Universitatea Transilvania din Brașov

HABILITATION THESIS

SUMMARY

Title: Research on additive manufacturing and quality analysis of polymeric industrial products

Domain: Industrial engineering

Author: Assoc. Prof. Dr. Răzvan Udroiu

Transilvania University of Brasov

BRAŞOV, 2023

The habilitation thesis presents a synthesis of scientific and professional results of the candidate dr. eng. Răzvan UDROIU, obtained and published after the completion, in 2003, of the doctoral thesis titled "Design and manufacturing of complex shape parts" and obtaining the title of Doctor engineer, CUM LAUDE, in the field of Industrial Engineering, within Transilvania University of Brașov (scientific advisor: professor dr. eng. Nicolae-Valentin IVAN). The author of the thesis currently holds the teaching position of Associate Professor, full time, in the Department of Manufacturing Engineering of the Transilvania University of Brașov.

The habilitation thesis "Research on additive manufacturing and the quality analysis of polymeric industrial products" presents the achievements that attest to the capacities and performances in the field of Industrial Engineering, regarding additive manufacturing and the quality analysis of the processes and products related to it. The processes of material jetting and binder jetting, as well as their applications, are mainly covered.

The paper contains the following main sections: **B1.1 Scientific achievements**, **B1.2 Professional achievements**, and **B2 Career development and development plans**. The first section highlights the scientific achievements being divided into six distinct chapters followed by a chapter of conclusions and personal contributions.

Chapter 1, **Research on the optimization of additive manufacturing processes for functional tests**, presents three case studies that treat the optimization of the position and orientation of one part, two parts and several parts on the built platform of additive manufacturing system. Also, the additive manufacturing of the rotor of a Pelton turbine is analyzed in two constructive variants. The results of the research consisted in the determination of positioning and orientation rules of the parts to optimize the manufacturing time and the materials consumption, in the case of material jetting and material binding processes.

Chapter 2, **Experimental research on the rapid tooling based on additive manufacturing**, comprises three case studies regarding the rapid tooling by additive manufacturing processes. In the first case study, a tool for making a bellows-type component is designed and manufactured by material binding process. The second and third case studies respectively present indirect RT and direct RT processes using PolyJet material jetting technology, and their applications.

Chapter 3, entitled **Methodology and experimental research regarding the planar surfaces quality analysis in additive manufacturing**, is structured in five subchapters. A literature review regarding the surfaces quality in additive manufacturing was presented. A new methodology regarding the surface quality analysis of the parts obtained by additive manufacturing, based on a test artefact was proposed. The methodology is validated by an experimental case study focused on PolyJet material jetting technology. The test artifact designed to investigate the quality of planar surfaces, consists of rotated platens around a

horizontal axis, and contains design configurations with editable geometry. The family of artifacts fit with different build platform sizes of the AM systems.

The effects of three main factors (artifact orientation, platen orientation, finish type) on the surface roughness of platens are investigated using the statistical design of experiments. A theoretical roughness distribution model including the post-processing was proposed, and compared with the experimental roughness distribution. The significant factors that influence the surface roughness are platen orientation, finish type, and their interaction. Also, the experimental roughness (Ra) for the PolyJet process was in the range of 0.5–15 μm for matte finish, respectively in the range of 0.5–4μm for glossy finish.

In **Chapter 4**, **Methodology and experimental research regarding the analysis of the surface quality of aerodynamic parts manufactured by additive processes**, a new methodology to anlysed the roughness of aerodynamic parts was proposed and validated by experimental research and case studies for material jetting technology (PolyJet). Two test artefacts of aerodynamic shape, for preliminary tests and validation tests were designed. Different orientations of the artifacts were analyzed based on keeping the same surface quality on the upper and lower surface of the sample. The surface roughness of the aerodynamic artefacts was analyzed in three different locations such as leading-edge, central, and trailing-edge zones, on upper and lower surfaces. The effects of main factors on the surface roughness of the artefact were investigated using the statistical design of experiments. The best results were obtained for XY orientation on the build platform for the artefact manufactured in matte finish. Also, the surfaces of the aerodynamic artefacts were analyzed and charaterised by microscopy.

Chapter 5, entitled **Methodology and experimental research regarding the analysis of the system performance and process capability in additive manufacturing**, presents a methodology for the analysis of an additive manufacturing system performance and additive manufacturing process capability, using statistical control. This methodology consists in six steps, starting with process specification followed by determination of the variability of the measurement system, cheking the critical capability assumptions, determination of AM system capability, determination of AM process capablity, and microscopy investigations. A case study based on PolyJet technology has validate the propose methodology. Batches of 50 samples of circular shape were additive manufactured of photopolymer resins. Two critical characteristics of the specimen were considered in this study.

A repeatability and reproducibility study was performed in order to determine the variability of the measurement system. Machine and process capabilities were determined and the results were analyzed based on the requirements from the statistical process control. The results show that capability indices of EDEN 350 machine and Polyjet process are over 1.67 within a capable tolerance interval of 0.22 mm.

The international tolerance grade for a circular part built by material jetting was determined as IT9 for radial dimension and IT10 for linear dimensions. The microscopy analysis has explained and validated some results from the capability study..

Chapter 6, **Methodology and research on the analysis of the internal structure of multi-material parts by non-destructive testing**, presents in the first part a methodology regarding the determination of internal defects of porosity type for a multi-material by X-ray computed tomography, and in the second part experimental investigations regarding the porosity characterization of a composite multi-material. This methodology consists of the following steps: CT scanning of samples from a multi-material, 3D morphological analysis of five samples, determination of porosity for each component material, and statistical analysis of pore characteristics.

General conclusions regarding the research after the completion of the doctoral thesis, and the **personal contributions** of the author of this habilitation thesis are presented in a separate chapter.

The second section, **B1.2 Professional achievements** present the main aspects regarding the author's professional experience, didactic activity and scientific research. The author's plans regarding the development of the didactic activity, scientific research and professional career are presented in detail in the third section of the work entitled **Evolution and career development plans**. The **bibliographic references** used in the elaboration of this habilitation thesis are presented in the last part of the work.

In summary, the thesis contains 125 figures, 29 tables, 6 original reports and 148 bibliographic titles.The elaboration of the habilitation thesis was based on the scientific results published in 16 scientific articles as main author and obtained in 15 scientific research projects as project director, after obtaining the title of doctor engineer.