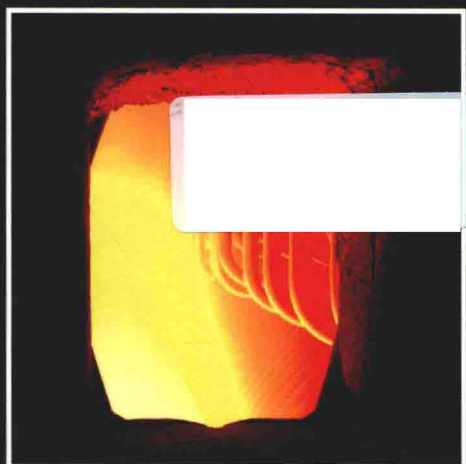


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Materials for Ultra-Supercritical and Advanced Ultra-Supercritical Power Plants

Edited by Augusto Di Gianfrancesco

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Preface

This book summarizes the worldwide contributions about materials development for cleaner coal technologies in the fossil fuel power plant and the consequent sustainability for planet earth future.

The industrial use of steam for generation of energy started in the 18th century and was the main driving force for the industrial revolution. In the 20th century the consumption of fossil fuels and in particular of carbon for steam power generation plants guaranteed the development of the global economy.

Since beginning of the 21st century the world of energy production has changed in an unbelievable way: from an exponential increase of the energy demand due to the increase of the world population and economies, to the world financial crisis that generated a huge drop of the energy demand mainly in the Organisation for Economic Co-operation and Development (OECD) countries, through the implementation of the renewable sources.

The fossil-fueled power plants will continue for several years to guarantee the energy supply for the increasing demand in the emerging countries due to their urbanization and industrialization improvement.

Asia-Pacific is the largest market, by size, and it is estimated to grow at the highest rate due to a large number of power capacity expansion projects in China and India. To meet the growing demand for power, China alone is expected to add about 70–90 GW of capacity every year to its power generation sector, whereas India is expected to add about 10–20 GW every year.

These aspects seem in contrast with the final document issued in the last COP21 conference held in Paris at the end of 2015, where it was agreed to maintain the increase of global warming below 2°C in 2050.

Achieving CO₂ emission control while keeping electricity prices competitive and available for all the population in the world countries is a key economic and technical challenge for the world community. Renewable sources have to be improved jointly to the strategy for lowering CO₂ emission from coal-based power plants including primarily raising electricity generation efficiency. In fact, coal remains in the foreseeable future, 30–50 years, the dominant means of electric power generation.

The efficiency of the pulverized coal power plants (PP) increased a lot in the last 30 years from the efficiency range of 30% for the subcritical (SC) PP up to the last and most efficient ultra-supercritical (USC) PP operating with 46–47% efficiency. These improvements were mainly due to the availability of most performance materials developed in the last 40 years able now to operate up to 600–620°C with steam pressure up to 300 MPa. A further improvement of the efficiency will be obtained with

the introduction of the next PP generation called advanced USC (A-USC), targeting efficiency in the range of 50%, where the steam service condition will be over 700°C and pressure over 300 MPa.

An additional reduction of the emission will be obtained with the capture, the sequestration, and storage (CCS) of the CO₂ gas. In fact, it is expected that by 2030 the new coal-fired PP will be operating high-efficiency, low-emission technologies with CCS, associated with the drop-off of the older SC PPs having efficiencies lower than 40%.

It is expected that the first new-generation demonstration plants will be in operation by 2020 in China or India. Despite the first idea generated in the European Union about the A-USC PP, the several R&D programs carried out and the demonstrated production capabilities of the new materials/components, the construction of demonstration plant is not more scheduled in near future in European countries; this is due the incredible improvement of the renewable energy capacities developed in the last 10 years.

After my master's degree in chemical engineering, with a specialization in materials science, at the first Rome University "La Sapienza" in October 1982, I soon started my career at the beginning of 1983 as young researcher at Centro Sperimentale Metallurgico (CSM) (Metallurgy Experimental Center) in Rome, Italy. The CSM was founded in 1963 as the corporate research center of the Italian steel companies, which were at that time mainly public companies; also, Italian automotive and oil and gas companies were shareholders. The CSM changed the name to Centro Sviluppo Materiali (Materials Development Center), maintaining the same acronyms, and it was privatized in the 1990s as consequence of the privatization of the Italian steel companies. I have been employed at CSM since the end of 2014.

