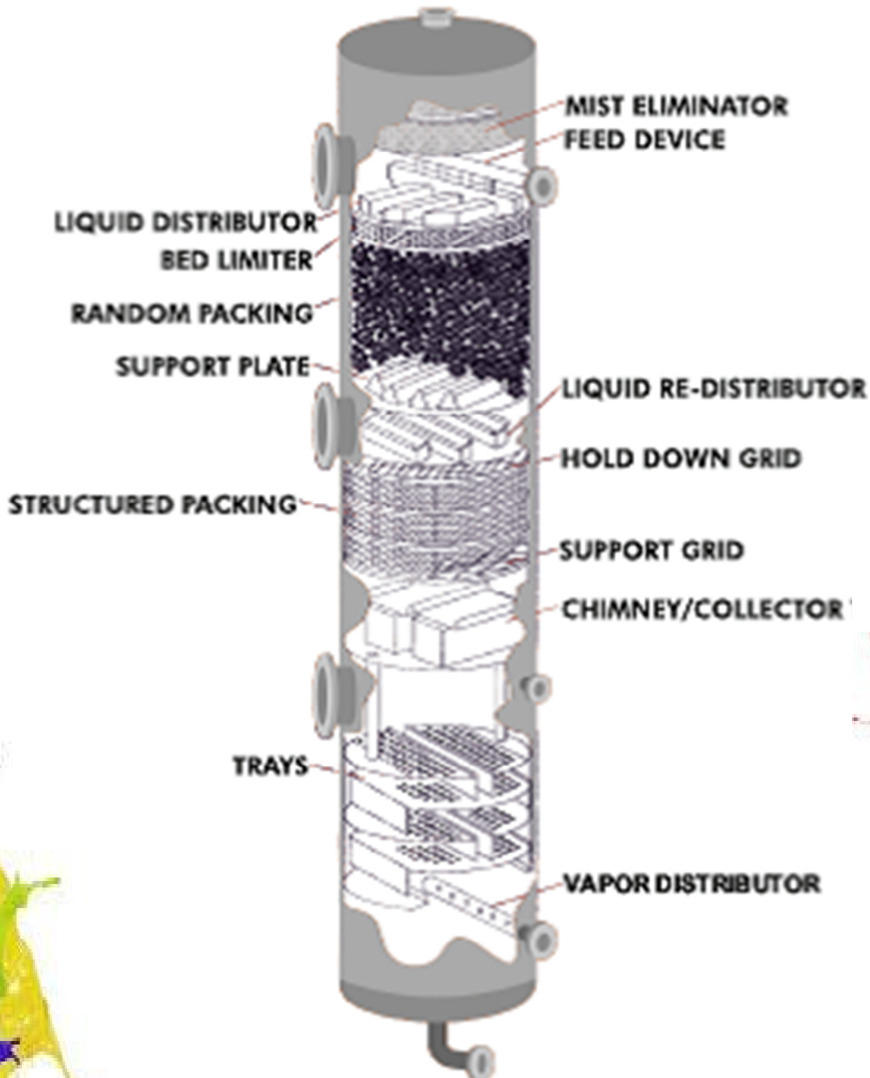
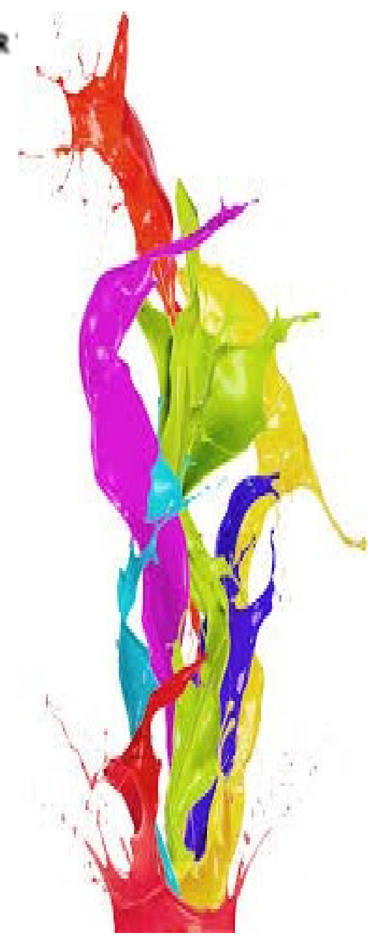
Pressure Vessel Newsletter

Volume 2014, March Issue





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In this issue…

REGULAR FEATURES

For any queries regarding the newsletter, please write to rtiwari123@gmail.com or call at +91 98109 33550

Photograph on the cover is provided by Kevin Enterprises.

From The Editor's Desk:

Welcome to the March 2014 issue of the newsletter. As is evident from the cover page, this is the time to celebrate colors. The festival of colors, Holi as it is known in India, is a free for all carnival. The festival represents, as all festivals do, a symbolic victory of good over evil. Holi also ushers in the spring season, and thus celebrates agriculture, good spring harvest and fertile land.

There is another event of historic proportions soon to be underway in India. Elections to the national parliament, held once every five years, will commence on April 7th and come to close on May 12th. These elections are hailed as being very important for the Indian economy which, in very near future, is tipped to be much larger than its present size. It will create new markets in almost all industries including those where pressure vessels will play a big role.

