2012 IEEE Colloquium on Humanities, Science & Engineering Research (CHUSER 2012), December 3-4, 2012, Kota Kinabalu, Sabah, Malaysia

Post-processor Program for ISO – 19902 Tubular Joints Design

Nelson Julio Cossa
Masters Student, Civil Engineering Department
Universiti Teknologi PETRONAS
Bandar Seri Iskandar, 31750, Perak – Malaysia
njcossa@gmail.com

Narayanan Sambu Potty & Mohd Shahir Liew
Lecturers, Civil Engineering Department
Universiti Teknologi PETRONAS
Bandar Seri Iskandar, 31750, Perak – Malaysia

Abstract— **This paper, presents a postprocessor subprogram for design of the tubular joints in ISO-19902 code. The subprogram was developed using Mat Lab and Net-Beans Java platform. Although the current design software provides extensive structural design checks, complementary analysis are, in some cases, necessary. Therefore, this subprogram is intended aid the engineers conduct complementary checks efficiently. Comparison of results showed that the unity check ratios obtained by using the post-processor, were consistently lower than SACS' joint can post processor. This paper also presents the design provision for the tubular joint of fixed offshore steel jacket platforms.**

Keywords – post-processor; tubular joints; ISO19902

I. INTRODUCTION

Fixed offshore steel jacket platforms consist two main parts, namely, the topside on which the operations take place, and the substructure, which supports the whole infrastructure. The substructure is built of tubular members welded together to form a tridimensional space frame, i.e. the jacket. Owing to their complex nature, the design of fixed offshore steel jacket platforms is performed with aid of various computer structural analysis programs such as the SACS – Structural Analysis Computer System [1]. These programs consist of set of modules or subroutine programs that interact with each other to execute structural safety checks, based on the design provisions in the international standard like, the American Petroleum Institute, code for design of fixed offshore platforms (API RP2A-WSD). Generally, these structural analysis programs are divided in two main parts, namely, pre-processor and the post-processor.

The pre-processor consists of modules that gather and store information such as the geometry, material and dimensions of the structure, loads and design provisions governing on the structure. Meanwhile, the post-processor consists of the programs that make use of the information obtained by the pre-processor to execute the structural checks and displays the report for posterior interpretation by the engineers.

Although these programs are designed, to produce results that simulate situations that resemble those of the actual structure, the engineers' judgment still plays a vital role in decision-making. Furthermore, there may be situation in which certain structural elements do not satisfy the code checks by the programs, but in fact, the elements might be safe. In these cases of uncertainty, the engineers may be obliged to conduct manual checks, to verify the programs' output. However, it is well known that manual calculations are often tedious and time consuming. This could even get worse if the engineers are not familiar with the design codes that have been recently adopted, such as the ISO-19902.

In recent years, there is a strong urge to adopt the load and resistance design methods, in form of ISO-19902 design code, in the offshore industry. This trend is driven by the belief that ISO-19902 produces uniform safety levels across members of different types (compression, tension, etc.) and different locations in the structure and creates harmonized design practice across the world [2]. The adoption of ISO-19902 means that the structural analysis programs have to be upgraded to incorporate the new provisions of design.

As part of project to calibrate the load and resistance factors for the adoption of ISO-19902 design code of fixed offshore steel jacket platforms in Malaysian waters, it was necessary for the structures to be designed and checked for the code in practice API RP2A-WSD[3][4]. Moreover, compare the results with identical checks for same structure designed using provisions of ISO-19902 [2].

This paper describes the development of a post processor for joint checks for structures designed using ISO-19902. It presents the steps through which the subprogram was developed, and compares the results with the existing SACS program, which contains provisions for joint check for API RP2A design. Note that this mini program is designed to facilitate the conduct of design checks efficiently.

II. TUBULAR JOINTS DESIGN PROVISIONS

A. *General tubular joint characteristics*

Tubular joints are the connections of two or more tubular members that form the jacket structures. A simple tubular joint consists at least of two members namely *chord* and *brace*. The chord is the member on which the other components members are welded, without piercing its walls. The chord is often reinforced by increasing the wall thickness or using stiffeners, and, in most cases, it has larger diameter than the other members. The reinforced section of the chord is referred as the *joint can*. The tubular joint design focuses on evaluating the ability of the joint can to support the loads from the braces. The braces are the members that are connected onto the surface of the chord walls. In some cases, they are also reinforced at the edges. These reinforcements are called stubs.

