# EDUCATION OF THE NEW GLOBAL ENGINEER: THE DUAL MASTER DEGREE BETWEEN BRAZIL AND FRANCE

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***Abstract.*** *The purpose of this paper is to describe a new way of educating elites. This is based upon the double double culture the students benefit: generalist and specialist (mechanical for instance) master level diploma and at least two years abroad. This program concerns the five French Ecoles Centrale and six top universities in Brazil.*

***Keywords:*** *higher education, generalist engineer, specialist engineer*

## 1. Introduction

Managers for to-morrow industry are now educated so to work in the frame of globalization. In many countries, the top technical universities take into account this need and give their best students the possibility of studying abroad. Among them two networks appear as pioneers in offering their students a true international experience, both long and exigent enough, to educate engineers with a double culture.

These networks are:

- in Brazil : two universities of the State of Sao Paulo ( University of Sao Paulo and Unicamp), three federal universities (UFRJ in Rio de Janeiro, UFRGS in Porto Alegre and UFC in Fortaleza) and a private university (PUC in Rio de Janeiro)
- in France: the group of the five French Ecoles Centrale (in Lille, Lyon, Marseille, Nantes and Paris).

Beyond the double culture of Brazil and France for higher education, the students are educated following two different way of education. In Brazil students are trained to become a specialist while in the Ecoles Centrale, students are educated as generalist engineers.

This paper will first describe the Curricula followed by the students in an Ecole Centrale and the history of the generalist engineer. Then we will introduce the program of the double graduation specialist (mechanical science)/ generalist as it is promoted by the 11 institutions mentioned above.

## 2. The generalist project of engineering education of Ecoles « Centrale ».

Originally, in France, schools of engineering were created late XVIIIth and beginning of XIXth century. This creation appears at a period when :

- Science begins to focus on reason, procedures and mathematical or experimental consolidation, leading to a difference with humanities and arts.
- State policy and government needs a new elite for developing infrastructures and contribute to science and technology improvement.
- Industry needs new specialists and managers within so-called « industrial revolution ».

In this context, three main kinds of institutions where defined and progressively created during XIXth century in France :

1) Separate scientific universities or faculties.

2) Public graduate schools of engineers dedicated to state needs, like Ecole Polytechnique and Ecole des Ponts et Chaussées.

3) Private graduate schools of engineering created on behalf of companies and dedicated to industrial development.

Ecoles « Centrale » of Paris, Lyon, Lille and Nantes were created in this last context (from 1825 to 1870) as private graduate schools of engineers to respond first to the needs of industry in their region. Very recently a 5th Ecole Centrale was created at Marseilles and a 6th Ecole Centrale is now under creation in Beijing (China)

Since their origin, The Ecoles Centrale are characterized by three main items:

1) A high level of education so as to prepare future high level technologists and future managers of industry. This inscribed Ecole Centrale curricula in a very selective process of recruitment and in what we would call to-day the graduate level of education.

2) A humanist approach of technological and scientific development. This conducted Ecoles Centrale to perform curricula which would articulate top technological education to human and social sciences.

3) An entrepreneurial approach instead of a preparation to administration and public organizations. This allowed a close articulation of the curricula with companies so as with economy and with a pragmatic approach of problems.