Where is the new market going to come from? To understand the answer to that question one needs to understand the demographic dividend that India is currently sitting on. Demographic dividend, put very simply, is the population under age of 25 years that is not in the job market yet but is expected to enter very soon. And that population is in excess of 600,000,000. Yes, you read it right. That is 600 million which if provided proper opportunities can be big producers as well as consumers of goods and services.

Which brings us back to the elections. And what the next government decides to do with the surge of people looking for employment in the not too distant future. Will it create the right environment so that the new entrants will flourish and help reap the demographic dividend? Or will it lead to large pool of unemployed men and women that will deplete the existing resources and become a demographic liability? Only time will tell. Businesses, however, must be prepared to tap into the huge opportunity and position themselves accordingly. We live in a global world where demographic dividend in one part of the world will create opportunities in other parts as well.

Here is hoping for the demographic dividend…

BASIC INTRODUCTION TO FATIGUE

How Welds Fatigue

Fatigue is the mechanism whereby crack grows in a structure. Growth only occurs under fluctuating stress. Final failure generally occurs in regions of tensile stress when the reduced cross-section becomes insufficient to carry the peak load without rupture.

In welded structures, fatigue cracks will almost certainly start to grow from welds, rather than other details, because:

- Most welding processes leave minute metallurgical discontinuities from which cracks may grow. As a result, the initiation period, which is normally needed to start a crack in plain wrought material, is either very short or non-existent. Cracks therefore spend most of their life propagating, i.e. getting longer.
- Most structural welds have a rough profile. Sharp changes of direction generally occur at the toes of butt welds and at the toes and roots of fillet welds (see Figure 1). These points cause local stress concentrations of the type shown in Figure 2. Small discontinuities close to these points will therefore react as though they are in a more highly stressed member and grow faster.

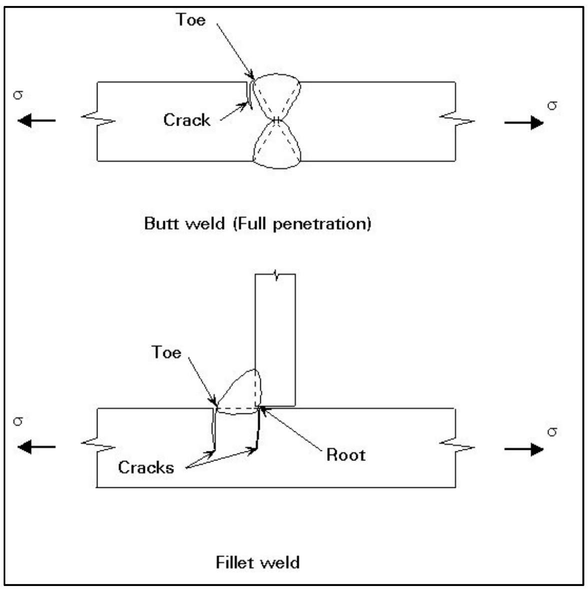

Figure 1: Local Stress Concentrations at Welds

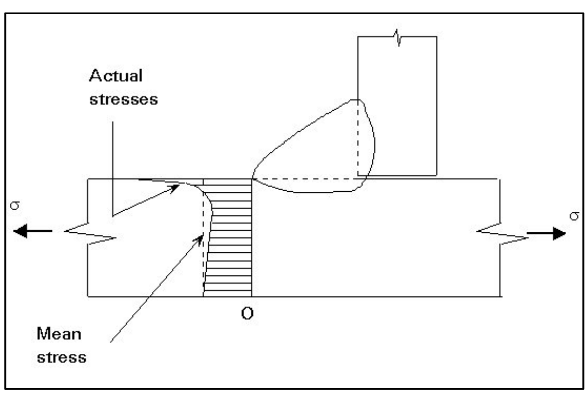

Figure 2: Typical Stress Distribution at Weld Toe

The study of fracture mechanisms shows that the growth rate of a crack is proportional to the square root of its length, given the same stress fluctuation and a degree of stress concentration. For this reason, fatigue cracks spend most of their life as very small cracks which are hard to detect. Only in last stages of life does the crack start to cause a significant loss of cross-section area, as shown in Figure 3. This behavior poses problems for in-service inspection of structures.

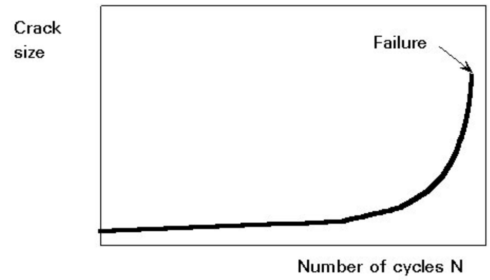

Figure 3: Typical Crack Growth Curve

Fatigue Strength

The fatigue strength of a welded component is defined as the stress range ($\Delta\sigma_R$) which fluctuating at constant amplitude causes failure of the component after a specified number of cycles (N). The stress range is the difference between the maximum and minimum points in the cycle (see Figure 4). The number of cycles to failure is known as the endurance or fatigue life.

