Summary of the habilitation thesis

The Habilitation Thesis "*Increasing the manufacturing efficiency by creating dedicated software systems and solutions for a better use of materials*" presents my activity in the field of Industrial Engineering from the professional scientific and academic point of view and is conducted after obtaining the PhD degree in September 2003. The title of my PhD thesis is "*NC Milling of 3D surfaces*" and was elaborated under the coordination and supervision of Prof. Ph.D. Eng. Nicolae-Valentin IVAN.

The Habilitation Thesis is structured in three parts:

- ***scientific and professional achievements*** **(B-i);**
- ***career evolution and development plans*** **(B-ii);**
- ***references*** **(B-iii).**

The Thesis approaches a research topic in the field of industrial engineering. The research activity is presented in two main directions:

- development of CAD / CAPP / CAM software systems dedicated to computer aided generation of the NC programs for CNC turning and milling machines or for the estimation of the processing costs of industrial products, presented in detail in the first chapter of this thesis;
- better use of materials in order to obtain complex structures with high mechanical strength and low mass, using a modern additive manufacturing process, selective laser melting (SLM) presented in detail in the second chapter.

The first chapter "Research on the computer aided generation of the NC programs for CNC turning and milling machines or for the estimation of the processing costs of industrial products", consists of three subchapters in which three original software systems are presented. The AutoCAD software with its programming language Visual LISP and the dialog windows language DCL were used. The CAD/CAM new created systems are dedicated to NC milling, NC turning or to manufacturing cost estimation of industrial products as follows:

The CAD/CAM System FASC-2000

In the first half of the period following the graduation of the doctoral studies I upgraded an original CAD / CAM system named FASC-2000 (Computer Aided Milling of Complex Surfaces). The upgrading of this system consisted in the extension of its area of applicability, from 2½ axes CNC machines to 3 axes CNC machines. Further I added new modules designed to diversify the types of surfaces that can be machined using the data provided by the system. In addition, the software area of applicability was extended from milling operations, for which it was originally designed, to turning operations.

Subsequently new modules were designed to diversify the types of the manufactured surfaces with the data provided by the system while increasing its area of application by adding to the milling operations the turning operations.

Within this software product the 3D manufacturing path is calculated in order to manufacture the designed surface; the optimal radius of the cutting tool is obtained automatically and the computer-user dialogue is carried out in the Romanian language; a technical support is also available to the user, also in Romanian.

To optimize the data input process the manufacturing design was half-automated. The manufacturing half-automation refers to:

- automatic retrieval of all the saved data that exists in the system (from the CAD phase);
- sequential dialogue guidance through dialog windows
  (the effect is of substantially reducing the input data times by reducing the number of wrong data and by quickly retrieving the information needed for the manufacturing process)
- automatic generation of the NC program in accordance with the machine processor functions.

After adding the manufacturing module for 3 axes NC machines I designed a new module for manufacturing pockets of any shapes. New commands were created within this software to get the pocket shape very quickly:

- the optimal machining path was calculated;
- a procedure was created for the automatic division of the manufacturing depth when necessary;
- the NC machining program was automatically created based on the input data and on the pocket shape;
- the computer-user dialogue and the technical support were carried out in the Romanian language;
- the manufacturing design was half-automated.

The next module was made for the machining of the closed contour channels. In this software product the design of the shapes having regular geometries is much simplified due to the creation of its own database which includes some of the most common regular geometric shapes (square, triangle, hexagon, circle channels);

The procedure for designing channel paths with new geometries was simplified by defining new commands in the Drawing menu which runs using the Romanian language dialog:

- a procedure was designed for successive processing of several equidistant channels having identical shapes if the channel width is greater than the diameter of the milling tool;
- the possibility for rounding the channel corners with a constant or variable radius was created;
- the NC machining program was automatically created;
- the computer-user dialogue and the technical support were carried out in the Romanian language;
- the manufacturing design was half-automated.

Another module was made for machining spiral-shaped paths. Within this software product 4 predefined paths having a spiral form were designed. The modelling can be made exclusively through dialog boxes. All the facilities of the previous module are available too (commands that run in Romanian language, fillet possibilities, computer-user dialogue in Romanian language, half-automated manufacturing).

The last module added to the FASC-2000 system, so far, was the module for machining dental surfaces. Within this software product, a geometric model to be used for generating different molar tooth shapes was designed. The previous mentioned facilities are available too (commands and computer-user dialogue in Romanian language, half-automated manufacturing etc.).

The "Fitting-NC CAD/CAM system dedicated for 2-axis NC turning machines" [Lancea-09, Ivan-05].