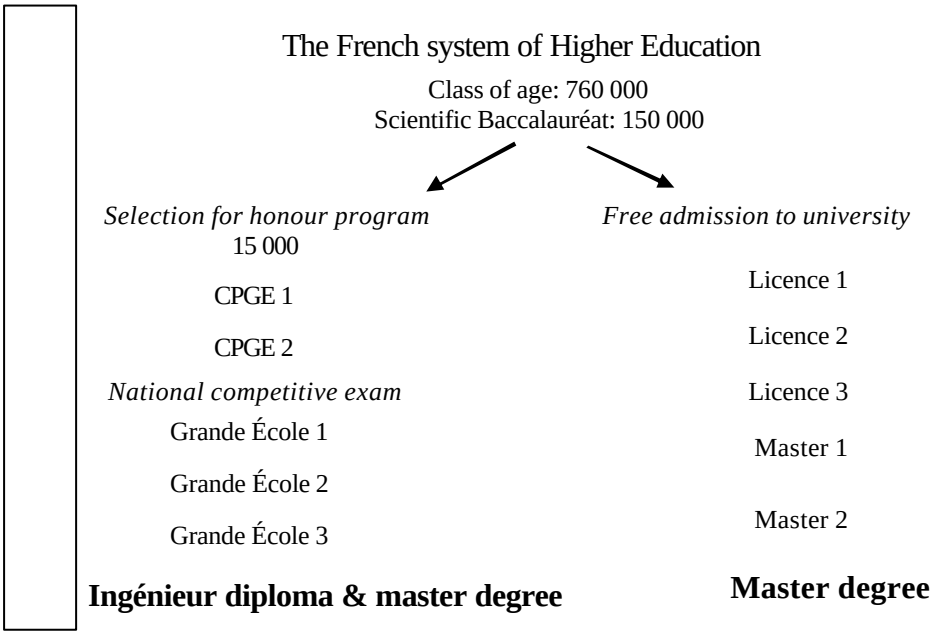


Figure 1 : general organization of the French system of higher education

In regards to university, the main structural characteristics of the five Ecoles Centrale education process are :

- Three separate and autonomous years of graduate studies after a two year special undergraduate intensive preparatory classes.
- A highly selective process of recruitment by a national competitive examination.
- A relatively small size : 1500 graduate per year, 600 full time academic staff, 650 PhD students for the five Ecoles Centrale.
- A financial autonomy extended to organization and decision-making.

**2.1. A « generalist » educative system**

One of the historical objectives for Ecoles Centrale was to associate a humanist approach to technological and scientific development. This conducted Ecoles Centrale to perform curricula which would articulate top technological education to human and social sciences. Nowadays, this objective is fulfilled by a specific organization of the three graduate-study years. The two first years are organized so to give a high level of knowledge and know-how based on what we call a « generalist » approach of engineering. The advanced studies dedicated to one field of engineering is so concentrated in the last master year program.

This means that during the first two years (3rd and 4th years of higher education), all the students are prepared to learn advanced basis in :

- Mechanical engineering
- Civil engineering
- Material science
- Chemical engineering
- Electrical engineering
- Control systems
- Computer engineering
- Applied Mathematics…

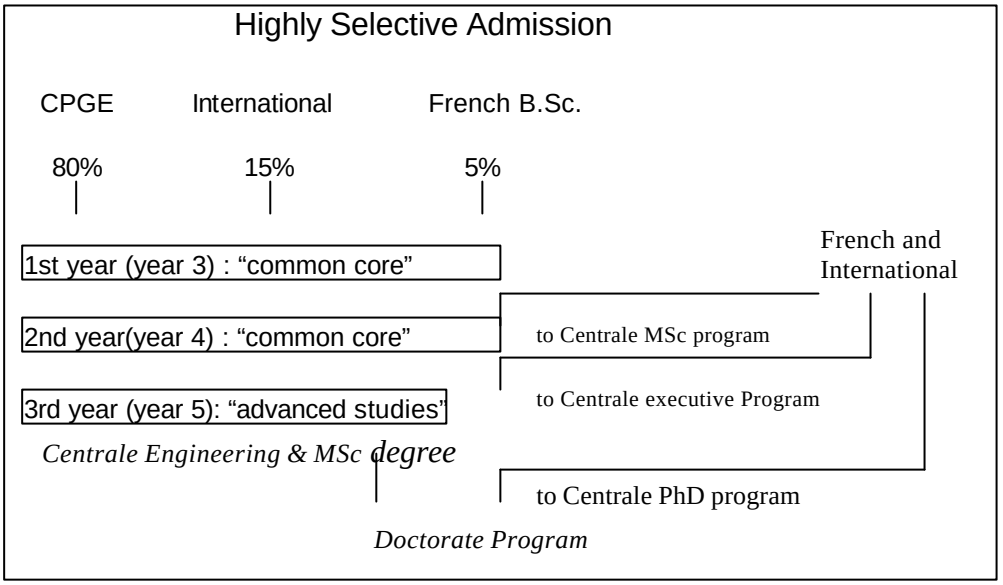


Figure 2 : selective process of admission to Ecoles Centrale

Furthermore, the close connection with future managerial competencies within industry implies that all students must also have a strong preparation to :

- Economics, social and human sciences
- Management sciences and applications
- Foreign languages and communication