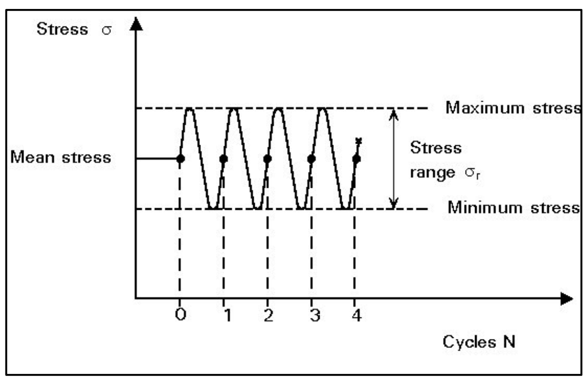

Figure 4: Constant Amplitude Stress History

For practical design purposes, there are two main factors which affect the fatigue life of a detail, namely:

- The stress range ($\Delta\sigma_R$) at the location of crack initiation. There are special rules for calculating this range.
- The fatigue strength of the detail. This strength is primarily a function of the geometry and is defined by the parameter ‘a’ which varies from joint to joint.

The fatigue life (N), or endurance, in number of cycles to failure can be calculated from the expression:

$$\mathrm{N} = \mathrm{a}/\Delta\sigma_\mathrm{R}^\mathrm{m}, \text{ or}$$

$$\log \mathrm{N} = \log \mathrm{d} - \mathrm{m}\log \Delta\sigma_\mathrm{R}$$

where m is a constant. For most welded details, m is equal to 3. Predictions of life are therefore particularly sensitive to accuracy of stress prediction.

The expression linking N and $\Delta\sigma_\mathrm{R}^\mathrm{m}$ can be plotted on a logarithmic scale as a straight line, and is referred to as an S-N curve. An example is shown in Figure 5. The relationship holds for a wide range of endurance. It is limited at low endurance end by static failure when the ultimate material strength is exceeded. At endurances exceeding about 5-10 million cycles, the stress ranges are generally too small to permit propagation under constant amplitude loading. This limit is called the non-propagating stress ($\Delta\sigma_D$). Below this stress range, cracks will not grow.

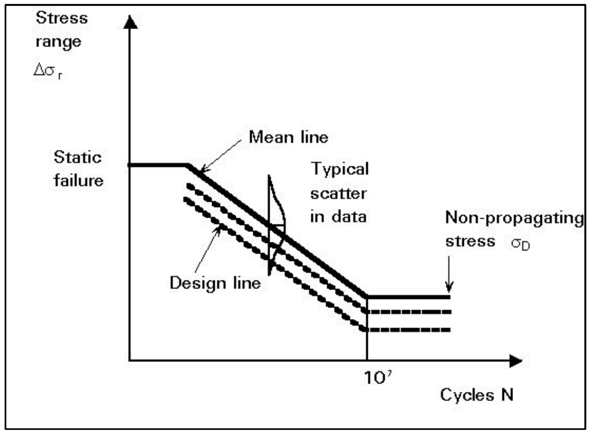

Figure 5: Typical S-N Curve for Constant Amplitude Tests

For design purposes, it is usual to use design S-N curves which give fatigue strengths about 25% below the mean failure values, as shown in Figure 5. 'a' is used to define these lines.

In non-welded details, the endurance is reduced as the mean stress becomes more tensile. In welded details, the endurance is not usually reduced in those circumstances. This behavior occurs because the weld shrinkage stresses (or residual stresses), which are locked into the weld regions at fabrication, orten attain tensile yield. The crack cannot distinguish between applied and residual stress. Thus, for the purpose of design, the S-N curve always assumes the worst, i.e. that the maximum stress in the cycle is at yield point in tension. It is particularly important to appreciate this point as it means that fatigue cracks can grow in arts of members which are nominally "in compression".

The rate of crack growth is not significantly affected by variations in proof stress or ultimate tensile strength within the range of low alloy steels used for general structural purposes. These properties only affect the initiation period, which, being negligible in welds, results in little influence on fatigue life. This behavior contrasts with the fatigue of non-welded details where increased mechanical strength generally results in improved fatigue strength, as shown in Figure 6.

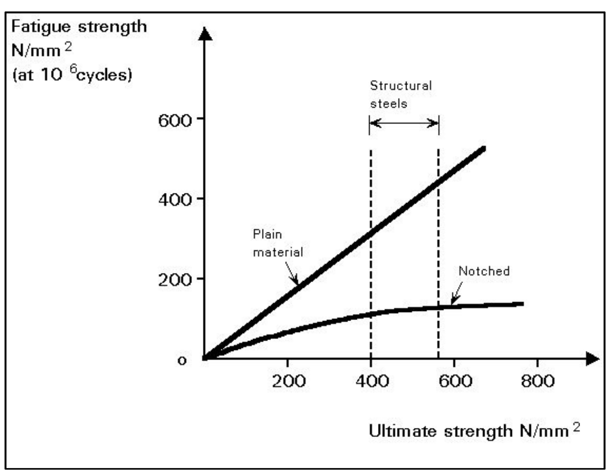

Figure 6: Effect of Mechanical Strength

Classification of Details

The fatigue strength parameter (K_2) of different welded details varies according to the severity of the stress concentration effect. As there are a wide variety of detail in common use, details with similar K_2 values are grouped together into a single detail class and given a single K_2 value. For the most commonly used details, it has been found convenient to divide the results into 14 main classes. These classes can be plotted as a family of S-N curves shown in Figure 7. The difference in stress range between neighbouring curves is usually between 15 and 20%.

