MODELING AND SIMULATION OF DENTAL PROSTHESES THROUGH CAD/CAE TECHNIQUE

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Abstract. *The modern solution for part production is the use of software that automates the process. In addition to better control of the whole design and production process, it allows for an overview of the entire part from any angle desired, cuts could also be done to observe dimensional details. This 3-D computational simulation of technical drawings is obtained through CAD software. In the CAD phase the components are modeled and during the CAE phase simulations are carried out thus allowing for the visualization of tensions, deformations and structural analysis by using the Finite Element Method. Seeking to better prepare students to graduate in mechanical engineering for the industrial reality, the techniques described previously (CAD and CAE) have been applied in projects of scientific initiation in the area of dental prostheses. The models of dental prostheses were made of wax, which were then scanned, making use of a 3D scanner. Then, using specific software, the imported surfaces were treated using CAD software so simulations using Finite Elements Method Software could be carried out. The project in question allows the scientific initiation student to be in contact with state of the art technology, both software as well as hardware, improving their knowledge in CAD modeling and CAE simulation. The student also had the opportunity to share the experiences and knowledge gained to other students that are part of other research and extension projects inside the university, demonstrating how productive this type of experience can be.*

Keywords*: Dental prostheses, Modeling/simulation, Engineering teaching*

1. INTRODUCTION

The metal-ceramic dental restorations still have been the intense using (due to the reliability of the metallic infrastructure, covered by the ceramic porcelain) (Craig and Powers, 2004), the degradation of the non noble alloys in the buccal environment it is a disadvantage of this restoration class, reason for the which the restorations integrally ceramic are conquering crescent use in the world dentistry (Anusavice, 2005; Botino, 2001; De Jager, 2005; De Miranda, 1999; Denry, 1999; Francischone, 2000; Gorman, 2000; Guazzato, 2004; Kancyper, 2000) with crescent entrance in CAD-CAE-CAM.

The dental implants have application in the ceramic dental field in the replacement of dental elements in individuals with losses partial or total of those elements. A masticatory loading action is an aspect that needs to be appropriately evaluated in the implantation systems study. Another aspect is the masticatory loading application point. This requests simulation studies and optimized modeling.

The simulation of the loading action on implantation systems it has been adopting in several works the finite elements method (FEM) for the accomplishment of the simulations. To find an analytical mathematical solution is very difficult in the analysis of complex geometries problems. The use of numeric methods like FEM is requested then. FEM is a technique for the solution obtaining for a complex problem through the subdivision of the problem in a group of sub-areas or elements. A continuous approximation function is assumed to represent the solution in each element. An approximate solution for the problem is obtained then by the combination of the solutions obtained in each element. The basic steps involved in an analysis by finite elements consist in:

a) to create and to discretize the problem solution in the finite elements, i.e., to subdivide the problem in nodes and elements.

b) to Assume a form function to represent the element knowledge, in the other hand, an approximation continuous function is assumed to represent the element solution.

c) to develop elements equations.

d) to combine the elements to represent the all problem and to elaborate the stiffness matrix.

e) to apply boundary conditions, initial conditions and loading.

f) to solve a linear or non linear equations algebraic group simultaneously to obtain the nodal results and element results, such as: stresses, strains, displacements, etc...

The Brazilian ceramic dentistry restoring is almost exclusively based on imported raw matters and imported processings and imported equipments mattered. The Rio de Janeiro - RJ Excellency Nucleus in Dental Ceramic (UFRJ/COPPE/PEMM, FO/UERJ, CETEM/MCT, FO/UVA) is Trying to contribute to modify this scenery to medium and long time it is developing activities to obtain a deep knowledge of these materials and imported technologies, as

well as the adaptation of Brazilian raw materials minerals to imported processes and, finally, to formulate compositions and new (Brazilian) processings, above all seeking the service of the poorest population.

The tendency is very clear in the convergence sense of the prostheses dental system production processes for the CAD/CAE/CAM, whose domain is limited to a restricted international companies group that they market on line (the teeth data profile patient are transmitted digitally and the prostheses return to the Dentist (or Prosthetic Laboratory) through postal. The technological challenge is really very big and to win it requests to begin now for the most elementary parts, parallel to the domain of the CAD/CAM technology generic (reasonably available in other fields, but is not in the Brazil dentistry).