Tubular joints are usually divided into two categories, namely *Simple joints* and *Complex joints*. Simple joints are those without overlapping of brace members and without the use of gussets, diaphragms, stiffeners, or grout. Meanwhile Complex joints are either ring stiffened, made of cast steel or are internally grouted tubular joints, whose behaviour is radically different from simple unstiffened welded joints [5][6]. Figure 1, illustrates the geometric configuration of the typical tubular joint.

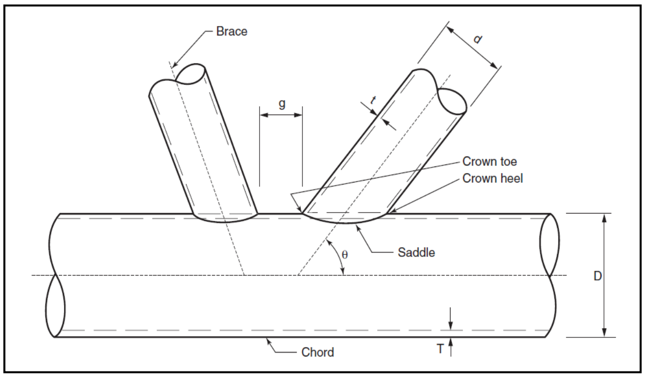

Figure 1. Typical Tubular Joints [5]

Definition of terminologies in Figure 1:

- θ = Brace included angle;
- g = Gap between braces;
- t = Brace wall thickness at intersection;
- T = Chord wall thickness at intersection;
- d = Brace outside diameter;
- D = Chord outside diameter.

The above parameters have been reduced to a number of non-dimensional geometrical ratios, which are used in evaluating the tubular joint strength, as follows:

- $\beta = d/D$
- $\gamma = D/(2T)$
- $\tau = t/T$

B. *Classification of tubular joints*

Typical joints are K, Y/T and X, classified based on their geometrical configuration or load pattern for each load case or both [2].

- K-joint consists of a chord and two braces on the same side of the chord. The components of the axial brace forces normal to the chord balance each other. While the components parallel to the chord add and are reacted by an axial force in the chord.

- Y-joint consists of a chord and one brace. Axial force in the brace is reacted by an axial force and beam shear in the chord.

- X-joint consists of a chord and two braces, one on each side of the chord, where the second brace is a continuation of the first brace. Axial force in one brace is transferred through the chord to the other brace without an overall reaction in the chord.

C. *Basic Design Equations*

Table I shows the different parameters and their limiting ranges, such that the joints are designed and fabricated effectively. Note that β, γ and g/D are non-dimensional ratios.

TABLE I. VALIDFY RANGES FOR PARAMETERS[2]

Parameter	Ranges
β	0.2 – 10
γ	10 – 50
θ	$30^{\circ} - 90^{\circ}$
Fy	≤ 500 MPa
g/D	> -0.6 (for K joints)

The design strength of tubular joints is evaluated for each brace connected to the chord. Therefore, it varies with the geometry and pattern of the loads acting on it. Although the basic strength formulation is similar for all types of joints (Equations 1 and 2), the difference is on the evaluation of the chord load factor (Q_f) and the basic strength factors (Q_u).

$$P_d = \frac{F_y T^2}{\gamma_R \sin\theta} Q_u Q_f \qquad (1)$$

$$M_d = \frac{F_y T^2 d}{\gamma_R \sin\theta} Q_u Q_f \qquad (2)$$

Where:

- P_d - is the design value of the joint axial strength (represents the ability of the joint can to resist the axial loading from the brace);

- M_d - is the design value of the joint bending moment strength (represents the ability of the joint can to resist the bending moment from the brace);

- γ_R - is the partial resistance factor for tubular joints, $\gamma_R = 1.05$.

The determination of the chord load factor (Q_f) and the basic strength factors (Q_u), is given in the ISO-19902 design code [2]. The Q_u depends mainly on the geometry and material properties of the joints. The Q_f takes into account the presence of nominal loads in the chord. The Q_f is attributed a value of one (1), when all the extreme fibers stresses of the chord are in tension [7].

D. *Strength Check*

Tubular joint designed to support the load action from brace, be it axial, bending moment alone, or combined, shall satisfy the following conditions [7]:

$$UC = \left|\frac{P_B}{P_d}\right| + \left(\frac{M_B}{M_d}\right)^2_{IPB} + \left|\frac{M_B}{M_d}\right|_{OPB} \leq 1.0 \qquad (3)$$

Equation 3, applies for all tubular joints. Where:

- UC - is the unity check ratio or joint utilization ratio;
- P_B - is the factored axial force in the brace member;
- M_B - is the factored bending moment in the brace member;
- IPB - represents in-plane bending moments and strengths;
- OPB - represents out-of-plane bending moments and strengths.