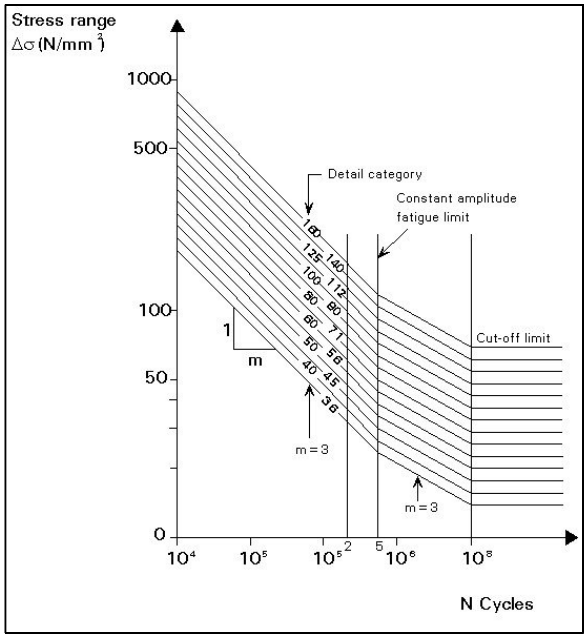

Figure 7: Family of Design S-N Curves

Stress Parameters for Fatigue

<u>Stress Area</u>

The stress areas are essentially similar to those used for static design. For a crack starting at a weld toe, the cross-section of the member through which propagation is used. For a crack starting at the root, and propagating through the weld throat, the minimum throat area is used.

<u>Calculation of Stress Range</u>

The force fluctuation in the structure must be calculated elastically. No plastic redistribution is permitted.

The stress on the critical cross section is the principal stress at the position of the weld toe (in case of weld toe cracks). Simple elastic theory is used assuming plane sections remain plane (see Figure 8). The effect of the local stress concentration caused by the weld profile is ignored as this is already catered for by the parameter ‘d’ which determines the weld class.

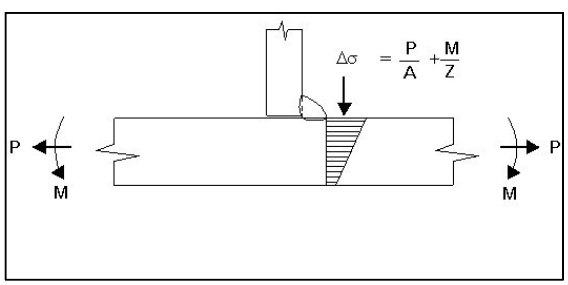

Figure 8: Design Stress Parameter for Cracks Propagating in Parent Material

In case of throat failures, the vector sum of the stresses on the weld throat at the position of highest vector stress along the weld is used, as in static design.

<u>Effects of Geometrical Stress Concentrations and Other Effects</u>

When a member has large changes in cross-section, e.g. at access holes, there will be regions of stress concentration due to the change of geometry. In static design, the stresses are based on the net area as plastic redistribution will normally reduce these peaks at ultimate load. With fatigue this is not so, and if there is a welded detail in the area of the geometrical stress raiser the true stress must be used, as shown in Figure 9.

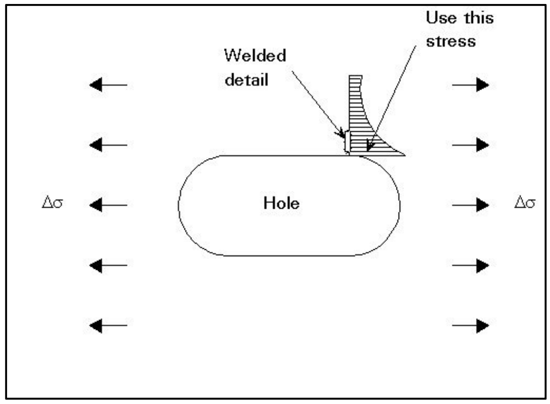

Figure 9: Design Stress Parameter for Cracks Initiating at Geometrical Stress Concentrations

Loadings for Fatigue

The designer's objective is to anticipate the sequence of service loading throughout the structure's life. The magnitude of the peak load, which is vital for static design purposes, is generally of little concern as it only represents one cycle in millions. The sequence is important because it affects the stress range, particularly if the structure is loaded by more than one independent load system.

For convenience, loadings are usually simplified into a load spectrum, which defines a series of bands of constant load levels, and the number of times that each band is experienced, as shown in Figure 10.

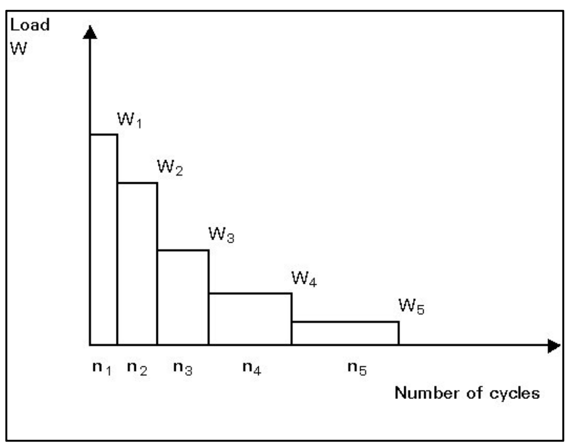

Figure 10: Typical Load Spectrum for Design

Slender structures, with natural frequencies low enough to respond to the loading frequency, may suffer dynamic magnification of stress. This magnification can shorten the life considerably.