The problem previously described is added to the fact that the clinical experience has been telling flaws cases in the bone integratable implants systems: screws loosening and the components fracture. Such flaws represent much damage for the professional that he is forced to restore the damaged components as for the patient, in some cases they are submitted to a new surgery for the relocation of the implant. Due to the flaws in the bone integratable implants systems, researches have been driven in the simulation field of element of the composion of the implant. Those researches are based in mathematical approximations, in it majority generated starting from 2D models, due to difficulty and complexity to generate a 3D model (Cardoso, 2001; Lehmann, 2005; Rock, 2007).

This project accomplished the stress analysis for the finite elements method with the use of the Ansys software in some dentistrical prostheses. They were determined the areas of larger stress concentration that they could cause the component flaw. Thus, with the simulations results obtained, it intends to contribute with new form knowledge to allow a better understanding of the flaws. that they are observed in practice clinic and they generate the form subsidies to the industry, mainly the Brazilian, that they come to aid in the improvement to the implants systems through the components geometry optimization as well as the formation of qualified work hand to act in this field, to obtain the maximum performance

2. MATERIALS E METHODS

This project consisted of two great distinct stages, being the first a attainment of the ceramic material and the second a simulation of this material using CAD/CAE techniques. In the first stage glass ceramic blocks they had been produced with Brazilian raw material (as collected, characterized and benefited for Team CETEM/MCT).

The composition of each batch was established by stoichiometry in detail studied on the phases diagrams and in the resultant composition of thermal expansion coefficient of test. The mixture was made in planetary mill with jar and microspheres of alumina, in way to obtain the nanometric range, that facilitated to the reaction between the components and the conclusion of the synthesis in lesser temperature and time. The product was broken again in planetary mill, conformed in rubber mold for the cold isostatic press the and sintered.

After the superficial cleanness and rectification, the ceramic and glass ceramical blocks had been submitted the semi- automated machining tests, as well as the determination of the density and microstructural characteristic (for posterior correlation with its final behavior and properties). The machined part was submitted to the final sintering, after what microstructural and mechanical characterizations had been carried through, searching the material properties determination for feeding of database in Ansys software.

The second stage CAD modeling of teeth that compose implantation systems was become fullfilled. Initially, through 3D scanning, with the aid of the 3D scanning device acquired of the Spatium company and Forma 4.0 Spatium software and a virtual model of the gotten mold of the mouth of the patient generated, this gotten by the group of integrant dentists of the group of Bioceramica (UFRJ/COPPE/PEMM). Software Geomagic Studio 9,0 served to generate a mesh on the surface of the scanned mold for posterior use in CAE software, which it determined some important data, as for example, the stress in the mold. The presence of the 3D scanner revealed of extreme importance, therefore it served of dimensional comparison between the patient mouth mold gotten and the model produced for the group of Dental Ceramics of the PEMM/UFRJ, thus it had verified if the proposal production technique is in agreement with the waited model for the patient buccal reality.

The Ansys software version 11 was used for CAE simulation. Since imported geometry, it had become the necessary adaptations so that software understood this geometry as a model to be generated the mesh and posterior simulation using the finite elements techniquef. The mesh was generated of mapped form to allow a optimization of the elements number. The element growth factor was of 1.5 for to exist not loss in the results precision. The boundary conditions had been applied and the loading had been applied axially in the prosthese apex and in second stage with with inclination of 30º, in the central point to the implantation axial axys. The movement restriction was applied in the external region block of cortical bone form that the set could work freely in all the degrees of freedom.

The von Mises equivalent stress was used in the post-processing, because it is considered appropriate and it is used wide in this type of work. The stress maximum values had been identified quantitatively and qualitatively. These values determine if it has component imperfection and the localization of the maximum stress and it indicates where a bigger concern for improvement of original geometry must exist. Thus it is possible to determine the necessity or not of the project optimization.

3. RESULTS AND DISCUSSIONS

Dental prosthese digital models had been gotten with the aid of the 3D scanner objectifying a model the most faithful buccal reality of the patient. The Figure 1 and Figure 2 are example of mesh gotten through the 3D scanner.