In my career, I have been fortunate to be involved practically in all the aspects concerning the steels and alloys for high-temperature applications in the power generation industries and in the aerospace engines.

In 1983, I was involved in the Italian team that produced the first European industrial heat of the steel grade 91. Then I started to investigate the effect of the alloy elements and the heat treatment times/temperatures on the mechanical properties; further, I studied the microstructural aspect and the mechanical properties of this steel and in particular the creep performance. In the 1980s, I started also the first integrated projects on this steel between the United Kingdom, Germany, and Italy sponsored by European Community. Therefore I contributed also in the investigation of microstructural evolution of this steel practically during my entire career at CSM, up to the discovery of the Z-phase also in this steel after very long-term aging.

I was also involved in the characterization, qualification, development, and pilot-scale production of the single-crystal, nickel-based superalloys and then in the titanium metal matrix composites for aircraft engines. At the end of the 1990s, my research activities turned back to the materials for power generation: tube, pipe, cast, and forged components made by steels and superalloys.

In 1991, I was one of the founders of the European Creep Collaborative Committee (ECCC) that is still alive and active to assess the European creep data for high-temperature materials. I was also active in the R&D COST actions for steel

development USC power plants and member of the management committee, as well as in the AD700 project, which was the first program in the world looking for materials to be applied in the A-USC PP.

During my working career, I was project leader of several national and EU programs, and I had the opportunity to attend several national and international Conferences, also as an invited speaker or member of scientific committee, to visit R&D centers, universities, and industrial plants in several countries. Therefore I had the opportunities to meet the main worldwide representatives of the scientific community in the field of high-temperature materials. This have been for me an incredible experience to learn, compare, discuss, and exchange my experience, improving my knowledge.

I am honored to be still in very good friendship with a lot of these colleagues around the world.

When in summer 2014 I was contacted by Elsevier Woodhead Publishing to be the editor of the book “Materials for ultra-supercritical and advanced ultra-supercritical power plants,” I remained astonished and in the meantime honored by this nomination.

This opportunity arrived after the success of the third ECCC conference held in Rome in May 2014, organized also with my little contribution, practically at the end of my career at CSM, but not really at the end of my working life in materials science and technologies for sustainable energy.

I prepared a draft of the book structure based on three parts, containing in total 24 chapters that was positively approved by the Elsevier reviewers and described as follows.

In the first part of this book, in , Chapter 1, the evolution of the operating conditions and of the layout of the steam PPs are described, as well as the main components.

In the further chapters are described the current best available materials for the different PP sections. In addition are discussed the low-alloyed ferritic steels for the water wall, the high-alloyed martensitic steels for the headers, steam line, turbine rotor, casing, and blades, up to the austenitic steel used for the reheaters and superheaters. The joining technologies, methodologies for the materials control, and characterizations are also described.

The second and third part of the book, respectively, are dedicated to the new materials and R&D programs for the development of the next A-USC PP generation.

Chapters 9 and 10 are focused on the development of the new martensitic and austenitic steels, and the following chapter is dedicated to the several superalloys still under development and investigations for the most critical components operating in the more severe temperatures and pressure conditions. Also in the second part, a chapter is dedicated to the joining technologies for these materials and components.

In the third and last part of the book, the research programs still running around the world targeting the design, the development, and the operating of demonstrative A-USC PP are summarized.

Based on this structure, I started to think how to handle this huge and exiting job, and I asked to my worldwide colleagues and friends to give me support to write this book that is a summary of the knowledge in the field of steels and superalloys for coal-fired steam PP.

The feedback was enthusiastic; only a few chapters were reassigned to other very well-reputed authors, and two chapters have been written by me because I did not have positive feedback from all the contacted persons, and I wanted to maintain the original structure.

Therefore I make my personnel acknowledgments to all the team authors because they have made the best to give a simple and, in the meantime, detailed and updated description of the materials, of their properties, and of the R&D programs in which all have been and are currently involved.

I hope that a broad spectrum of readers may find this book interesting and useful. Please convey to me your comments and suggestions on any aspect of the present book.

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