STX-21 ニュース

独立行政法人 物質･材料研究機構 超鉄鋼研究センター

(http://www.nims.go.jp/stx-21/)

'05 年 11 月号 (通巻第 99 号)

発行 独立行政法人
物質･材料研究機構
超鉄鋼研究センター
平成 17 年 11 月 1 日発行
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1. Research and Production of Advanced Steels

Dr. Han DONG, Director of ISM, CISRI and Director of NERCAST

It's an honor of me to be invited to give a plenary speech on the 9^{th} Ultra-Steel Workshop, which was successfully held on July 20-21, 2005 in Tsukuba. This workshop once again provided an opportunity for steel people in Japan to show their most recent research achievements in the fields of ultrafine grained steels, heat resistant steels, high strength bolt steels as well as advanced steel processing and the realization of new structural systems using ultra-steels. It was also a good chance for steel people from around the world to exchange new ideas concerning the development of advanced steels. It was one of the well-organized workshops that I ever attended.

Since the end of last century, steel people all around the world have been showing strong interest at grain refinement into microns or sub-microns in scale to seek a potential way to increase strength without any loss in ductility and toughness. The administrations of Japan, Korea, EU and China funded the nationwide research projects for grain refinement in steels, Ultra Steel and Super Metals in Japan, HIPERS' 21 in Korea, Ultrafine Grained Steels in EU, and NG Steel in China. Based on these research projects, a large amount of research results were published.

The Ultra-Steel project started in 1997 in Japan, focusing on the development of advanced steels with double strength and double life. In the first five years, several types of ultra-steels were developed together with new technologies related with them. In the second phase, "double strength in service and more than doubled life of structure" have been pursued with attempts to apply them into the specific steel structures. We are glad to know from the Japanese researchers that these attempts are being driven successfully with accumulating further new findings under good collaboration with end users. These include high strength corrosion resistant steels for bridge, heat resistant steels for high efficient and coal-fired power plant, and ultrafine grained steel sheet for automobile.

A typical example is the fabrication of recyclable ultra-fine grained 800 MPa steel plates 25 mm in thickness for new infrastructure.

Like the Ultra-Steel project in Japan, the HIPERS' 21 project, which started in 1998 in Korea, was in an effort to develop three kinds of innovative structural steels, i.e. 800 MPa grade structural steel, 1500 MPa high strength bolt steel, and seaside corrosion resistance steel. Apart from the former two kinds, another kind of 400 MPa grade plain low carbon steel was also included in the NG Steel project, taking into account the big amount of production of plain carbon steel rebar in China. One characteristic of these advanced steels is ultrafine grains of several microns or sub-microns in scale that can be obtained by thermomechanical method. While the Japanese researchers like to use the traditional term TMCP (Thermomechanical Controlled Process) for the process that results in ultrafine grained microstructure, the Korean researchers and the Chinese researchers call it SIDT (Stain Induced Dynamic Transformation) and DIFT (Deformation Induced Ferrite Transformation), respectively, considering the important role of strain or deformation during the ferrite transformation. Besides the experimental works in laboratories that lead to some understandings of the phenomena, field productions have also been tried and showed great successes. Like the Ultra-Steel project in Japan, the NG Steel project in China is now at its second five-year phase, which also covers some other kinds of steels, such as weathering steel, high nitrogen steel and fatigue resistant spring steel.

With the rapid development of China's steel production and consumption in recent years, it is of great importance for us to develop and use advanced steels instead of conventional steels to alleviate the increasing burden on iron ore supply, transportation, energy consumption, and environment pollution. To focus on the development of advanced steels with the characteristics of high performance, energy saving, resources saving, near-net shape and low cost, the National Engineering Research Center for Advanced Steel Technology (NERCAST) was launched in June 2004 under the authority of the National Development and Reform Commission of China. It is a share holder R&D center, whose shareholders include eight major steel plants, three metallurgy oriented universities, one metallurgical engineering company and one steel research institute. The target of NERCAST is to research and develop advanced steels instead of conventional steels to meet demands for energy saving, resources saving and environment benign in the steel processing and application.

The traditional methods to increase the ultimate tensile strength of plain carbon steel are to increase the carbon and/or manganese content, but such methods obviously reduce the weldability of the steel. Our research results show that the strength of plain carbon steel can be improved largely if the ferrite grains are refined to micron scale. The ideas to develop new plain low carbon steel were to be promoted in both the rebar and strip production in some Chinese steel plants. A good combination of strength and ductility has been obtained in the advanced plain low carbon steel rebar and strip produced in steel plants. Higher strength and toughness could be achieved in hot rolled steel rebar and strip through microstructure control by the addition of microalloying elements.

