

Abstract of Postdoctoral Thesis

BEHAVIOR OF METAL AND COMPOSITE MATERIALS UNDER MECHANICAL-THERMAL STRESSES

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The postdoctoral thesis named **“BEHAVIOR OF METAL AND COMPOSITE MATERIALS UNDER MECHANICAL-THERMAL STRESSES”** represents a synthesis of my concerns and scientific activity in the period following the defense of the doctoral thesis from 2002, at the POLITEHNICA Timișoara University, titled “Optimization of the strength structures of metallurgical equipment”, under the guidance of Prof.univ. dr.Eur.Ing. Tiberiu Dimitrie Babeu, when I obtained my PhD in Mechanical Engineering.

Although some of the postdoctoral studies have remained in the field of metallurgical equipment, their approach has a multidisciplinary character, requiring knowledge in the following fields: Mechanical Engineering, Materials Science, Mathematics and Computer Science.

The presentation of the research conducted so far reflects the experience gained through the didactic and research activity carried out during 28 years at the Faculty of Engineering Hunedoara, POLITEHNICA UniversityTimișoara.

The significant scientific and professional achievements have been earned from two approaches. In the first approach, the increase of the durability of the rolling cylinders was studied, by observing the behavior of the materials needed for their manufacturing (steels and cast iron) under the action of the operational mechanical and thermal stresses. The second approach had as results the production, characterization and testing of composite materials, made of organic fibers, intended for brake pads for small vehicles and medium performances. The two research directions were correlated with the didactic activity carried out, in the sense that, on the one hand, we involved the students in the research activity, and on the other hand, the scientific results obtained were capitalized in the didactic process.

The postdoctoral thesis includes the most important results obtained from the two research directions approached, which materialized in two scientific research contracts awarded through national competition, an invention registered at OSIM (Romanian State Office for Inventions and Trademarks), a monograph published by a renowned CNCSIS publishing house, two computer applications and 150 scientific papers, of which 22 Web of Science, 31 BDI (ISI Proceedings and Scopus), 31 in other data base and the rest in other databases.

The quality of the rolling cylinders influences the production and the quality level of the rolled products. During the production process, the quality of the rolling cylinders is assessed based on their hardness, strength and stability at high temperatures. These characteristics determine the high wear resistance as well as their resistance to sudden temperature variations. Fulfilling these requirements implies, on the one hand, the correct choice of material and manufacturing technology, and, on the other hand, their proper operation.

The research carried out in this direction over a period of 15 years was summarized in this postdoctoral thesis and represents a first main research approach adopted during the postdoctoral period. The adressed topic includes elements of fundamental, applied and industrial research.

The aim of the approched reasearch topic refers to the increase of the durability during the operation of the hot rolling mills cylinders, by evaluating their behavior when subjected to mechanical and thermal stresses.

The specific objectives pursued in this research relate to:

- The analysis of the factors leading to the breaking of the hot rolling cylinders;

- The theoretical study of the distribution of temperature fields on the surface and in the radial section of the cylinders during the hot rolling process;
- The design and the assembly of the installation needed for the determination of the temperature variations on the surface and in the surface layer of the hot rolling cylinders as well as of the equipment used for determining the rolling forces, adapted to the experimental rolling mill;
- The experiments made in laboratory conditions in order to observe the thermal regime of the hot rolling cylinders;
- The determination of the mechanical, thermal and equivalent stresses of the hot rolling cylinders;
- The optimization of the stress level of the rolling cylinders;
- The study of the thermal fatigue resistance in order to assess the durability of hot rolling cylinders;
- The comparison of the results obtained in the laboratory with the industrial ones;
- The proposals of materials with high resistance to thermal fatigue for the manufacture of hot rolling cylinders;
- The study of the possibilities of transposing the experience gained in the field of thermal fatigue of hot rolling cylinders to the fixed and mobile machine parts of the internal combustion engines;
- The designing, assembly and validation of the installation used for the study of the thermal fatigue resistance of the machine parts subjected to the thermal fatigue phenomenon during the operation process.

