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vgbe Technical-Scientific Report

9 % to 12 % Cr Steels – Design, Manufacture, Fabrication and Safety Concepts

VGBE-TW 531e (2023)

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Preface

The aim of this report is to summarize the current state of knowledge in Germany on the quality-compliant production, processing, and design of the now established 9 % to 12 % Cr steel grades used in the energy and process industry and their applications. Furthermore, information and suggestions are given for the periodic inspection and monitoring of components made of these steel grades under operating conditions. In addition, information is provided on new international research priorities and areas.

The authors agree that this document cannot be all-encompassing, as there is now a huge wealth of scientific publications on this family of materials and on individual varieties. It is rather a compilation of relevant information as an introduction for the end-user in conventional power plant technology as well as in future energy conversion plants. The authors' collective has included both in-depth details and comparative considerations.

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1 Introduction

The combustion of fossil fuels is the oldest form of thermal energy conversion used by humans. Today, this continues to be a basis both for the operation of conventional power plants to generate electrical energy, and for the plants in the chemical, petrochemical and refinery industries to produce process steam or heat fluids for processing reasons.

For high efficiency in energy conversion, the temperature of the water/steam cycle upstream of a steam turbine must be correspondingly high. These required temperatures must be guaranteed or endured by the suitable, high-temperature steel grades. Whether steam boiler plant, pressure vessel plant, piping system or turbine, all require steel grades with comparably high creep-rupture strength and oxidation resistance as well as reliable manufacturability and testability. For this purpose, the martensitic materials described in this report were introduced into the technology and continuously developed further.

Whenever a significant development took place in this steel family, it always showed a far-reaching step forward in development for the entire energy and process industry. The history of martensitic materials begins in the 1920s. 100 years later, it is impossible to imagine thermal power plants and the process industry without these materials. They are the current basis for use at component or surface temperatures of up to approx. 635 °C in conventional power plants and up to approx. 700 °C in refinery process furnaces.

During the significant changes in the energy sector towards CO_2 neutral energy conversion, it is important that the expertise surrounding this family of steels can be passed on to the responsible professionals in a well-structured and easily understandable form. In the transitional period of energy provision, conventional power plants will still be required due to their systemic importance and they will bridge the lack of storage capacities. The steel family under consideration here is also still needed in chemical, petrochemical and refinery plants, as well as for future energy conversion concepts, such as hydrogen-fueled combined cycle plants.

As an introduction to this document, some terminology needs to be explained in order to prevent recurring ambiguities or misunderstandings.

The term “martensitic”:

The grades of this steel family are used for the above-mentioned applications with a fully tempered martensitic structure. The matrix is a very fine-grained ferrite, with finely dispersed, partly larger precipitates and a high dislocation density. In the microstructure, the superior contours of the martensite (an optical superstructure) are clearly visible, which arise from the austenitization heat during cooling towards room temperature. In this process, certain alloying elements delay the transformation process, so that accelerated air is usually sufficient to achieve 100 % martensite structure. This is an elementary intermediate step in heat treatment process, as otherwise the material and service properties required after final tempering would not be available.

Another special feature is the technical language used for these steel grades. Whenever certain things are used, utilized, discussed and analyzed over and over again, local terms become global standard terms.

This has been done analogously, for example, with the materials X20 (X20CrMoV12-1), P91 (X10CrMoVNb9-1) and P92 (X10CrWMoVNb9-2). X20 is simply the abbreviation of the longer standardized short name. P91 and P92 are the ASME material designations for unheated pipes = “P=Pipe”. In the operational context, it is now standard to speak only of P91 and P92, regardless of whether forgings (“F..” as in Forging) or heated tubes (“T..” as in Tube) are meant. To address this uncertainty in this document, the materials have been named Grade 91 and Grade 92.

Furthermore, “C” (as in Cast) as a leading abbreviation classifies the material as the cast variant of the corresponding steel grade. The C91 designation is an example of this.

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