European Technology Development *Ltd*

Project for Group Sponsorship

FERRITIC, MARTENSITIC, STAINLESS STEELS & NI-BASED ALLOYS

REVIEW OF MATERIALS, DATA, PLANT EXPERIENCE & NEW DEVELOPMENTS

for DESIGN AND LIFING OF HIGH TEMPERATURE PLANT

Project Acronym: Materials & Data Review

A Group Sponsored Project

ETD Project No: **1089-gsp-proj07**

Contact

Dr Ahmed Shibli
European Technology Development
6 Axis Centre, Cleeve Road, Leatherhead,
Surrey KT21 2HR, UK

ashibli@etd1.co.uk (direct) or etd@etd1.co.uk

Tel: + 44 1372 363 111
Or, + 44 1372 363 112

www.etd1.co.uk

October 2007

SUMMARY

The development of new alloys for use in high temperature plant is taking place at a rapid rate in Europe, Japan, USA and elsewhere. Research organisations, alloy producers, plant manufacturers and plant operators are actively involved in this process. At the same time various committees and bodies such as NIMS in Japan, European Creep Collaborative Committee (ECCC), Japan Standards committees, ASME committees etc. are regularly reviewing data to update and refine the prediction of material long term rupture strength and creep-fatigue interaction from relatively short to medium term tests. 9-12Cr martensitic alloys for temperatures up to 600/ 625^{o}C are already in use and new alloys with higher rupture strength, better weldability, high temperature oxidation resistance etc. and their welding consumables are being developed for use at these temperatures. At the same time various projects and research/ industry groups are looking at the development and/or validation of newer alloys for use at even higher temperatures of 700 or 750^{o}C, including the use of Ni-based alloys.

In addition to better performance, the cost analysis and economy of the use of various available materials is an important aspect of the materials choice. The choice of available materials for high temperature plant designers and manufacturers is getting ever bigger and more complex. Similarly the choice of materials for plant owners and operators for component replacement is also now quite large. And this includes the choice of using the existing well established materials or the newer materials with not very significant in-plant experience or even the newer developments with little or no in-service experience. Again the cost analysis and economy plays a very important role in decision making for the privatised and profit motivated industry of today. The cost analysis must not include only the material costs but also the cost of component fabrication/ welding and transportation, plant operation, monitoring, inspection and maintenance and how this may or may not be affected by the choice of materials. The plant component performance, cracking/ failure rate and repair will no doubt be affected by the choice of materials. This means that the plant operators, designers/ manufacturers and service providers all need to be aware of the choice of materials in terms of their performance and the costs involved. Furthermore, they need to be aware of the strength values specified by different standards and codes and any recommendations by national or international groups for their revision. For plant component integrity and life assessment, plant operators and service providers need to know which are the most appropriate code values to use for their particular circumstance and how these were derived. They need to know the background to the development of some of these values. This proposal is ***aimed*** at providing such information for the popular or potential new materials for high temperature plants in the form of a detailed and easy to follow document.

This project will comprise of four sub-projects covering four groups of materials namely Ferritic, Martensitic, Austenitic Stainless Steels and Ni-Based Alloys. The sponsors will have the choice of sponsoring any one or more than one of the sub-projects. Thus four reports/ documents, each covering one of the four sub-projects, will be produced for the project sponsors.

1. BACKGROUND AND INTRODUCTION

In year 2000 ETD were sponsored by a number of industries and R&D organisations from Europe, USA and Japan to review the performance and research experience of 9Cr martensitic steels, in particular P91, for use in supercritical and ultra supercritical power plant boilers. In this study both research and plant experience from around the world were comprehensively reviewed and reported to the sponsors in a clear, easily comprehensible and succinct form. Half a decade later (in 2005/2006) further studies were commissioned by some of these and some new sponsors to review and update plant and research experience in the use of P/T91. In addition, this second study involved analysis of the plant and research experience in the use of other high strength steels such as P92, P122, T23 and T24. This second review also included the integrity and life assessment issues for these steels. This was completed successfully in October 2006.

Because of the ETD's leadership and involvement in many leading edge European and international industry projects involving high temperature plant materials, particularly in the European industry-research collaborative projects and networks, and its knowledge of the new and recent developments in Japan and USA the company is in the best position to conduct such reviews. Furthermore, ETD's involvement in failure analysis and integrity assessment of many of the components made from some of these steels and showing cracking or other integrity problems in the European, Middle Eastern or Asian plant has given it a first hand experience and insight into these problems.