In order to achieve these objectives, a thorough documentation in the specialized literature as well as a detailed analysis of the technical reports on the behavior of the hot rolling mills during operation were necessary. In this regard we used the data received from the Hunedoara Steel Factory. The results of the laboratory studies were implemented later at industrial level.

The separation of the temperature fields producing thermal stresses into symmetric and asymmetric, their experimental confirmation and the transposition of the research on the thermal fatigue resistance of hot rolling cylinders to other machine parts subjected to this phenomenon, by designing and assembling a suitable installation in this respect, represent the DEGREE OF ORIGINALITY AND INNOVATION of this research.

The second direction of research got materialized following my appointment into the advisory committee of a doctoral student who studied the materials used for the braking systems of vehicles for his PhD thesis. As a result of my involvement in the research activity, a new perspective opened regarding the finding of ecological materials that would offer superior performances to the functioning of the products. The main objective of this line of research is to develop friction materials for brake pads, based on natural fibers, capable of reducing the emission of fine particles resulting from the braking systems of vehicles. The testing and the assessing of their functionality were done via a multi-analytical approach. The use of different experimental tools provides a complete characterization of the raw materials and surfaces resulting from the manufacturing technology. The chosen organic fibers are the coconut fiber and the crushed seashell powder. They are wear-resistant and can be combined with other materials without adverse effects on the environment and human health.

The specific objectives pursued during the research are:

- The study of the specialized literature on composite materials and their manufacturing technologies;
- The choosing of the recipe components and of the sintering technology parameters;
The laboratory production of coconut fiber and shellfish powder composites;
- The determination of the physical-mechanical and tribological characteristics;
- The testing of the produced materials in accordance with the current standards.

The research conducted in this direction does not offer immediate practical applicability, because of the price of the organic raw materials. However, these studies have opened up new research directions concerning the use of other economically advantageous types of organic fibers or a combination of fibers (flax fiber, rape fiber, cane fiber) for the production of friction materials.

THE POSTDOCTORAL THESIS respects the structure imposed by the current norms of CNADTCU (Romanian National Council for Attestation of University Degrees, Diplomas and Certificates), including two parts, structured on 7 distinct chapters and a selective bibliography.

PART I contains seven chapters.

CHAPTER 1: SYNTHESIS OF THE SCIENTIFIC, DIDACTIC AND ACADEMIC RESULTS

This part of the thesis is dedicated to presenting the most relevant results obtained during my professional career. In this section, the directions approached in the postdoctoral scientific, didactic and academic activity are outlined. In terms of the didactic activity, the references highlight the teaching activity and the guidance of bachelor's and dissertation papers, the hard work done for the modernization and endowment of the laboratories with teaching material, as well as the didactic role of the publishing activity consisting in publishing courses and laboratory guidance papers for the students and graduates. Modern teaching-assessment methods based on the principles of quality assurance in learning were adopted for the didactic activity. The scientific research activity materialized into the grants received as director, as well as member of advisory committees for doctoral students and into the publishing activity having as main objective the publishing of specialized books and scientific papers. The extensive scientific research facilitated the knowledge transfer to my students and helped me to continuously improve and refresh my specialized and teaching attainments. This synthesis highlights the main directions representing the base of my personal development, but also the contributions made for the institutional progress.

CHAPTER 2: BEHAVIOR OF MATERIALS FOR THE MANUFACTURE OF HOT ROLLING CYLINDERS UNDER THE ACTION OF OPERATING STRESSES summarizes the author's main research direction. This chapter provides a brief introduction to the field of hot rolling cylinder research, marking the direction in which this research is to be conducted. For this purpose, the causes leading to the breaking of the hot rolling mill cylinders during their operation were studied, an analysis of the materials from which the respective cylinders are manufactured being carried out by using the existing data received from the Hunedoara Steel Factory. The conclusions of this study show that the breaking of almost half of the cylinders during the rolling process, in the analyzed period, was due to the inadequate thermal regimes to which they are subjected during the operational process. These regimes have caused the occurrence of the thermal fatigue phenomenon, respectively of thermal shocks, and that is the main reason why the subsequent research has moved on in that direction. The distribution of temperature fields on the surface and in the radial section of hot rolling cylinders was also analyzed in this chapter based on the specialized literature. The resulting conclusions show a separation of the thermal fields into symmetric and asymmetric, the theory being confirmed by the subsequently performed experiments.