Microalloying elements play an important role in grain refinement and precipitation, which bring about strength increase and toughness improvement. Through grain refinement to about 2 microns, the yield strength of microalloyed steel can be increased from less than 400 MPa to 600 MPa, which is the target of a new microalloyed steel we developed. It is believed that DIFT is the effective mechanism to form ultrafine grains in microalloyed steels. Through DIFT rolling, ferrite grain in hot rolled strip can be refined to about one micron in size. The effect of microalloying elements on DIFT is still ambiguous. Our research results show that it is important to let Nb precipitation occur before potential ferrite induced from austenite to realize DIFT rolling in Nb microalloyed steels since DIFT will be promoted through the addition of Nb only if Nb precipitates during deformation, which may depress recrystallization and increase accumulative deformation energy.

In general, high strength steels are very much susceptible to delayed fracture when the tensile strength is over 1200 MPa. In our center, 1300 MPa and 1400 MPa grade steels of delayed fracture resistant bolt have been developed for automobile engine and suspension. It is medium carbon Cr-Mo steel with the addition of microalloyed elements V and Nb to refine the grain size and to form carbides for hydrogen trapping, which are believed to improve delayed fracture resistance. Industrial trials for the new delayed fracture resistant steels were performed in Dongbei Specialty Steel Co. The steels were melted in EAF and refined in LF/VD. The prior austenite grain sizes of the new steels were around 8 microns, while that of a commercial Cr-Mo steel was around 20 microns. The new steels showed a much higher K_{ISCC} value than the commercial Cr-Mo steel at the same strength level, as well as the transgranular fracture instead of intergranular fracture.

Ultrahigh strength steels are mainly used in the aeronautic and aerospace equipment, in which high specific strength is greatly demanded. In our center, a steel with the ultimate tensile strength of 2000 MPa and fracture toughness of over 100 $MPam^{1/2}$ has been developed through secondary hardening and the purification steelmaking, with the sum of sulfur, phosphorous, oxygen, nitrogen and hydrogen contents less than 50 ppm.

The large amount of stainless steel consumption in China could bring about resource shortage worldwide. The high nitrogen steel (HNS) could be used as a candidate to replace the high nickel stainless steels. Based on ideas to get high nitrogen contents into melts and keep them in solution during solidification, a Cr-Mn-N high nitrogen stainless steel has also been developed in NERCAST with nitrogen content of 0.68% and twice the yield strength of the commercial stainless steel AISI 316.

Exchanging ideas is a common purpose in international networking. Actually, based on the nationwide projects on advanced steels, several platforms for international exchange have already been established. The first one is the ICASS (International Conference on Advanced Structural Steels). It was successfully held in Japan in 2002 for the first time and in China in 2004 for the second time. Next year, the third ICASS will be held in Korea. The ISUGS is the second platform for steel people around the world to exchange their research achievements on ultrafine grained steels. This year, the third ISUGS will be held in China, following the first in Japan in 2001 and the second in Australia in 2003. Of course, the Ultra-Steel Workshop also plays an important role as such a platform like HIPER’21 Workshop and NG Steel Workshop once did. Other bilateral symposia such as the Japan-China Workshop on Automobile Materials and the Japan-China Symposium on USC Materials are also important in the specific field. Still, we can find some other opportunities, for example, ISIJ Meetings or CSM Annual Meeting. We encourage our researchers to share new ideas with steel people around the world through these platforms. Besides, we would also like to have research collaboration with steel people around the world.

Steel is one of the advanced materials, due to its high performance, rich in resources, mass in production and low price. Steel is also a complicated material with an amazingly large number of variants, especially phases in steels, and new discoveries are still being made. The products made with steel are safer, stronger and better in value. That’s why people in steel society always show strong interest in the research on advanced steels.

2. TOPICS

軽水炉用構造材料の高温水中低サイクル疲労試験のデータベース構築

耐食グループ Xinqiang Wu （現在中国金属研究所）
片田　康行


はじめに

H13 年度より原子力委託研究の一環として、軽水炉用構造材料の高温水環境中非定常条件下の低サイクル疲労挙動の検討が進められているが、得られたデータや解析結果の効率的な利用を図るために、ノートパソコンでも気軽に利用できるユーザーフレンドリーなデータベースの開発を進めている.