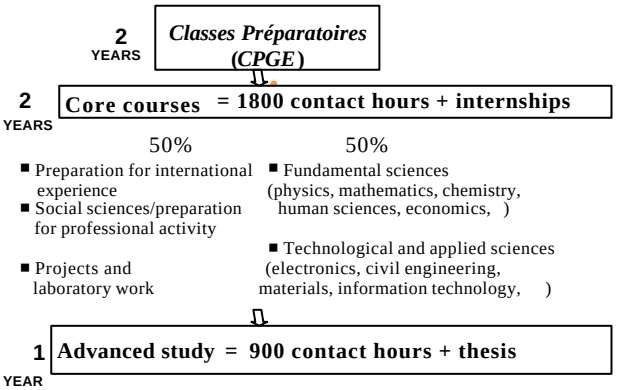


Figure 3 : the generalist curriculum of Ecoles Centrale

The objective of such a program is to prepare our future engineers to all the technical and management kinds of jobs and sectors in industry and to allow them a team spirit and practice. As we know, nowadays technical systems and products involve various disciplinary fields, projective know-how and consciousness of effects. This need a extremely open-minded preparation (in terms of variety of fields of education and in terms of reflexive capacities) as well as a high level of scientific and technological knowledge. Thus, in terms of didactics, formal lectures are associated to project-work activities.

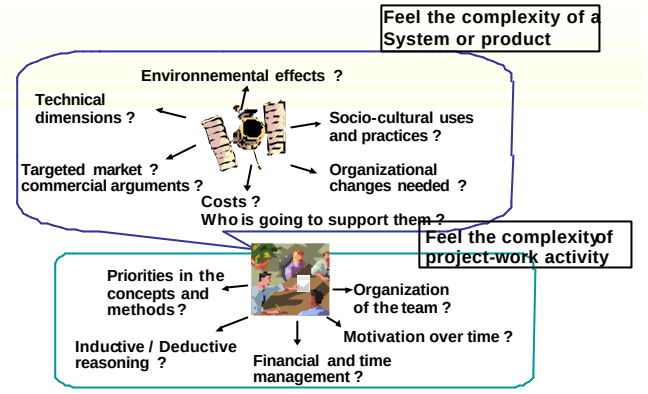


Figure 4 : complexity and multidimensionality of nowadays systems and products

On this solid basis, students of Ecoles Centrale can then appropriate with a strong efficiency and reflexiveness one particular domain of engineering. The fifth and last year of their education is so organized as an advanced education program associating a scientific orientation and a professional preparation.

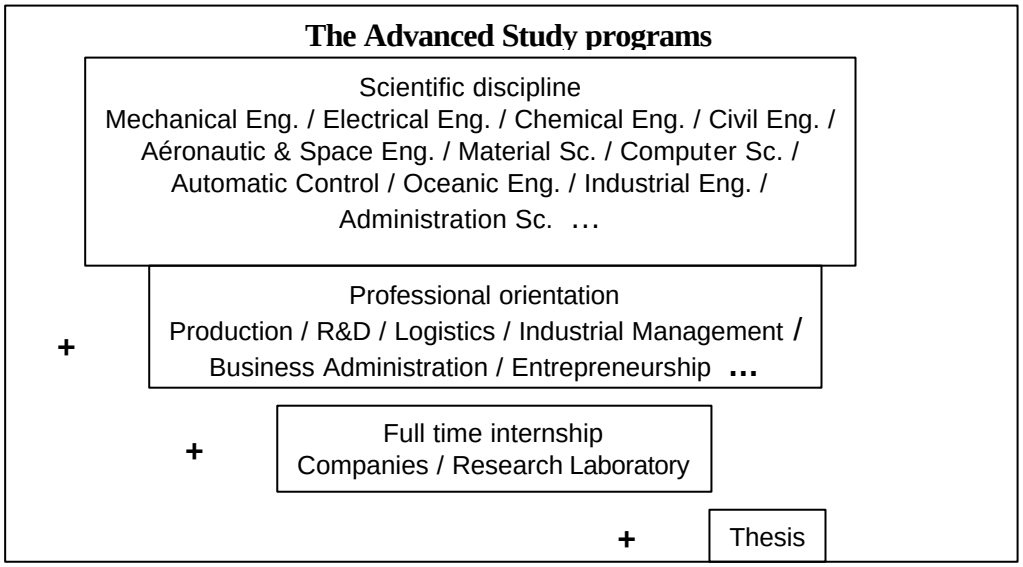


Figure 5 : diversity of scientific and professional orientation
proposed in the last graduate year of Ecoles Centrale.

