by its author if a receiver knows the context in which the artefact was conceived and if he has the necessary knowledge to interpret it. The notion of artefacts is a reflexive one (a document artefact could be composed of section artefacts, which could be composed of figure artefacts, etc.). Thus artefact capitalization could be a means to capitalize at least part of the knowledge resulting from the realization of research projects. We intend to think that a scientific concept could be count in the immaterial capital if it exists in the shape of artefact and if an actor of the firm is able to interpret it.

Artefact characterisation

To deepen the research project analysis where artefacts are produced, sociological observations [21] have identified more than a hundred artefacts which could be classified into two typologies:

- Purpose typology:

- Bibliographical artefacts: Publications, reports, books, etc.

- Project Management artefacts: Project plan, meeting reports, etc.

- Intermediate result artefacts: Software and hardware developed for a project, data gathered and treated, etc.

- Control typology, characterized by [23]:

- Structuration that consists of linguistic components (that bring significance by instructions or formalisms) and rhetorical components (that bring meaning by contextual elements),

- Sharing by the ability of "pushing" information,

- Accessing by the ability to "pull" information,

- Capitalisation by the ability to store and process information for interpretation and later re-use, as suggested by the knowledge management cycle model [24]: identify, acquire, structure, combine, share, distribute, use, preserve and eliminate.

In respect with this Control typology, artefacts could be characterized as [25]:

i) - Structured Information (SI) (for example an industrial design), which will be barely be dealt with in this article because they are rather well controlled by actual quality management;

ii) - Semi Structured Information (SSI) (for example reports/minutes, articles, etc.); that we intend to harness by ANITA and BASIC-Lab approaches

iii) - Non Structured Information (NSI) (mail, dialogue, etc.) which can relate to the resolution of common research problems within teams, that we address by MICA-Graph approach

In order to characterize more precisely and to improve the management of these artefacts of , Research Activities, methodological and software tools have been developed. SADT, Functional Analysis and UML models enabled to elaborate the basis of three software prototypes specification of the ANITA, BASIC-Lab and MICA-Graph approaches to harness Semi Structured Information (SSI) and Non Structured Information (NSI) respectively.

4.2 Characterizing and Improving the Management of specific Knowledge

ANITA approach

By ISO standards, the document references in Research project teams are clearly identified however their contents are not characterised in an explicit way, so relevant facts in these Semi-Structured Information (SSI) could be lost.

An indexation describing the context is be a way to characterize the content. It could be supplemented profitably and accurately by free text annotation. The annotation could be considered as high added value information insofar as it represents the expert time required to read the document and to index/annotate. According to research [24], traditional paper annotation is mostly a personal exercise (or dedicated to a very limited group) because of the difficulties of sharing information writing on paper. Also the software annotation tools on the market do not offer enough possibilities in term of structuration, access, sharing and capitalization [25]. So, for the Semi Structured Information (SSI) harnessing, the ANITA approach and its prototype allows to index information content description with contextual meta-data and to attach annotations to artefacts.