<u>Cycle Counting</u>

In practice, most stress histories in real structures are of the variable amplitude type, shown in Figure 11, as opposed to the constant amplitude shown in Figure 4. Such histories pose problem in defining the number and amplitude of the cycles.

The first step is to break the sequence into a stress spectrum as shown in Figure 11 using a cycle counting method. There are various methods in use. The two most used are the Rainflow Method and the Reservoir Method.

Calculation of Damage

Under variable amplitude loading the life is estimated by calculation of the total damage done by each cycle in the stress spectrum. In practice the spectrum is simplified into a manageable number of bands as shown in Figure 12. The damage done by each band in the spectrum is defined as n/N where n is the required number of cycles in the band during the design life and N is the endurance under that stress range (see Figure 13).

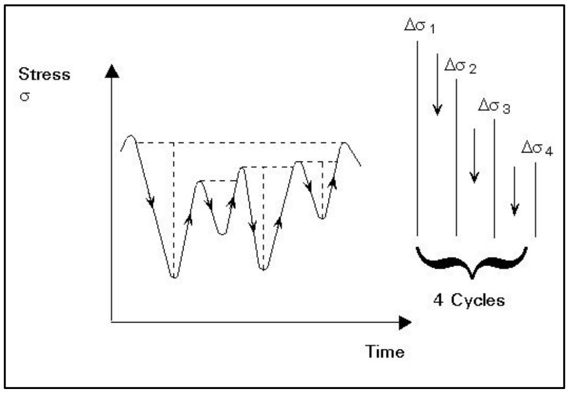

Figure 11: Variable Amplitude Stress History and Resulting Stress Spectrum

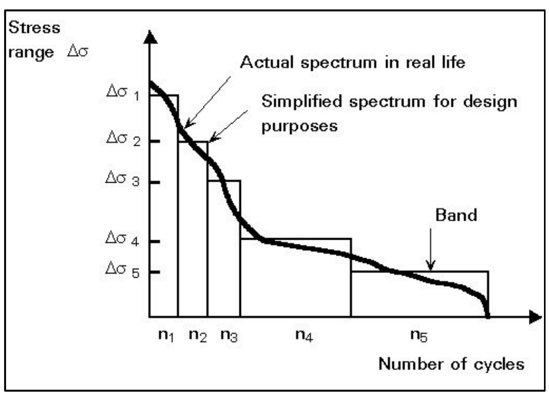

Figure 12: Simplification of Stress Spectrum

If the failure is to be prevented before the end of the specified design life, the Palmgreen-Miner's Rule must be complied with. This rule states that the damage done by all bands together must not exceed unity, i.e.:

$$\frac{n_1}{N_1} + \frac{n_2}{N_2} + \cdots \frac{n_n}{N_n} \leq 1$$

Concluding Summary

- Fatigue and static failure (whether by rupture or buckling) are dependent on very different factors, namely:
  - Fatigue depends on the whole service loading sequence (not one extreme load event)
  - Fatigue of welds is not improved by better mechanical properties
  - Fatigue is very sensitive to geometry of details

- Fatigue requires more accurate prediction of elastic stress
- Fatigue makes more demands on workmanship and inspection

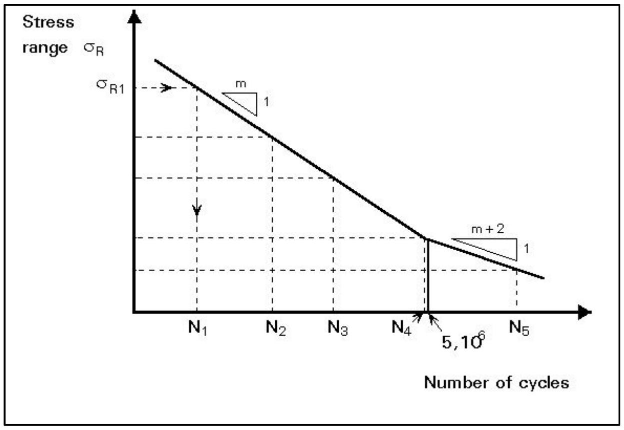

Figure 13: Determination of Endurance for Each Band

- It is therefore important to check early in design whether fatigue is likely to be critical. Acceptable margins of safety against static collapse cannot be relied upon to give adequate safety against fatigue.
- Areas with high live/ dead stress ratio and low category 36 details should be checked first. The check must cover any welded attachment to a member, however insignificant, and not just the main structural connections. [Note that the Weld Category details are not discussed in this write up. The reader is requested to refer to the original article for Weld Category details]
- If fatigue is critical, then the choice of details will be limited. Simplicity of detail and smoothness of stress path should be sought.
- Be prepared for fatigue critical structures to cost more.

Source: *ESDEP (The European Steel Design Education Programme) was published in 1993. This is the first of 15 lectures on Fatigue. The content has been edited and slightly condensed.*

TRAINING ANNOUNCEMENT

DESIGN & FABRICATION OF PRESSURE VESSELS: ASME SECTION VIII, DIVISION 1

Pressure vessels, along with tanks, are the workhorses for storage and processing applications in the chemical, petroleum, petrochemical, power, pharmaceutical, food and paper industries. ASME BPV, Section VIII, Div. 1 Code is used as a standard for the design and fabrication of pressure vessels by most companies across the world.