CHAPTER 3: STUDY OF THE THERMAL REGIME OF HOT ROLLING CYLINDERS, presents the achievements of the postdoctoral period regarding the equipment used to determine the temperature variations on the surface and in the radial section of the hot rolling cylinders, as well as their experimental ascertainment, approached by using two methods: oscillography of the rolling process and use of analog modules and electronic computing technology. In order to analyze the temperature distribution inside the hot rolling cylinders, a mathematical model was developed to confirm the data gathered from the conducted experiments. Knowing the temperature variations in hot rolled cylinders makes it possible to study the durability and stability of the various steel and cast iron brands used for their manufacturing and provide sufficient evidence for the research carried out in this regard. Furthermore, the separate study of the symmetric and asymmetric temperature fields allows us to determine separately the thermal stresses they generate, while the effects of the stresses acting on the hot rolling cylinders are superpositioned.

CHAPTER 4: ASSESSMENT OF THE STRESSES ACTING ON THE HOT ROLLING CYLINDERS, shows the scientific contributions and achievements regarding the determination of the mechanical, thermal and equivalent stresses acting on the surface of the hot rolling cylinders. These studies were conducted within the research grant awarded through national competition AT, Nr. GR/19.05.2006 code CNCSIS 45, Topic 3. The research shows that the mechanical stresses affecting the rolling cylinders during the operational process, have practically insignificant values. The stresses that lead to the destruction of their calibers are the thermal stresses produced by the asymmetric temperature fields. They have a cyclical character, are repeated at each rotation of the cylinders and are mainly responsible for the occurrence of the thermal fatigue phenomenon. In this context, the study of the thermal stresses acting

on the rolling cylinders is urgently needed not only to reduce the number of the cracks caused by the thermal fatigue phenomenon, with the main purpose of increasing the service life, but also to avoid the especially dangerous thermal shocks, caused by the big, instant temperatures variations, leading to the shearing of the cylinder caliber cords in their maximum section. In the final part of the chapter, an optimisation of the equivalent stresses was carried out, the optimisation field allowing the formulation of recommendations in order to mitigate the destruction of the cylinder calibers and to avoid their breaking caused by the thermal shocks.

CHAPTER 5: ASSESSMENT OF THE THERMAL FATIGUE RESISTANCE OF HOT ROLLING CYLINDERS, presents the main scientific achievements related to the durability of the hot rolling cylinders by assessing their thermal fatigue resistance, determined based on the actual number of stress cycles until the occurrence of the first cracks on the surface of the samples subjected to experiments because of the thermal fatigue phenomenon. The studies were conducted within the research grant awarded through national competition AT, Nr.32 940/22.06.2005 CNC SIS code 24, Topic 6 and Topic 7/2005. In order to carry out the experiments, four brands of steel and two brands of cast iron were chosen, materials used to manufacture the industrial rolling mill cylinders. At the end of the experiments, the best behaviour observed was manifested by Adami steel, a steel brand having in its chemical composition carbon levels reaching the upper limit and an appreciable content of chromium and nickel. The other studied brands of steels and cast iron withstood relatively well the stresses exercised by the thermal fatigue phenomenon in an easy stress regime and had an acceptable behaviour under the stresses generated in medium and heavy stress regimes, the laboratory results being compared with those from the industrial environment. The research led to the conclusion that the thermal fatigue phenomenon is more accentuated at relatively low rotational speeds of the rolling mill cylinders. Further on in this chapter, two materials used for the manufacture of hot rolling were proposed to be subjected to the assessment of the thermal fatigue resistance being subjected to an average stress regime. The results obtained showed that the two proposed materials have a better thermal fatigue resistance than the steel and cast iron types used at that time for the manufacture of rolling cylinders. The chapter ends with the determination of the thermal shock parameters for the six studied materials. The best behaviour to the effects of thermal shock was manifested by the cast iron FNS 2, while the steel brands are the most exposed to its occurrence. The research conducted in the postdoctoral period on hot rolling mill cylinders had a practical importance for the Hunedoara Steel Factory, and it is part of the technological improvement action plan concerning the hot rolling cylinders manufacture and operation processes.