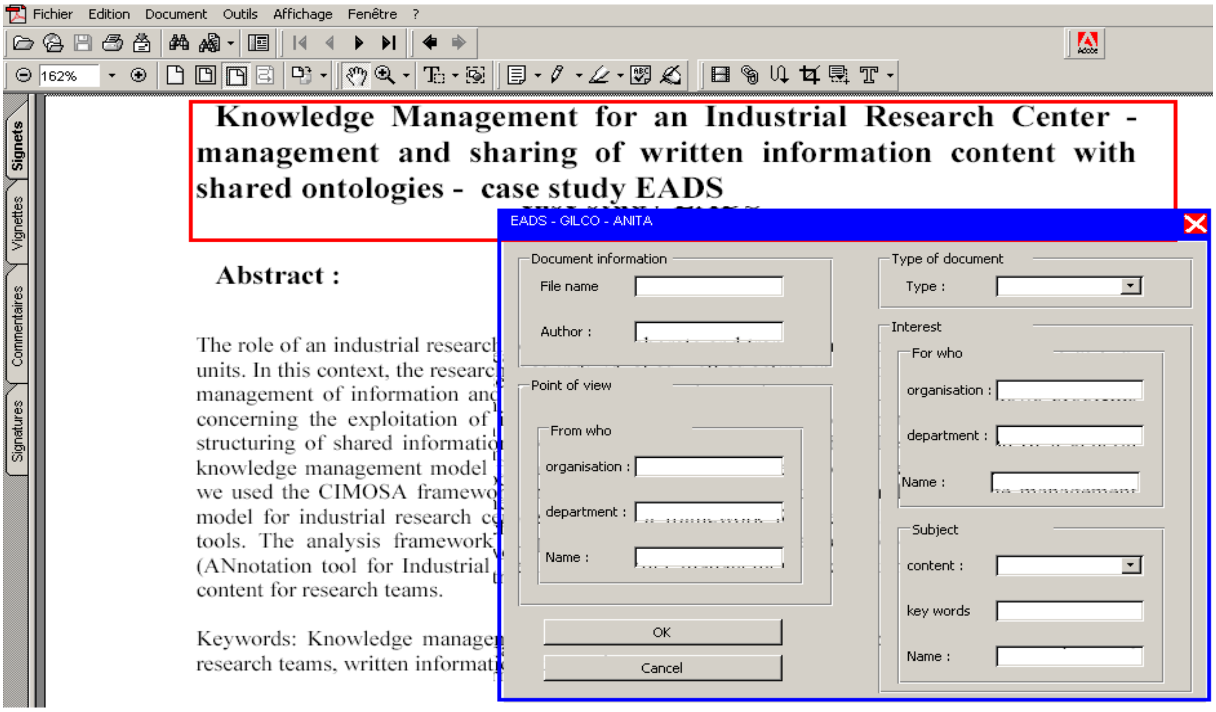

Figure 1. User interface for the attribution of points of view with contextual meta-data

BASIC Lab approach

This prototype allows adding documents and annotations to a centralized repository, to create projects and concepts and to define document zones. These elements can be linked together in order to use them for a particular interest. For example, a researcher can add a document judged interesting. Then, he may define the zones of the documents considered to be the most interesting ones, establish where in the document are the explanations of the scientific concepts used by the author(s) and add comments to the document or to zones of it. The researcher could also select some elements to keep in his personal list of favourites and choose the ones thought to be potentially valuable for a particular project. The other team members of a project could also include other artifacts thought to be useful for studying a phenomenon, sharing in this way a part of their knowledge. Additionally, the elements in the prototype are hyperlinked, to facilitate the navigation among them and the access to the different artifacts. The prototype is installed on a server, which allows that several users access it at the same time.

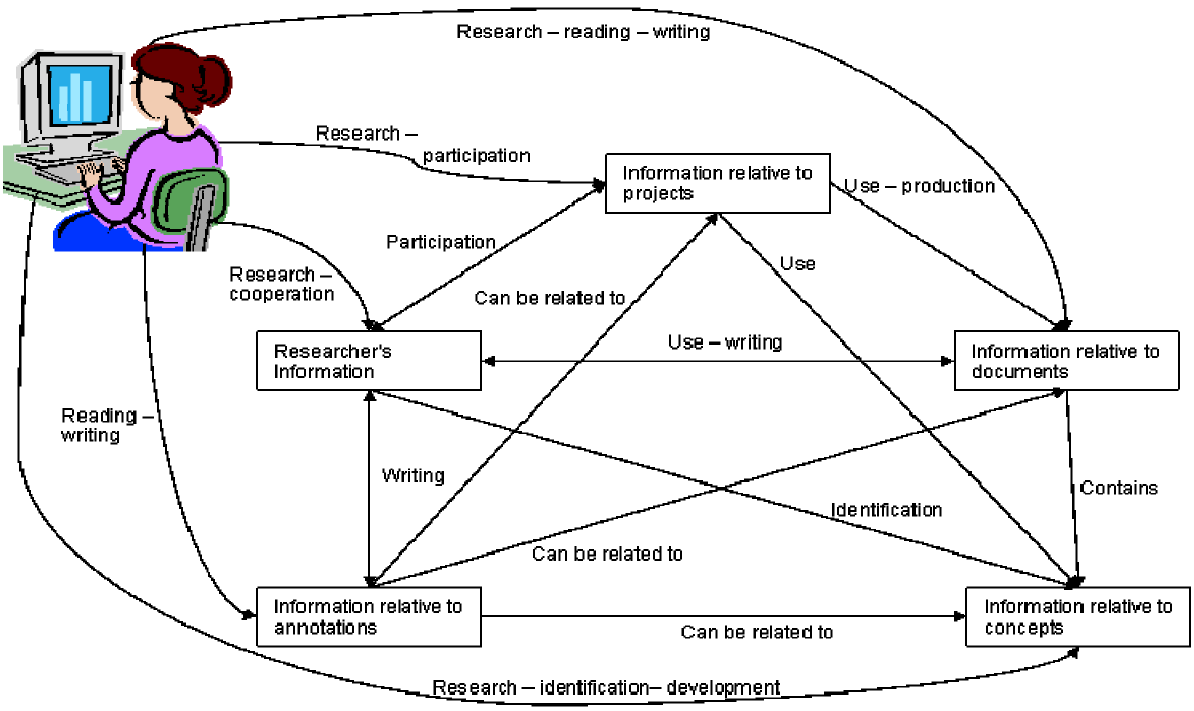

Figure 2. Scenarios of utilization of a tool for supporting bibliographic research

MICA-Graph approach

In the context of the research project teams, SSI (Semi Structured Information) is not agile and flexible enough to handle conversation and to allow quick synchronisation between researchers about, for instance, scientific concept via: dialogues/sketches or Non Structured Information (NSI). With the intention of harnessing scientific concept, a framework is first built and a software prototype called MICA-Graph [25] is then produced according to four main points of view: structuration [26], access, sharing information and knowledge capitalization [27].