We would like to announce training course for "Design and Fabrication of Pressure Vessels: ASME Section VIII, Div. 1" on April 7-9, 2014 at Chennai, and on April 10-12 at Coimbatore. This course provides the information that will help you understand the ASME requirements for the design and fabrication of pressure vessels. The course material follows the contents of 2010 edition of the code, and is replete with worked examples covering important aspects of pressure vessel construction. This hands-on learning will allow you to master in 3 days what would otherwise take up to a year or more of on-job training.

The contents of the training course will be as follows:

- Introduction to Boiler and Pressure Vessel Code
- Materials of Construction
- Low Temperature Operation
- Joint Efficiencies
- Design of Components
- Openings and Reinforcements
- Fabrication, Inspection and Tests
- Markings and Reports
- Tall Towers and Pressure Vessel Supports
- Nozzle Loads
- Fatigue Analysis
- Introduction to ASME Section VIII, Division 2

15% Special Holi Discount

The instructor, Ramesh Tiwari, is internationally recognized specialist in the area of pressure vessels, heat exchangers, materials, and codes and standards. He holds Bachelor's and Master's degrees in mechanical engineering from universities in India and United States. He is also a registered Professional Engineer in the State of Maryland in the United States. Mr. Tiwari is a member of ASME Boiler & Pressure Vessel, Section VIII Subgroup on Heat Transfer Equipment, and a member of ASME International Working Group on B31.1 for Power Piping in India. In this capacity, he has made invaluable contribution in resolving technical issues in compliance with the ASME codes for Code users. Mr. Tiwari has over 24 years of design engineering experience on a variety of projects spanning industries such as oil & gas, power, nuclear, chemical, petrochemical, pharmaceutical, food etc. He has provided engineering advice and code interpretations to senior management and guidance to several companies he has worked for in the US, India and Germany. He has initiated and implemented numerous innovative ideas to improve working process and quality, and developed and conducted training programs for peers as well as clients. Mr. Tiwari is an approved pressure vessel instructor at NTPC, a premier thermal power generating company in India and at several other companies, both public and private.

Registration fee for the training course is Rs. 25,300 for professionals and Rs 16,000 for students (inclusive of service tax). Discount of 15% is available for group registration of 2 or more participants. Special Holi discount of 15% is available if registration is done on or before March 21st. Registration fee includes training, a collection of articles on design and fabrication of pressure vessels, copy of the presentation, certificate from CoDesign Engineering, and beverages and lunch on all days. It excludes travel to and from New Delhi, accommodation, and meals and beverages other than those provided during the course. We invite you to make nominations.

In case of any queries, including the registration process, please email at learning@codesignengg.com, or call at +91 98109 33550.

DEFINITION OF WHAT IS MEANT BY CAST IRON, WROUGHT IRON AND STEEL

TATA Steel

Cast iron, wrought iron and steel are all essentially alloys of iron and carbon.

Although the actual situation is much more complex, cast iron, wrought iron and steel can all be thought of as alloys, principally of iron and carbon. To complicate matters, though, it is worth mentioning that there are no precise definitions of the relative makeup of the three types of steel.

Iron is extracted from naturally occurring ores and we can think of these ores as providing the source material, Iron Oxide (FeO).

In the early days of iron and steel production, iron oxide ores were mined but the sources of iron oxide have now been worked out.

When iron oxide is heated at high temperatures it becomes transformed into iron.

When iron oxide is heated at high temperatures of 1600 to 3000°F, the oxide is reduced to the metal and the resulting reaction can be expressed as:

Iron Oxide + Carbon *heated along with a blast of air yields* Iron + Carbon Monoxide (a gas released into the air)

i.e. $FeO + C ==> Fe + CO$

In practice, this process does not yield pure iron, but an impure product called pig iron. This pig iron contains impurities such as Iron Carbide (Fe_3C) which make the material hard and brittle. It is, however, the raw material from which cast iron, wrought iron and steel can be produced.

Cast iron is the material produced by remelting this iron (known as pig iron), possibly along with some scrap iron.

The remelting of pig iron, and scrap iron, whilst blowing air into the molten mass until the carbon content is between 2.4 and 4.0% produces contemporary cast iron which can exist in two forms: grey (Graphite) cast iron and white (Iron Carbide) cast iron.

In the early days of cast iron production, it was difficult to control the level of carbon and other impurities such as sulphur (which has a particularly detrimental effect on the properties of iron). This means that the strength and properties of the material were very much a hit-and-miss affair. Nor was it possible to be sure that the molten material had been able to flow through all of the mould before setting. Consequently, the early cast iron structural elements were often load tested before being used in a building. And putty was sometimes used to plug holes in large section such as circular columns.

Wrought iron is achieved by simple reprocessing of cast iron.

The strength deficiencies of cast iron were eventually partly addressed by the development of a process termed "puddling". This involved reheating cast iron and manually mixing air in with the molten mass. Because of the nature of the puddling process the volumes that could be produced by this process at any one time were small. This, in turn, limited the size of structural components that could be made of this type of iron.

The material produced this way had reasonably high tensile strengths and was much more ductile than cast iron.

The process of producing wrought iron improves the tensile strength. This made it suitable for beams, and the ductility meant that its behaviour in column elements was more predictable than cast iron. However, its use in columns was rare due to the comparative cost of cast and wrought iron.