III. Program Architecture

The subprogram consists of four stages, namely, user input, parameter validity check, tubular joint strength evaluation, unity checking, and output, as shown in Figure 2. In the input stage, the user inserts design parameters such as the type of joint, diameter and thickness of the chord and brace, angle value, and factored loads acting on brace (axial forces and bending moments).

The parameter checks are executed on the second stage of the subprogram. This validation check is based on the limiting values given in Table I. If these limits are violated, the sub program, displays an error message, highlighting the violation.

In the third stage, the tubular joints strength is evaluated based on Equations 1 and 2. Subsequently these are checked using the Equation 3. If the check is not met, the program will show a message, prompting the user or the engineer to edit the input values, hence redesigning the joint.

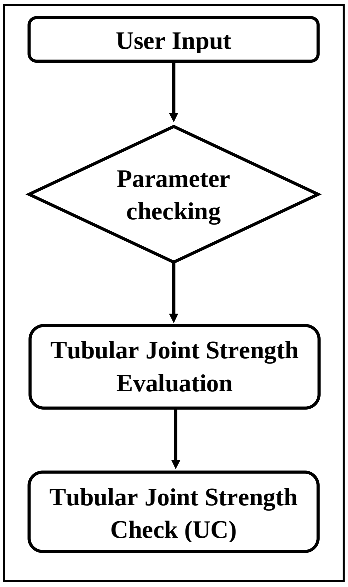

Figure 2. Flowchart of the subprogram

The program was initially, written and tested in Mat Lab. The Java based Graphical User Interface (GUI), as shown in Figure 3, was developed using the Net-Beans IDE [8].

IV. Verification of Program

A platform located in the Malaysian Water of South China Sea was used to verify the output of the program. This platform was installed at a water depth of 71.5 meters. The platform was designed for a 100-year return storm criteria as stated in the API RP2A-WSD 21st Edition. The design properties of the platform are shown in Table II.

TABLE II. Design Properties of Platform

Description	Parameters
Water Depth	71.50 m
Highest Astronomical Tide (HAT)	2.40 m
Lowest Astronomical Tide (LAT)	-0.20 m
100-year return storm surge	0.60 m
100-year return wave height and period	9.90 m and 10.20 sec
100-year return wind (3-second gust)	44.00 m/s
100-year return current	Surface: 1.05 m/s
	Mid-depth: 0.95 m/s
	Bottom: 0.55 m/s

The jacket platform was modeled and structural analyses carried out using the SACS 5.2 software. The linear static design analysis performed were focused on identifying the maximum loading, that is the forces and moment acting on the tubular joints for the given 100-year return storm condition values.

The values of the unity check (UC) ratios, which show the joint utilization of selected tubular joints, are shown in Table III. These values were obtained using the design program, SACS, developed for the API RP2A-WSD (third column) and the proposed subprogram (fourth and last column), which was developed based on the ISO 19902. From these values, it can be observed that the proposed subprogram, generally, produces values that are relatively lower that those obtained using the SACS program. This complies with the theoretical understanding that the ISO 19902 design provisions would produce lower unity check values. That is because, as compared to the API RP2A-WSD the ISO 19902 estimate relatively higher tubular joint strength.

TABLE III. Comparison of UC Ratios from SACS and the Developed Program

Joint No.	Type of Joint	API RP 2A-WSD (SACS)	Subprogram
100	T	0.2470	0.0901
108	T	0.0500	0.0426
115	T	0.0920	0.0766
121	X	0.0290	0.0370
150	X	0.1650	0.1333
169	X	0.4600	0.4340
170	K	0.0400	0.0363
200	K	0.0300	0.0172
202	K	0.0224	0.0094

V. Conclusions

Engineers have relied on the computer programs to design and check the safety of complex structures. However, the design codes are always in constant development, and it takes significant time for the programs to be updated. This paper presented a program that is intended to assist to the engineers in the design the tubular joints of fixed steel jacket platforms.