The thesis, which marks the conclusion of the process, can even be scientifically or professionally oriented. This thesis is directly articulated on the personal work which is done during the six month full time internship in a research laboratory or in a company.

### 2.2. Disciplinary and generalist approach for engineering education.

The organization of Ecole Centrale education process is so quite different from usual more specialized curriculum in university. But generalist education has to defy the exponential evolution of scientific and technological level today (and tomorrow) required for innovation, research and development in specific domains and, simultaneously, has to defy the professional exigencies for managing development, research and innovation. This means a constant relation between a high disciplinary-based knowledge and constant social, human and professionally-based competencies (know-how). Such a *complex situation* is the principal difficulty for generalist education process like Ecoles Centrale one.

### 2.2.1. Specialist and generalist

In the short time given to engineering education, a student cannot evidently pretends to knowing as much in a disciplinary defined domain in a generalist curriculum as in a specialized curriculum.

Must of the time, specialized graduate curricula are constructed after about two years of general preparation and one year of specific bases to the domain. In such a context, one student will have at least three years devoted to knowledge in a defined domain of sciences and technology. It is so impossible to objectively compare it to what can be obtained by one year of advanced studies after a generalist education curriculum. In a positivist approach, the comparison is impossible.

Why should we pretend that the generalist curricula of the French Ecoles Centrale are relevant indeed? The answer is not a fact of « cultural exception », as we say in Europe ! Our opinion and the opinion of an industry who recruits our engineers in a high position, is that this comparatives question is a false question. The problem is not to compare the *amount* of knowledge one student has (or has not) in a defined domain but to compare the *potential of assimilation* one student has when he/she faces to a question.

So, instead of trying to organize a sort of an extended encyclopedic spoon feeding of knowledge, our generalist program tries to focus to the «required necessary » knowledge involved in science and technology development. This «required necessary » knowledge pretend to educate our engineering students so as to solve any question issued from research, innovation or development, whatever the field of which the question is initially issued. Our students will then try to answer in a personal way or in a collective approach extending this way from a team work to a more complex organizational aspect like entrepreneurial companies. This is the main reason for an organization constructed with two first years preparatory classes mostly oriented towards mathematics and conceptual tools, two years of relevant engineering knowledge and project practice and, as a conclusion, one year of advanced study in one dedicated field of engineering.

So, our educational problem does not pretend to give an encyclopedic knowledge but it pretends to give a student the relevant knowledge that can concern a wide spectrum of engineering sciences. We are conscious that this proposal is quite provocative within a scientific community based on common concepts, tools, methods and references. But, in our point of view, the question is not so to point differences (or oppositions) but to propose complementarities. Many ways leads to quality. Our way is not in opposition to another one. It is just a different answer which tries to contribute to the diversity and the richness of our world. Such a richness and diversity, which is clearly assumed by Brazil in various fields of society and knowledge, seems us particularly appropriate to be presented here.

### 2.2.2. A contemporary epistemological reference for generalist engineering curricula

From the disciplinary point of view, solution can no more be found on an encyclopedic basis. What was eventually possible during the XVIIIth and XIXth century is no more possible. Auguste Comte, who is as famous in Brazil as he is in France, can no more be exclusively taken in such consideration for solving nowadays exigencies of complexity. However, responses to this complexity needs to be compatible with the constant evolution of knowledge which is still (and necessarily) based on a more and more specialized orientation.

Instead of trying to find what would be, in any case, a weak solution to this impossible and evolutive problem, Ecoles Centrale curricula consist to change the *setting* of the problem. Such a renewal can be articulated to the epistemological propositions of H. A. Simon about what he proposed to call « artificial sciences ». As H. A Simon observed it in the late XXth century, we can observe that :

1) An engineer, like an architect or a manager is a *professional* : they all conceive artifacts, even if those artifacts are different in nature.

2) Engineering faculties and schools became « *schools* » of physics (based on analysis of natural phenomenon) and applied mathematics.

3) The exigency of a scientific knowledge both *high level* and *academically sound* is in conflict with the empirical, intuitive and informal character of the professional knowledge.

So, we have to :

1) Imagine a scientific knowledge about conception of artifacts that could be both high level and academically sound.

2) Imagine a professional school that leads to an equal level in artificial sciences and in natural sciences.