After updating the FASC-2000 system with new modules another system was created: *Fitting-NC*, a CAD / CAM system for 2-axis NC turning. This software system is no longer an update of an existing product, it is a completely new product. To create it the following steps were taken:

- a new interface was fully designed;
- the CAD module is also a new one being designed so that all the input data used for modelling the fitting part can be taken over the dialog boxes;
- the new CAM and simulation modules were fully designed;
- the system has new commands implemented and a computer-user dialogue in Romanian language;
- the system also is guiding a half-automated manufacturing.

The "WinCOST software system dedicated for estimating the manufacturing costs of the new industrial products" [Lancea-07a, Lancea-07b, CNCSIS-06]

Another software package to which I contributed by implementing new mathematical models was in the *WinCOST* software system and was designed to estimate the manufacturing costs of the new industrial products. Within this software system I obtained new mathematical models for calculating the auxiliary times for cutting operations and for determining the auxiliary times for gear cutting.

The second chapter, "Superior use of materials in order to obtain complex structures, with high mechanical strength and low mass, by using a modern additive manufacturing process: selective laser melting (SLM)" comprises four subchapters.

In the first two subchapters a brief presentation of the additive manufacturing technology is made. The chapters present the current state of the research undertaken for a better use of materials and the existing types of additive manufacturing.

The last three subchapters present the research undertaken in three research grants which I earned as a director.

Microstructural Analyses on Selective Laser Melted Inconel 718 As-built and Heat Treated

Within this grant [ESTEEM9 - 20], the microstructure of three types of parts, built of Inconel 718, by selective laser melting (SLM - Selective Laser Melting) were analysed. Most of the research, under this grant, was conducted in Poland at the AGH University of Science and Technology (Akademia Górniczo-Hutnicza), Faculty of Metal Engineering and Industrial Informatics.

To make these determinations, at the beginning the parts were designed and afterward several parts were manufactured using SLM technology. After manufacture, the parts were split into three sets: two sets were subjected to heat treatments, by using two different kinds of cycles and temperatures exposure, and the third set remained as built. All these procedures were performed at the Research-Development Institute of Transilvania University.

All the subsequent analyses, of the three sets of parts, regarding their microstructure and their chemical composition, was performed at the AGH University of Science and Technology.

Research on the resistance to environmental stress and corrosion of materials used for building sustainable energy systems, manufactured by SLM

Within this grant [Sfera-13] the resistance to environmental stress and corrosion of three types of materials, obtained by selective laser melting was analysed. The research was carried out in Italy at the National Agency for Energy, Environment and New Technologies ENEA (Ente Nazionale per l'Energia, l'Ambiente e le Nuove Tecnologie).

First the geometric shape of the analysed samples was developed and designed after which the materials of the samples were chosen in accordance with the tests to be subjected.

The following steps were accomplished:

- selection of the manufacturing process for the samples (SLM) and the machine (SLM 250HL);
- effective manufacture of samples specifying the chosen manufacturing parameters;
- description of the analysed case studies and of the equipment used to carry out the research;
- analysis of the microstructure and microhardness of samples of Ti-6Al-4V alloys subjected to a combined test: temperature-humidity-ultraviolet radiation and at a corrosion test;
- presentation of conclusions;
- analysis of the corrosion influence on the lifetime of the AlSi10Mg alloy, manufactured by SLM, obtained after following the accelerated tests.

Learning and understanding of manufacturing techniques by Selective Laser Melting (SLM) in order to acquire the skills necessary to operate the SLM250HL machine at an advanced level

Within this grant [Lancea-17b] the influence of heat treatment on the microstructure and mechanical properties of TiAl6V4 parts, manufactured by selective laser melting, was analysed. A titanium Grade 23 powder (also known as TiAl6V4 ELI, which is the high purity version of TiAl6V4 alloy used in the previous project) was chosen to produce six identical specimens through SLM, having a Lattice structure obtained as a three-dimensional pattern of a 3D cell.

The above presented steps regarding the choice of the samples shape were completed. The difference is that in this situation the best SLM machine in the company *SLM Solutions* and the best material at that time were used for manufacturing (February 2018).

After the fabrication of the samples half of them were subjected to a homogenization heat treatment in order to perform a comparative analysis of the microstructure and mechanical properties of the two sets of samples.

By analysing the microstructure of the as-built and heat-treated samples was found that the heat treatment lead to a much uniform structure, having less pores and more stable phases. At the same time, heat-treated samples proved a better mechanical resistance too. In these conditions it can be concluded that the homogenization heat treatment of TiAl6V4 parts, manufactured by SLM, is useful.

The Habilitation thesis ends with the bibliography containing all the reference materials used for writing this paper.