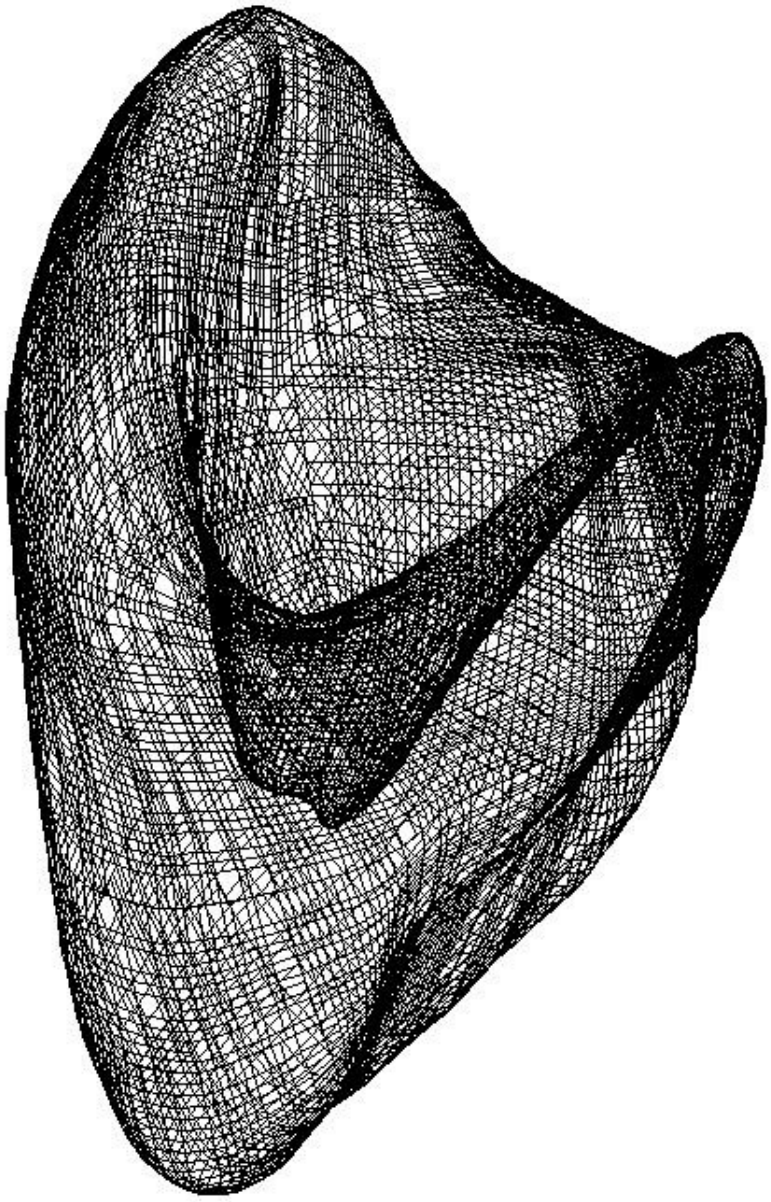

Figure 1. Dental Prosthese Mesh (detail 1)

It had analyzing the Figure. 1 and Figure 2, it had observed dental prosthese geometry is well faithful to the he geometry of the real model, this is due to the 3D scanner device precision that it obtained to produce a mesh sufficiently refined. Same geometry when imported for inside of Ansys software (CAE simulation), as Figure. 3 and Figure 4, kept its dimensional characteristics, but Ansys software generates initially a mesh with lower refining in relation the mesh generated for the 3D scanner, Thus it is need all a post-processing work.

The 3D prototyping technology gains more field that it allows the acquisition and data handling with more precision, beyond the time gain in the acquisition of these data, but the treatment of these data requires qualified professionals and it is demanding qualified worker so that the information are not lost.

This is part of a bigger work, where this first stage consisted of evaluating of the new material for application in dentistrical ceramics produced by group of dentistrical ceramics of the PEMM/COPPE would resist the masticatory

classic efforts. This project was carried through by scientific initiation students without any previous contact with CAD modeling softwares of and CAE simulation form that the model was simplified considering only the masticatory efforts on the porcelain, without it is considering the too much involved efforts in prosthese, since the students throughout a period of IC (one year), they do not have skillful time to all absorb the necessary content to the development of a deepened work more. The objective biggest was to the insertion of these students in this high technology.

The results demonstrate that the simulated material is presented promising, but as the model sufficiently it was simplified, bigger conclusions alone after a deepened study more regarding the same.