Since the second review referred to above some of the sponsors requested ETD to consider conducting a similar review of other new steels/ alloys developed recently and being used in plant or being considered for future use for new plants or for component replacement. This time the request was to review a number of alloys (including Ni-based alloys and traditional low alloy steels) used both for the boiler and the turbine components.

Here the materials of interest are: ***Low-alloyed ferritic steels*** such as 16Mo3, 13CrMo4-5, P/T22, P/T23, P/T24; ***High alloy martensitic steels*** such as 9-12%Cr X20, P91, P92, P122, VM12; ***Austenitic Stainless Steels*** such as TP347HFG, S304H, HR3C, NF709, Sanicro25; and, ***Ni-based alloys*** such as Inc.617, Nim.263, Inc.740 etc. Other alloys used or being developed for boilers and steam turbines and of interest to our sponsors will also be studied.

The ***fabrication processes*** studied will include: Bending, heat treatment, weldability, controllability, etc. The ***mechanical characteristics*** studied will include aspects such as: mechanical properties (static, fatigue, creep etc.). ***Physical properties*** (thermal conductivity, coefficient of thermal expansion etc.), metallurgical properties (nature of constitutive phases, transformation temperatures, cooling characteristics/ transformations) and high temperature oxidation and corrosion behaviour will be reviewed. In addition to the technical work, ***financial*** data related to material costs will also be reviewed.

Data from published papers, various national, industry and international codes, standards and from private industry reports/ sources provided for this purpose will be used for the analysis. An important aspect of this work will be the ***plant experience***, if the material is already in use, and its behaviour in terms of cracking and failure.

Proposed Study

ETD are conducting this 18 month review study of steels used, or expected to be used in future, in power plant boilers, HRSGs, steam turbines and petrochemical/ process plant. The objective is to review the available creep, creep/ fatigue, oxidation, corrosion and time-independent data (such as fracture toughness and tensile strength) and to review available data sheets and latest research findings and plant experience. On this basis recommendations will be made on the use of data sheets considered most suitable or the choice of the datasheets. Furthermore, study will be conducted on the implications for plant using these steels as new or replacement materials. Both similar and dissimilar metal welds will also be studied. This study will be conducted as follows:

- Access published and unpublished (through private contacts) information from a number of Japanese, European, North American and other potential contacts.
- Interview important players in this field such as plant operators, manufacturers, service providers, and researchers, by visiting where necessary, and build up a dossier of experience.
- Collect and review information on inspection strategies adopted by the plant users such as hardness tests, checks on heat treatment records, microstructure, NDE, etc.
- Review more significant work published since the introduction of these steels with special emphasis on new and more recent work.
- Review available/published information on work funded by individual organisations, national bodies, European Commission (such as the projects 'HIDA Applicability', 'Integrity of Repaired Welds' etc.), European Pressure Equipment Research Council's work and the work published by European Creep Collaborative Committee (ECCC) through its projects 'Creep', 'Weld Creep' and 'Advanced Creep' and any published information that may be available from EPRI (USA), NIMS (Japan) etc. Various conference proceedings will also be consulted to benefit from the findings and data presented in there.
- Various aspects of the use of these steels will be studied and special emphasis will be placed on the behaviour of ***welds*** and ***weld repairs*** when operating under creep, creep/ fatigue conditions and performance in steam i.e. steam side oxidation and fireside oxidation.

2. DELIVERABLES

In terms of the *deliverables*, a Mid-Term Report will be issued at the end of month 9 of the project. At the start and throughout the project duration sponsors will be invited to make their input to the project from their own experience and in the light of their own need and requirements. However, at the mid-term stage sponsors will have a more formal opportunity to review the work, its findings and its direction and make input re their requirements and need.

In addition, periodic email messages will be sent out to the sponsors letting them know of any *important findings* that may be useful to them in the interim.

Final Report

The detailed Report structure will depend on the findings of the study. It is nevertheless envisaged that it will have the following broad sections:

- Introduction.
- Findings from R&D experience in terms of creep, creep-fatigue and corrosion behaviour.
- Findings from plant experience.
- Material property values and data sheets from various national, international and industry codes and standards.
- Welding, weld consumables and weld heat treatment
- Implications for the plant using various steels
- Implications for HRSGs
- Implications for petrochemical and process industry.
- Inspection, monitoring and life assessment and potential in-service problems with these materials
- Implications for the future use of new steels
- National and international sources of data.
- Recommendations.
- Detailed bibliography and references.

3. PRINCIPAL INVESTIGATORS

Shown in the full proposal.

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