CHAPTER 6: ASSESSMENT OF THE THERMAL FATIGUE RESISTANCE OF FIXED AND MOBILE MACHINERY COMPONENTS OF INTERNAL COMBUSTION ENGINES, presents the expanding of the experience gained in the field of hot rolling cylinders over the fixed and mobile machinery components of internal combustion engines subjected during their operation to the phenomenon of thermal fatigue. In this regard, an installation has been designed and built in order to be able to conduct relevant experiments. The project documentation for this equipment was used by the author of this postdoctoral thesis to receive the patent No. 126966/ 30.03.2016 named "Installation for the study of thermal fatigue resistance". The installation was awarded 3 gold and 1 silver medals as well as two diplomas of excellence at several national invention exhibitions. This chapter presents in detail the design, construction and operation guidelines of this installation, as well as the principle of experimental research. At the end, the experimental assessments validating the concept of the installation are detailed.

CHAPTER 7: STUDY ON THE CHARACTERISTICS OF ECOLOGICAL COMPOSITES FOR THE MANUFACTURING OF BRAKE PADS FOR VEHICLES, presents the main scientific achievements in the field of production, characterization and testing of environmentally friendly friction materials used for the manufacturing of brakepads for small and medium performance vehicles. The chapter analyzes two friction materials, one with coconut fiber and the other with crushed seashell powder. The physico-mechanical and tribological characteristics were determined for both materials. The friction material with coconut fiber was tested for intensive braking in the laboratory, on an experimental installation designed and built for this purpose. The installation was awarded a gold medal and a diploma of excellence at some national invention exhibitions. In order to validate the composition of the friction material, brake pads were manufactured and mounted on the front axle of a vehicle in order to

determine their braking performance, the experiments being conducted in a workshop for Periodic Technical Inspections. The braking performance of the eco-pads has been compared to that of the semi-metallic brake pads, homologated according to the ECE R90 standards, which have been mounted to the same vehicle and tested under the same conditions. As a result of the tests performed, it was found that the brake pad produced in the laboratory shows an appropriate behaviour and can work in real operating conditions. However, the test conditions and parameters used for these experiments cannot exactly simulate all the test conditions when driving the vehicle on the road. The final validation of the recipe should be based on the results of the on-road performance. Nevertheless, in order for the brake pads produced in the laboratory to be subjected to road performance tests, preliminary tests are required to ensure that the friction material can operate under the actual running conditions of the vehicle. The final validation test of the friction material produced in the laboratory will be performed by determining the braking capacity parameters of the vehicle equipped with coconut fiber break pads when driving on the road, but these tests will be the subject of a different paper.

Concerning the friction material made with crushed seashell powder, we can mention that it has been produced in the laboratory, its physical-mechanical and tribological characteristics being defined, and will be further tested according to the standards in force.

Like any research conducted on a certain topic, it cannot be reported as completed at a certain moment, as new development and knowledge enhancement opportunities can be constantly identified, the resumption of certain research stages by using a different approach or by imposing new work techniques being always possible, opening up future research perspectives and directions.

PART II: PERSPECTIVES FOR PROFESSIONAL, SCIENTIFIC AND ACADEMIC CAREER DEVELOPMENT, presents the main directions and objectives which will form the basis for the development of the teaching and scientific research career. Thus, the career development plan is summarized, both from an academic perspective, as well as from a scientific and professional one, aiming mainly to increase the popularity of the POLITEHNICA Timișoara University at a national and international level.

Finally the post doctoral thesis includes the list of the general bibliographic reference articles, books and papers and own publications used for the elaboration of this postdoctoral thesis.

Due to its original elements, the conducted research allowed the use of new approaches in the studied fields and opened a multitude of research directions that the author of this postdoctoral thesis plans to develop continuously.

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