In recent years a trend of the use of the fast prototyping is observed, before restricted to the sector metal-mechanic, applied to the medical-dentistrical field, this fact brings great advantages for the patients. It an overview of the available bibliography, it observes despite the fast prototyping in the medical-dentistrical field is used sufficiently of the images acquired for computerized tomographs for the accomplishment of party to suit of prototyping, therefore these supply information on size, direction and localization of the implantations. The use of the biomodels gotten through the fast prototyping technique becomes the planning and execution of more necessary, agile and safe implantations bone integratable mainly in the cases of severe atrophies of bone. The bio models obtained of analysis of the patient anatomical condition and real simulation of the procedure is possible, to prevente or to reduce eventual complications during the surgical procedure. Moreover, the gotten surgical guides through the technique of fast prototyiping with the information generated in the programs that allow the accomplishment of virtual surgeries, it represenst a new horizon in the implantodonty where the surgical procedures become simpler previsible insurances (Menezes et al, 2008).

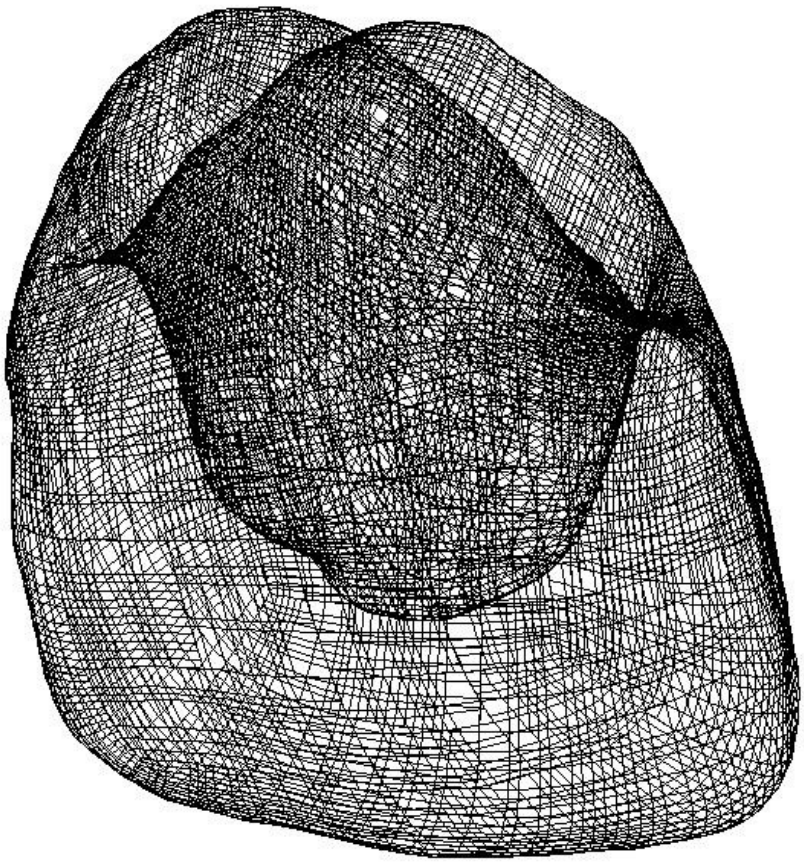

Figure 2. Dental Prosthese Mesh (detaile 2)