This leads us to a pragmatic problem :

=>to identify and to state the necessary professional capacities of engineer.

=>to create pedagogical situations that allow an interaction between discipline-based scientific knowledge and those professional capacities.

=>to impulse a work leading to identify and to state a high level and academically sound « projective knowledge » (scientific capacities).

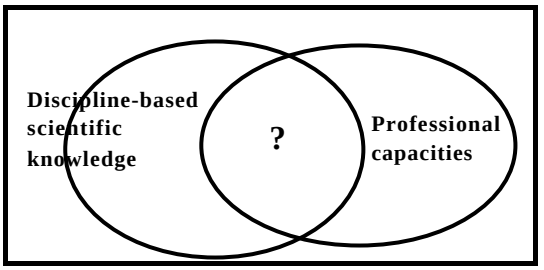


Figure 6 : scientific capacities in-between scientific knowledge and professional capacities ?

### 2.3. From engineering capacities to scientific capacities and relevant pedagogical situations

#### 2.3.1. A relevant disciplinary-based scientific knowledge

The generalist defy is so to identify first necessary relevant knowledge which would concern major fields of engineering. As it is impossible to pretend being exhaustive, our programs of study are very focused on scientific and technological approaches which not only would concern one field of engineering but that would also be able to concern or to be extended to other domains of knowledge. This is the case, for example, of similitude theory in Fluid Mechanics which also concerns certain models in Finance and architecture. It is also the case of Shannon works using Boolean algebra to describe how works an electrical circuit and, doing so, establish links between logics and physics in many different domains.

Of course, such an example will seem rather theoretical. The point is not to limit the scientific program to such transversal aspects but on such a basis to develop their heuristics consequences in the different fields of engineering with relevant examples and practical assets and works. Thus, in a scientific and disciplinary approach, we think that some advanced basis can be relevant for various domains not only in terms of theoretical basis but also in terms of applications and in terms of heuristics developments.

#### 2.3.2. Relevant professional competencies

Once identified such basis issued from various engineering fields and advanced scientific paradigms, the other point is to connect uses and development of such a knowledge in relation to professional situations at an academic sound level.

Usually, professional situations are considered as empirical ones and in tension between methodological tools and doctrinal statements depending on local situations, both aspects that reduce their academical (and scientific) relevance. This, generally, positions professional approaches as a complementary education part, out of scientific purposes but necessary to engineer education. Now, after H. A. Simon pioneer works on sciences of artificial, several authors in USA and Europe at least (Fergusson, Schön, Vicenti, Perrin, etc.), tried to point out professional capacities that could be able to be related to an academic sound level. In Ecoles Centrale, such a work has also be done, concentrating on several capacities like : designing, realizing, innovating, organizing, deciding, ... All those capacities have been declined more specifically.

If we take the example of « designing », which is well known to-day to be considered as relevant to innovation as to science itself (Perrin), this capacity can be declined on the following basis : designing (or conceive) can be first related to several capacities like : formulating the problem, formalizing it, modeling it, etc. Thus, at a more precise level, each of the previous sub-capacities can, their selves, be made explicit so as to give enough legitimacy to professional finalities and so as to take their complete part in the engineering curricula.

| | | |
|---|---|---|
| DESIGNING (CONCEIVE) | FORMULATE THE PROBLEM | -Identify the phenomenon, the idea or project to be conceived...<br><br>-Develop a system of relevant questions... |
| | FORMALISING | - Formulate the various functions which are involved<br>- Choose a relevant formalism to represent the problem<br>- Validate the formalisation |
| | MODELLING | - Assimilate symbolic languages<br>- Take over vious models<br>…/… |
| | IMAGINING SOLUTIONS BASED ON MODELLING | .../... |
| | SELECT SATISFACTORY SOLUTIONS | .../... |

### 2.3.2 Relevant pedagogical situations

In this double context of relevant scientific knowledge for generalist curricula and relevant professional competencies declined in sub-capacities, the objective of relevant pedagogical situations appears quite simple : join the efficiency of magisterial classes articulated to practical works and exercises and project activities linked to the previous competencies.

For Ecoles Centrale , this means to produce an organization like shown in previous figure 3 and 5 : an academic organization of generalist engineering associated to project-activities academically sounded.