データベースの概要

開発したデータベースは**図 1** に示すように、データバンク、データ検索機能、図表データおよび文献データの4つからなり、Windows 2000 以降のバージョンで動作する。すべての制御用プログラムは MS-Excel 2000 を用いて Visual Basic で記述されている。

データバンク：データバンクには、試験片コード、実験条件、供試材、試験片、環境因子、微視的組織、熱処理履歴および割れ･破面形態等を含むすべての実験データ、並びにデータソース等が含まれている。

データ検索：検索機能には、**図 2** に示すように、材料名、試験片採取方位、実験環境、硫黄含有量、各種水化学条件、荷重条件、試験温度、表面仕上げ状態等の情報が格納されている。検索結果は、数値データ表あるいは S-N 曲線のいずれかの選択が可能で、S-N 曲線の場合、ASME 設計曲線との比較やデータの回帰曲線と回帰式の表示が可能である。**図 3** に検索結果の例を示す。

図表データ：このデータには、これまで本研究で得られたすべての図表のみならずいくつかの関連する参考文献から得られた解析結果が併せて収められている。これらの図表は、A：材料因子、B：荷重因子、C：環境因子、D： ASME 設計曲線との比較の4つのカテゴリーに分けられ、すべての図表は JPEG 形式で格納されている。

文献データ：このパートには、データソースとしての参考文献が、論文とプロシーディングスに分けて掲載されている。これらのすべての情報は PDF ファイルで格納されており、Excel のハイパーリンク機能を用いて、データベースへアクセスできるようになっている。

今後の展望

開発したデータベースの利用方法としては、構造部材の設計安全評価、材料選択、現象のモデル化支援等の直接的な利用だけでなく、知識ベース化を図ることにより実験室では実験困難な因子の組み合わせによる仮想実験データの評価も可能であろう。このデータベースについては、既在の NIMS 材料情報データベースとの連携も考慮してさらなる有効利用を進めたい。

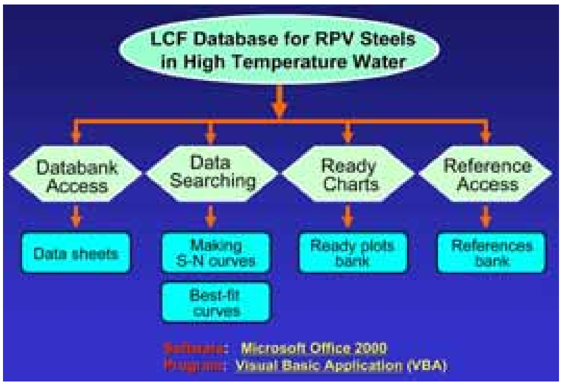


図 1　データベースの概略

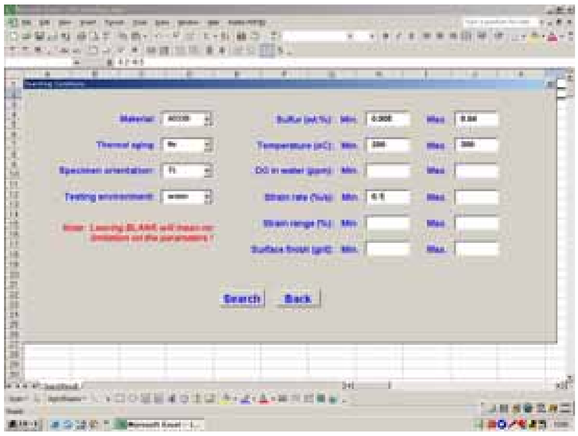


図 2　検索条件の入力例

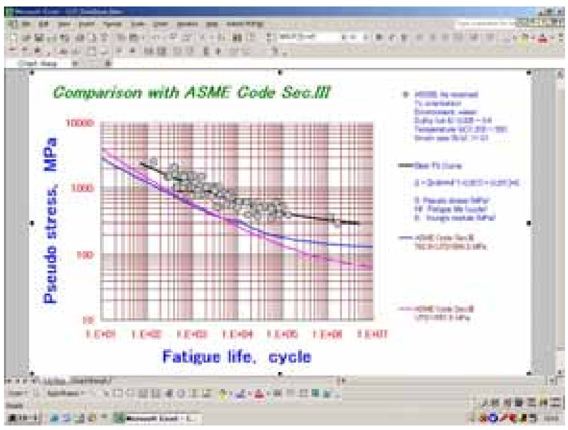


図 3　図表データの例

3. センター便り

高効率発電用材料に関する MPA-IfW-NIMS ワークショップ参加報告

蒸気温度と圧力を高めた超々臨界圧(USC)火力発電を中心とした高効率の発電用材料に関するワークショップ(International Workshop on Performance and Requirements of Structural Materials for Modern High Efficient Power Plants)が、平成17年9月6、7日にドイツ南西部、フランクフルトの約30km南に位置するダルムシュタットで開催されました。本ワークショップは超鉄鋼研究センターおよび材料基盤情報ステーションがシュツットガルト大学材料試験研究所(MPA Stuttgart)ならびにダルムシュタット工科大学材料試験所(IfW Darmstadt)と締結している研究協力に関する覚書に基づくもので今回が5回目となります。