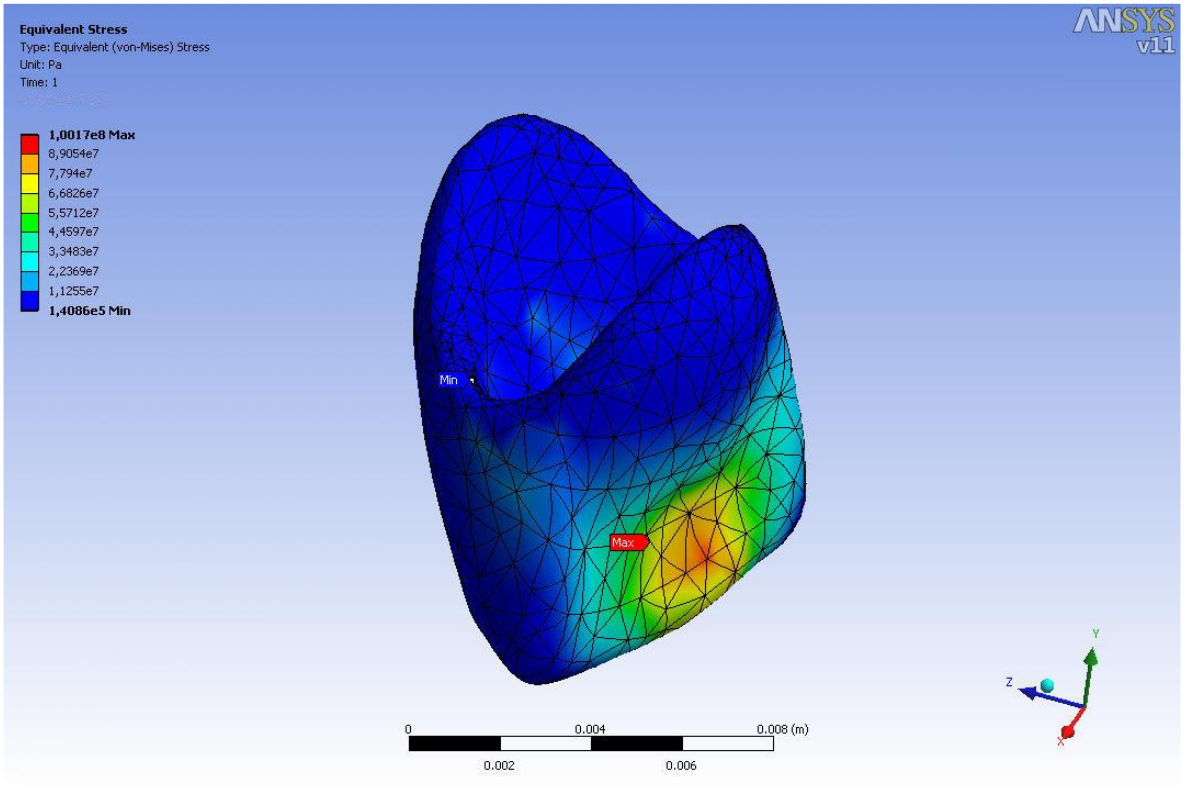

Figure 3. Dental Prosthese CAE Simulation (stress)

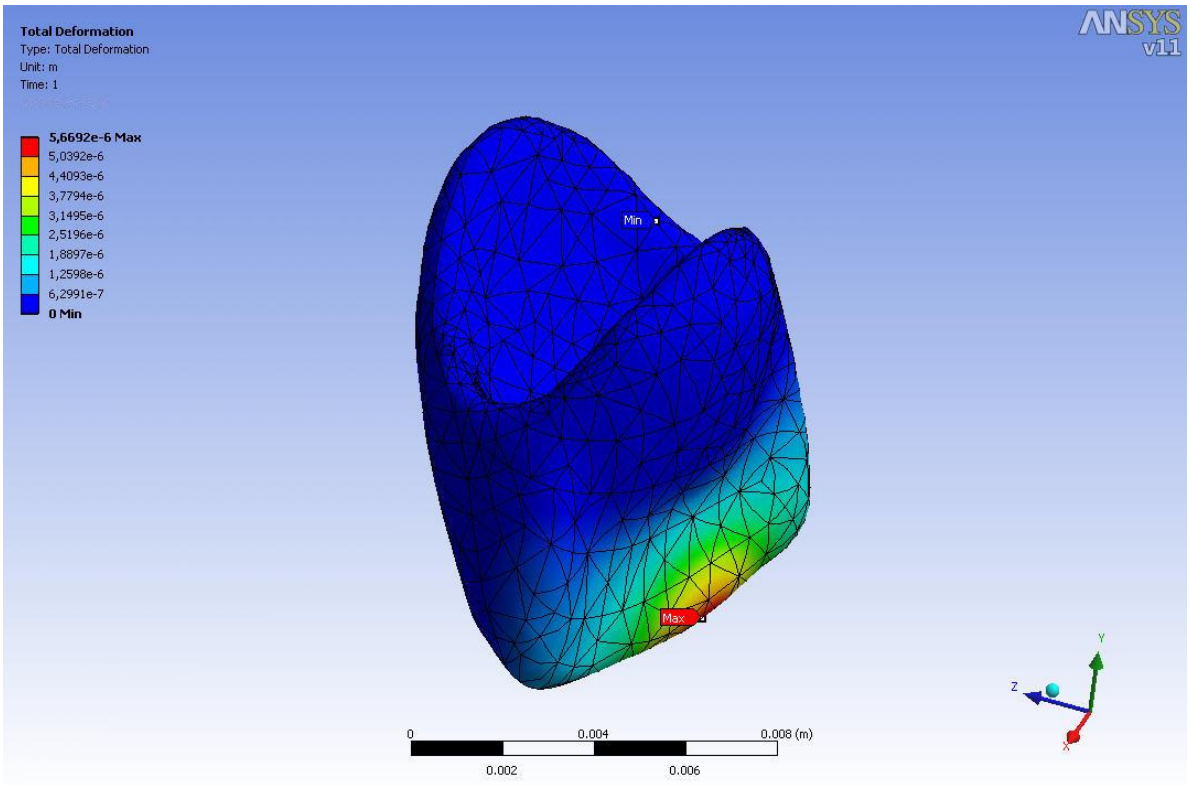

Figure 4. Dental Prosthese CAE Simulation (strain)