Such a program suppose to develop pedagogical situations that facilitate interaction between capacities and discipline-based knowledge. This implies :

- A revision of compulsory program equally based on a disciplinary approach and on a system engineering approach in each technological field.
- A long cross-disciplinary and team based project-work.
- Various optional associated seminars deepening disciplinary aspects or professional competencies

Simultaneously, the creation of a department of "Sciences of engineering" can be proposed so as to :

- Train faculty members to a system engineering approach by managing cross-disciplinary projects.
- Manage the project-work activity.

As a consequence, what we can see as clear competencies developed by our engineers, though in research and in professional positions is their :

- Ability to pose a problem.
- Improvement in modeling empirical problems.
- Awareness of cross-disciplinary problems and of complexity.

## 3. The Double Degree between Brazil and France

The main aim of this scheme proposed on the basis of the T.I.M.E. (Top Industrial Managers for Euroope) network that was set 15 years ago within Europe and that gathers 45 universities is to educate high potential students. These Brazilian and French students benefit a double double culture. First they are educated through the two complementary systems i.e. the generalis t French system and the specialist Brazilian system. Every student graduates in Brazil and France with the true upper degree of each institution at a master level (5 years of higher education). The students totally fulfill the requirements of the two degrees as fixed by the national and university rules. With an one-year-more curriculum, the students are totally recognized as graduated master students who can be recruited by companies or who can decide to study for a PhD

Another very important aspect is that the students must follow at least two years of the partner curriculum abroad. The scheme as described in figure 6 takes into account the beginning of the academic year depending of the location in the south or in the north hemisphere.

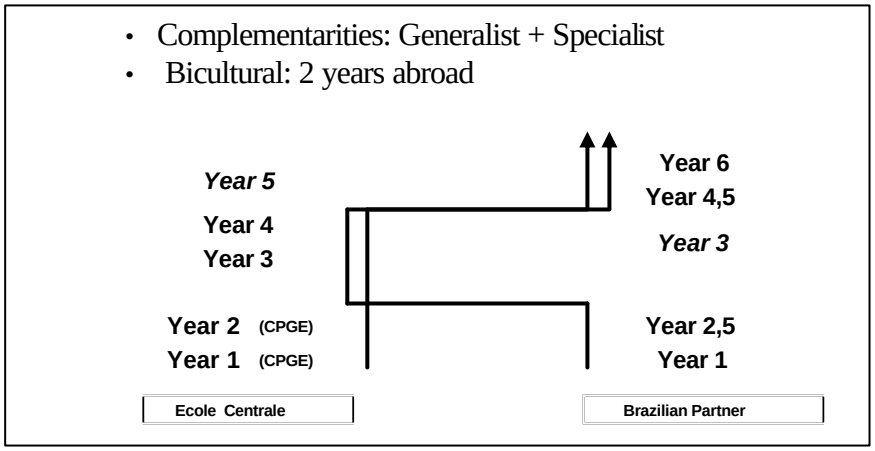


Figure 7: The double degree scheme

This high quality exchange program requires a large implication of professors of the institutions. However this time consuming program presents a great interest as it requires a good knowledge of the other institutions. This induced the mobility of the academic staff with as a consequence the promotion of common researches. This dual degree Brazilian- French program already enabled the cooperation of several laboratories in CAPES/COFECUB activities and in dual PhD students. Of course this program is of the greatest interest for the Brazilian and European companies which are now convinced of the interest of the increase in the Brazil- France economic exchange and cooperation.

## 4- Acknowledgements

This program has been promoted thanks to the strong investment of several Brazilian colleagues. The authors want to thank the main persons in charge of this cooperation that are the following professors: Adnei Melges de Andrade (USP), Carlos Frederico Borges Palmeira (PUC Rio), Eduardo Gonçalves Serra (UFRJ), Joao Cesar Motta (UFC), Joao Jose Hiluy Filho (UFC), Joao Manoel Gomes da Silva (UFRGS), Jose Pissolato (UNICAMP), Luís Augusto Barbosa Cortez (UNICAMP), Marcos A. da Silveira (PUC), Renato Machado de Brito (UFRGS), Ricardo M. Naveiro (UFRJ), Vahan Agopyan (USP). Brazilian and French authorities funded this exchange program and the Ecoles Centrale and the Brazilian universities want to thank CAPES, French Ministry of Foreign Affairs and especially EIFFEL grants and Brafitec responsible.

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