One difficult NSI part is the graphical artefacts, that is to say: sketches; which is less structured than textual information because the linguistic components or formalism are not predefined (the shape significance is built in the action) and the contextual components, most of the time, are verbal and thus volatile [23]. The MICA-Graph approach hypothesis is to give enough elements to allow sketch interpretation in a distributed and asynchronous way to such an extent that it would be possible to partially understand a sketch without being involved in the sketch building process.

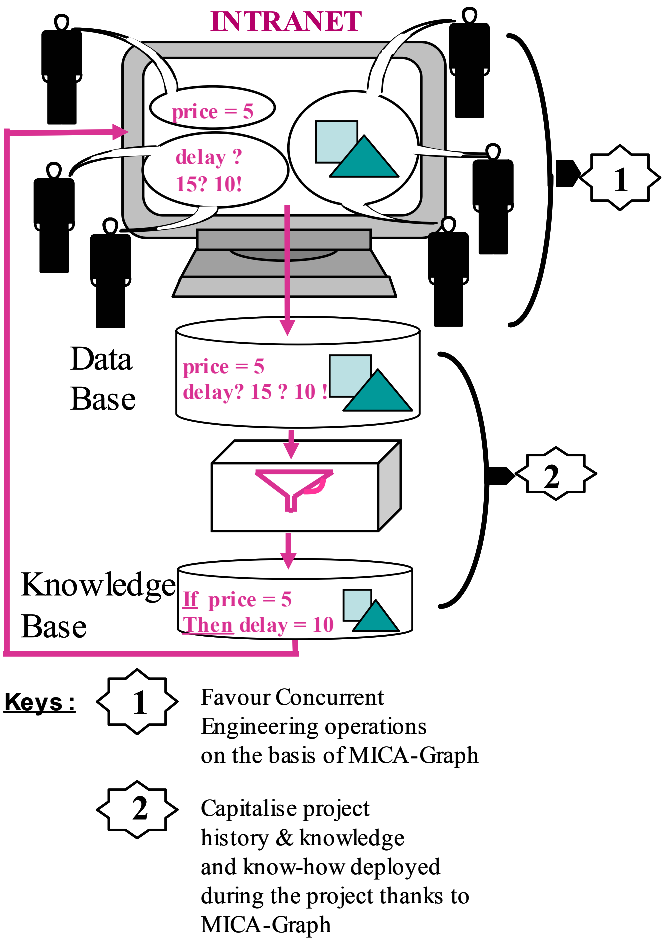

Figure 3. Principles of MICA-Graph Tool

All this methods allows characterizing and identifying very precisely the specific Knowledge used in Research Activities. In that way they will allow to value more precisely the impact of Knowledge Management on Research Activities.

4.3 Valuing the Impact of Knowledge Management on Activities: eSmac Implementation

As written above, valuing the impact of Knowledge Management is crucial for Research Activities. The "operational" approaches presented above tend to value this impact. Nevertheless such methods aren't used largely by Research Activities Managers. In fact, a lot of these methods considers the Knowledge Management as a specific process of the R&D Development Process. Nevertheless as we explained in this paper it is quite difficult to distinguish Knowledge Management Process and Research Process. The Research Process is a Knowledge Management Process. Furthermore, the Research Activities could be considered as specific Knowledge Management Systems. That is the reason why we propose to use the eSmac method to value the efficiency of Knowledge Management in R&D Department.

In fact, as explained above, eSmac aims at identifying the value-added by a KMS to the Knowledge of the Department. It could be a very good indicator to value the efficiency of R&D or Engineering Design Department.

Nevertheless, in order to use eSmac it is necessary to characterize very precisely the specificity of the KMS. Therefore, the combination of ANITA, BASIC-Lab, MICA-Graph approaches and eSmac should probably be necessary to value efficiently the Knowledge Management in Research or Engineering Design Department.

5 Conclusion

All these "operational" approaches to value the impact of Knowledge Management on Activities are quite emergent. However they are supported or developed by organisms intimately linked to companies (European Commission, French CIFRE Ph-D…). They fulfil operational needs more and more explicitly expressed by companies, i.e. to identify precisely the concrete impact of KM on the operational processes of the company.

It is worth noticing that despite a lot of Knowledge Management Evaluation methods have been developed, few of them seems to be used in organizations and in Engineering Design Activities. However, Engineering Design and Research Activities are one of the most important operational activities of a company and have to be optimize.

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Corresponding authors :

Gardoni Mickaël
INPG
Laboratoire GILCO
46, avenue Félix Viallet
38000 Grenoble - France
Phone: (33) (0)4 76 57 43 33
Fax: (33) (0)4 76 57 46 95
E-mail: gardoni@gilco.inpg.fr

Aurélie Dudezert
Ecole Centrale Paris
Laboratoire de Génie Industriel
Grande Voie des Vignes
92295 Châtenay-Malabry - France
+33 1 41 13 16 05
Aurelie.Dudezert@.ecp.fr