The dentistrical field use the computerized tomography sufficiently as party to suit of fast prototyping for the planning of the surgery of implantodontia, but few papers are found with regard to the study of the dental implantation. The scarcity of paper that perhaps study only the dental implantation maybe must be tp the fact of that the fast fast prototyping applied to the study of the implantation demands acquired deep knowledge in regular engineering courses and it uses the high technology, still little available in the human resources formation centers.

This paper searchs to help to fill this emptiness acting in this field, the metal-mechanics field applied to the implantodonty, where professional they are scarce due to deepened necessity of knowledge normally given in the regular courses of engineering mechanics and materials engineering. Thus, it is intended with the described actions in this paper, in such a way to stimulate theprofessional formation in the materials line (new materials) how much in the line metal-mechanics (CAE simulation), beyond quality gain and technician-scientific productivity for the publication of more papers in this interfacial field.

The quality increasing and amount of publications in the line metal-mechanics applied to the implantodonty, the interest of all a field will started, in to respect of specialized worker and the technologies that can be used to advantage in the industries.

The digital prototyping technology transforms the way into as one determined product is generated, that is, it occurs a great time and quality gain when compared with the traditional procedures. The recognized importance and its use in the academic enviroment appears slowly. The infrastructure lack makes these new methodologies and technologies do do not obtain to substitute the old practical education to the project development it results in prepared students for the current industrial reality (Forti, 2005).

The technology is always in constant development thus new specialties form for the necessity of improvement in determined field, today the necessity of professionals who dominate the materials field and CAD/CAE/CAM technology appears. These professionals are not formed in regular graduation courses and it has searching to stimulate the specialization of them, still while graduation students and later as postgraduates, this paper was proposed in regular mechanics engineering course from to stimulate the interest of students mechanical and material engineering.

This research paper also aims at the increase of the publications amount in the dental ceramic materials field for the interaction between the research groups formed in the UFF (modeling/simulation) and the existing groups in the UFRJ (experimental in dental ceramics). Beyond, to stimulate research lines that contribute for the scientific and technological development of Rio de Janeiro State, with Brazilian production and value aggregation to the local raw material.

The students of the EEIMVR/UFF have little contact with the experimental part of the materials field throughout its regular courses and this paper was a chance for the nucleation of this contact, mainly to respect to the new materials (material ceramic). A deepened study more regarding the properties of these new materials and consequently of its microstructure he was important, therefore for the stage in the CAE simulation some values of mechanical properties of these new materials had been required.

Some teachers of the EEIMVR/UFF already had perceived the necessity to work with softwares that they assist the creation and development of parts/equipment, searching to not only provide a theoretical teaching, but also to provide to the students capacity to think and to create solutions, beyond executing them, it had seeing the companies and industries demanding as requisite not data theoretical knowledge, creative or methodological ability, but also an experience in two or three softwares at least different in the prototyping field.

4. CONCLUSIONs

The graduation students performance in practical similar to presented in this paper (scientific initiation) is extremely important, therefore it allows that the students can be developed applying concepts learned in classroom, that is, they leave of the education institutions as better professionals and it is facilitating its insertion in the work market.

The students had having the chance to place in practical knowledge presented in some discipline, thus, they had having the chance to correct failure in its formations, beyond to have contact with high technology in CAD/CAE line available only for some students in function of the complexity to learn this technology for bigger students groups.

The execution of the activities of this project had been stimulated the capacity to think and to create solutions, that is, they were inquired about the next steps for the solution to the problem, and it stimulating with this its critical senses. This practical also allowed that the students had contact next with some people in the search to data and solutions, teaching them not only as to also use the knowledge learned in classroom, but as to deal professionally with other professionals, that is, to learn to work in group, mainly when the co-worker diverges to his opinion to the solution of determined problem.

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