The production of true wrought iron in Britain ceased in 1973, so what is marketed today under that name is either old material recycled or a type of mild steel.

The invention of the Bessemer process allowed the oxidization process after remelting to be carefully controlled and the carbon content could therefore be held at a particular level, providing good tensile strength and ductility.

In what we refer to today as steel the carbon content will typically be below 1%. For most structural steel the actual value will be in the region of 0.2%. It is the addition of elements such as silicon and manganese that allow the carbon levels to be controlled with some accuracy, and the manganese also has the beneficial effect of neutralising the otherwise harmful effects of sulphur.

The resulting material has equally high tensile and compressive strengths along with a high degree of ductility.

There is a wide range of steels which can be classified in various ways.

The terminology relating to the classification of different steel types is not precise. Broadly speaking steels are described in the following table.

Mild Steels	Up to 0.3% Carbon
Medium Carbon Steels (or simply Carbon Steels)	0.3 to 0.6% Carbon
High Carbon Steels	Over 0.6% Carbon

To form steel into the kind of sections used in structures ingots are heated and then forged or rolled repeatedly, each repetition getting closer to the desired cross sectional shape.

Source: *TATA Steel*

API 510 PRESSURE VESSEL INSPECTOR

API Authorized Pressure Vessel Inspectors must have a broad knowledge base relating to maintenance, inspection, repair, and alteration of pressure vessels. The API Authorized Pressure Vessel Inspector Certification Examination is designed to determine if individuals have such knowledge. The following is a list of specific topics in which the API Authorized Pressure Vessel Inspector should be knowledgeable.

I. THICKNESS MEASUREMENTS, INSPECTION INTERVALS AND VESSEL INTEGRITY

API Authorized Pressure Vessel Inspectors should be able to check and perform calculations relative to in-service deterioration, repairs, rerates, or alterations.

The following categories describe the minimum necessary knowledge and skills:

1. <u>CORROSION RATES AND INSPECTION INTERVALS</u>

   The Inspector should be able to take inspection data and determine the internal and external inspection intervals. He must be able to calculate:

   - Metal Loss (including corrosion averaging) (API-510, Para 7.4)
   - Corrosion Rates (API-510, Para 7.1)
   - Remaining Corrosion Allowance (API-510, Para7.1)
   - Remaining Service Life (API-510, Para, 7.2)
   - Inspection Interval (API-510, Section 6)

2. <u>JOINT EFFICIENCIES</u>

   The inspector must be able to determine the joint efficiency "E" of a vessel weld. He should be able to determine:

   - Weld Joint Categories
   - Type of radiography (full, spot, or none) performed basis the nameplate markings (RT-1, RT-2, etc.);
   - Joint efficiency by reading Table UW-12;
   - Joint efficiency for seamless heads and vessels Sections per UW-12 (d); and
   - Joint efficiency for welded pipe and tubing per UW-12 (e)

3. <u>STATIC HEAD</u>

   The inspector must be able to compensate for the pressure resulting from static head. All static head will be based upon a Specific Gravity of 1.0. The inspector should be able to:

   - List the static head/pressure conversion factor (0.433 psi/ft);
   - Know the difference between vessel MAWP and vessel part MAWP;
   - Calculate static head pressure on any vessel part;
   - Calculate total pressure (MAWP + static head) on any vessel part;
   - Calculate maximum vessel MAWP given vessel parts MAWP and elevations

4. <u>INTERNAL PRESSURE</u>

   The inspector should be able to determine:

   - The required thickness of a cylindrical shell based on circumferential stress given a pressure;
   - The vessel part MAWP for a cylindrical shell based on circumferential stress given a metal thickness;
   - The required thickness of a head (ellipsoidal, and hemispherical) given a pressure;
   - The vessel part MAWP for a head (ellipsoidal, and hemispherical) given a metal thickness;
   - Whether a head (ellipsoidal or hemispherical) meets Code requirements given both pressure and metal thickness

5. <u>EXTERNAL PRESSURE</u>

   The inspector should be able to:

   - Calculate the maximum allowable external pressure; and

- Calculate whether a cylindrical shell or tube meets Code design for external pressure given a wall thickness and a pressure

6. PRESSURE TESTING

   The inspector should be able to:

   - Calculate a test pressure compensating for temperature.
   - Be familiar with the precautions associated with hydrostatic and pneumatic testing, such as minimum test temperatures, protection against overpressure etc.
   - Be familiar with all steps in a hydrotest procedure
   - Be familiar with all steps in a pneumatic test procedure

7. IMPACT TESTING

   - The inspector should understand impact testing requirements and impact testing procedure
   - The inspector should be able to determine the minimum metal temperature of a material which is exempt from impact testing (UG-20 (f), UCS-66, UCS-68(c).)

8. WELD SIZE FOR ATTACHMENT WELDS AT OPENINGS

   The inspector must be able to determine if weld sizes meet Code requirements. The inspector should be able to:

   - Convert a fillet weld throat dimension to leg dimension or vice versa, using conversion factor (0.707); and
   - Determine the required size of welds at openings (UW-16).

9. NOZZLE REINFORCEMENT

   The inspector should:

   - Understand the key concepts of reinforcement, such as replacement of strength removed and limits of reinforcement.
   - Credit can be taken for extra metal in shell and nozzle
   - Be able to calculate the required areas for reinforcement or check to ensure that a designed pad is large enough.
   - Be able to compensate for corrosion allowances.
   - Weld strength calculations are excluded.