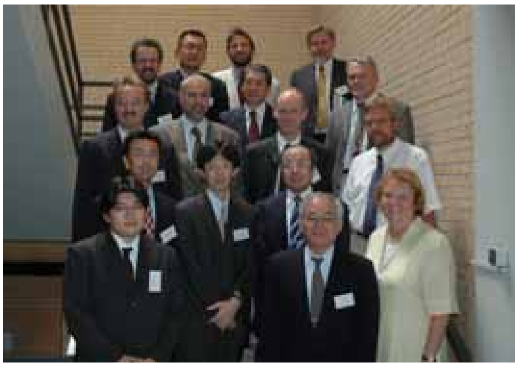
大幅な発電効率向上を可能とする蒸気温度650～700℃超級USC発電プラント実現のために必要となる高強度高温構造部材に関して、高Cr耐熱鋼を中心にオーステナイト耐熱鋼・Ni基耐熱合金を含め、その材料特性とニーズを焦点に議論が行われました。発表は欧州から10件（内、MPAおよびIfWから6件）、日本から11件（内、NIMSから8件）の計21件、参加者はドイツを中心に欧州から約70名、日本からは14名の計80名強でした。

講演は①新耐熱鋼の開発・最適化・キャラクタリゼーション、②ボイラ構造体としての設計・挙動と損傷計測、③溶接部の破壊と長時間挙動およびクリープデータ評価、の3セッションで行われ、欧州からはCOST522プロジェクトを継承して2004年度から始まったCOST536プロジェクトにおける高Cr耐熱鋼開発の展望、既開発先進9Cr耐熱鋼の組織解析と組織変化のモデリング、高Cr耐熱鋼溶接継手のクリープ強度評価、IfWで実施しているクリープ破断データ評価とクリープ変形モデリング、高温構造物のクリープき裂進展評価などに関する発表が行われました。また、日本からは国内における高Crおよびオーステナイト耐熱鋼・Ni基耐熱合金の開発状況、NIMS開発高ボロン9Cr耐熱鋼の組織とクリープ強度および溶接継手におけるTypeIV破壊抑制機構、既開発先進高Cr耐熱鋼の析出挙動と長時間組織安定性、大径溶接鋼管・溶接継手の実体内圧クリープ試験と余寿命評価などに関する発表があり、活発な議論が行われました。材料開発、長時間クリープデータとその解析に関しては日本のポテンシャルの高さを再認識しましたが、欧州では650～700℃級USC実現に向けてCOST、Thermieなど国家・欧州レベルのプロジェクトを推進しており、日本においてもその必要性を痛感致しました。また、研究面ではクリープや組織変化のモデリングに関する研究も活発に行われているのが印象的でした。

ライン川を遠方に見下ろす郊外の古城で行われた懇親会では本場ドイツのビールや白ワインを片手に「Cheers!」「Prost!」「Kanpai（乾杯）!」とグラスを重ね、欧州の第一線の耐熱鋼・クリープ研究者達と交流を深めました。今後も、特にMPA、IfWとは研究協力・情報交換を通じてさらに連携を深め、本分野の研究を推進して世界的に取り組みがなされている火力発電プラントの高効率化に貢献していきたいと考えています。

最後に、本ワークショップの開催に多大な御尽力を頂いたProf. BergerをはじめとするIfW Darmsradtのスタッフの皆様に深く感謝申し上げます。次回、本ワークショップは2007年3月にNIMSで開催される予定です。

(耐熱グループ　仙波潤之)


発表者と IfW Darmstadt の Prof. Berger　(前列右端)


懇親会会場からの風景

10月の出来事・行事		今後の予定	
H17.10.2-5	6th Int'l Special Emphasis Symposium on Superalloys 718, 625, 706 and Derivatives（ピッツバーグ、米国）	H17.11.2-4	International Conference on Super-high strength steels（ローマ、イタリア）
H17.10.17-19	Int'l Symposia on Lead and Zinc Processing 2005 (Kyoto: Pb &Zn'05)（京都テルサ）	H17.11.8-10	HSLA Steels'05　&　ISUGS 2005（海南島、中国）