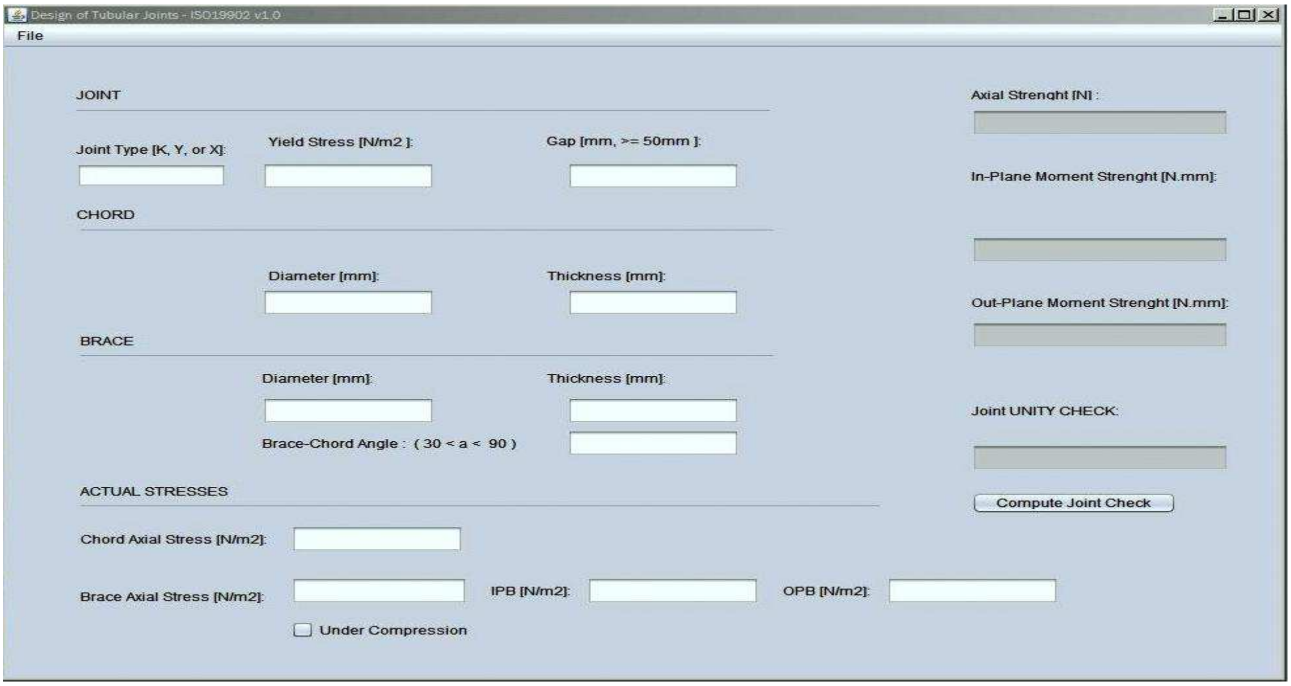

Figure 3. Graphical User Interface of the subprogram

The output of the tests showed that program has matching results as those obtained using the SACS 5.2 joint can subprogram. The program was developed for the design of tubular joints of fixed steel offshore structures using the ISO-19902 code, which did not feature on SACS 5.2. Furthermore, checks need to be conducted to improve the performance of the program.

ACKNOWLEDGMENT

The author would like to acknowledge the support provided by the Center of Graduate Studies (CGS) of Universiti Teknologi PETRONAS and the assistance provided by Guilherme Dinis Chaliane Junior and Calibio Nhavene in developing the subprogram.

REFERENCES

[1] SACS, 2012. SACS by Bentley.[online] Available at: http://www.sacs-edi.com/index.asp [Accessed 29 June 2012]

[2] ISO 19902:2007, "Petroleum and natural gas industries - Fixed steel offshore structures," 1st ed. Geneva: International Organization for Standardization, 2007.

[3] N. J. Cossa, N. S. Potty, A. B. Idrus, M. F. A. Hamid, and Z. Nizamani, "Reliability Analysis of Jacket Platforms in Malaysia - Environmental Load Factor," *Research Journal of Applied Sciences, engineering and Technology*, vol 4(19), October 2012.

[4] N. J. Cossa, N. S. Potty, M. S. Liew and A. B. Idrus, "Reliability of Tubular Joints of Offshore Platforms in Malaysia," World Academy of Science, Engineering and Technology, vol. 60, pp. 838 - 844, 2011.

[5] S. Y. Ma, J. V. Sharp, I. E. Tebbett, "A Comparative Study of the Design Basis for Complex Tubular Joints," in Offshore Technology Conference, Houston-Texas, 1-4 May 1989.

[6] N. S. Potty, N. J. Cossa, Z. Nizamani, and A. B. Idrus, "Tubular Joints Strength Models in API RP2A WSD, API RP2A LRFD and ISO 19902", in Proc. 4th World Engineering Conference - WEC, Kuching - Malaysia, Aug 2-5, 2010.

[7] API RP2A-WSD, "Recommended Practice for Planning, Design and Constructing Fixed Offshore Structures - Working Stress Design," 21st ed. Washington: API Publishing Services, 2005..

[8] NetBeans IDE , 2012. Oracle Corporation. [online] Available at: http://netbeans.org [Accessed 30 June 2012]