II. WELDING PROCEDURE AND QUALIFICATION EVALUATION BASED ON ASME BOILER AND PRESSURE VESSEL CODE, SECTION IX

A. WELD PROCEDURE REVIEW

   The inspector should have the knowledge and skills required to review a Procedure Qualification Record and a Welding Procedure Specification and to be able to determine the following:

   - Determine if procedure and qualification records are in compliance with applicable ASME Boiler and Pressure Vessel Code and any additional requirements of API- 510
   - Determine if all required essential and non-essential variables have been properly addressed.
   - Determine that the number and type of mechanical tests that are listed on PQR are the proper tests, and whether the results are acceptable.

B. ASME Section VIII, Div. 1 and API-510: GENERAL WELDING REQUIREMENTS:

   1. ASME Section VIII, Div. 1

      The inspector should be familiar with and understand the general rules for welding in ASME Section VIII, Div. 1, Parts UW and UCS such as:

      - Typical joints and definitions
      - Weld sizes
      - Restrictions on joints
      - Maximum allowable reinforcement

   - Inspection requirements
   - Heat treatment

2. API 510

   The inspector should be familiar with and understand any rules for welding in API-510. Any rules for welding given in API-510 shall take precedence over those covering the same areas in ASME, Section VIII, Div. 1.

III. NONDESTRUCTIVE EXAMINATION

ASME Section V, Nondestructive Examination

A. Article 1, General Requirements

The inspector should be familiar with and understand;

- The Scope of Section V,
- Rules for use of Section V as a referenced Code,
- Responsibilities of the Owner / User, and of subcontractors,
- Calibration,
- Definitions of "inspection" and examination",
- Record keeping requirements.

B. Article 2, Radiographic Examination

The inspector should be familiar with and understand;

- The Scope of Article 2 and general requirements,
- The rules for radiography as typically applied on pressure vessels such as, but not limited to:
  - Required marking
  - Type, selection, number, and placement of IQI's,
  - Allowable density
  - Control of backscatter radiation
  - Location markers
- Records

C. Article 6, Liquid Penetrant Examination, including Mandatory Appendices II and III

The inspector should be familiar with and understand:

- The Scope of Article 6,
- The general rules for applying and using the liquid penetrant method such as, but not limited to;
  - Procedures
  - Contaminants
  - Techniques
  - Examination
  - Interpretation
  - Documentation and
  - Record keeping

D. Article 7, Magnetic Particle Examination

The inspector should be familiar with and understand the general rules for applying and using the magnetic particle method such as, but not limited to;

- The Scope of Article 7,
- General requirements such as but not limited to requirements for:
  - Procedures
  - Techniques
  - Calibration
  - Examination
  - Interpretation

- Documentation and record keeping

E. Article 23, Ultrasonic Standards

The inspector should be familiar with and understand;

- The Scope of Article 23
- The general rules for applying and using the Ultrasonic method
- The specific procedures for Ultrasonic thickness measurement as contained in paragraph 7.

<u>ASME Section VIII, Div. 1 and API-510</u>

General nondestructive examination requirements:

- ASME Section VIII, Div. 1: The inspector should be familiar with and understand the general rules for NDE (UG, UW, Appendices 4, 6, 8, and 12)
- API 510: The inspector should be familiar with and understand the general rules for NDE in API-510.

Source: *This information has been taken from an API publication that provides a list of topics in which API Authorized Pressure Vessel Inspector should be knowledgeable.*

NEWS AND EVENTS

Intergraph® Acquires GT STRUDL® from the Georgia Tech Research Corporation

Intergraph® Process, Power & Marine, part of Hexagon and the world's leading provider of enterprise engineering software to the process, power and marine industries, announced today the acquisition of GT STRUDL®, a leading computer-aided structural engineering (CAE) software system, from the Georgia Tech Research Corporation of Atlanta, Ga. As part of the acquisition, the 10 skilled staff and management team members of the Computer-Aided Structural Engineering Center (CASE Center) have joined Intergraph. GT STRUDL is widely used in a variety of industries such as nuclear power and nuclear defense industries, conventional power generation, general plant structures, offshore structures, marine applications, general civil engineering and infrastructure structures.

In the United States nuclear industry, GT STRUDL is widely used by major companies in the design, maintenance and upgrading of safety-critical structures such as turbine buildings, boiler buildings, equipment support structures, pipe support systems and other related civil engineering structures. The acquisition of GT STRUDL will strengthen Intergraph's existing suite of engineering analysis solutions for the power, process and offshore industries.

Developed by the CASE Center within the School of Civil and Environmental Engineering at Georgia Institute of Technology, GT STRUDL uniquely integrates graphical modeling, frame and finite element linear and nonlinear static and dynamic analysis, structural frame design, graphical analysis and design result display and structural database management all into a powerful, menu-driven information processing system.

To view this press release, please visit the Intergraph press room at:
www.intergraph.com/assets/pressreleases/2014/02-10-2014

13th Turkish International Oil & Gas Conference

April 9-10, 2014
Ankara, Turkey

Offshore Technology Conference 2014

Reliance Center, May 5 – 8, 2014
Houston, Texas

2014 ASME Pressure Vessel and Piping Conference

Hyatt Regency Orange County, July 20 -24, 2014
Annaheim, California

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