International Journal of Advanced Technology in Engineering and Science
Vol. No.5, Issue No. 05, May 2017
www.ijates.com
ijates
ISSN 2348 - 7550

AN INVESTIGATION ON PIPING AND STRESS ANALYSIS ON ASTM A106 GRADE B CARBON STEEL PIPING

G.Siva Karuna[1], M.Gangadhar Rao[2]

[1]*Dept of Mechanical Engineering, Lendi Institute of Technology and Management (India)*

[2] *Dept of Mechanical Engineering, Sai Ganapathi Engineering College (India)*

ABSTRACT

Piping systems are present in most of the industries, associated with the transport of fuels, processing of crude oils and chemical plants. Due to the nature of those fluids, the design of the piping system that transports them is a task of great responsibility, which must follow codes and standards to guarantee the system's structural integrity. Many a times the piping systems operate at a temperature higher than the temperature at which they are assembled, leading to the thermal expansion of the system's pipes and since no piping system is free to expand, the thermal expansion will lead to stresses. Besides the stresses caused by thermal expansion, the studied systems will also are subjected to constant loads caused by their weight, as well as occasional loads like wind, earthquake. In this perspective, calculation methodologies were developed in order to do quick analysis of the most common configurations, according to the codes like ASME B31.3, allowing that way improvements on the flexibility of the projected systems.

This is project is performed to carry stress analysis on steel pipes and piping in petroleum industry. Steel piping material includes carbon steels, alloy steels and stainless steels. Stress analysis is conducted on carbon steel piping's with various diameters, insulations and number of bends mathematically. These mathematically calculated stresses are compared to the stresses on piping analysis software. CAEPIPE is the piping analysis software used for this purpose in this project.

I. INTRODUCTION

The early piping systems were constructed between 3000 B.C. and 2000 B.C. in the ancient Mesopotamia for irrigation of large areas of cultivated land. Due to the growing need to cultivate larger areas, piping systems had a crucial role in the development of big cities. During the industrial revolution with the discovery of steam power, piping systems also turned out to be essential in the exploration of oil. At present piping systems are constantly present in residential and commercial buildings, in industrial facilities. In oil refineries and others industrial process plants, pipelines represent between 25% and 50% of the total cost of the facilities.

Pipes are the most delicate components in any process plant and are also the busiest entities. They are subjected to almost all kinds of loads, intentional or unintentional. It is very important to take note of all potential loads that a piping system would encounter during operation as well as during other stages in the life cycle of a process plant. Since piping systems are associated with facilities of high degree of responsibility, stress analysis represent a fundamental stage of the piping design, in order to prevent failures and cause of accidents. Taking into account that piping systems are subjected to multiple loads, stress analysis represents a complex task. Besides the stresses caused by the piping weight, fluids and isolation, piping systems are also subjected to temperature changes, internal and external pressure and occasional events such as water hammer, wind and earthquakes.

Due to the temperature variations that occur in piping systems, between the installation and operation temperatures, they will be subjected to expansion and contraction. In the general terms, both contraction and expansion are called thermal expansion. Since every piping system has restrictions that prevent the free expansion, thermal expansions will always create stresses, but, if the system is flexible enough, the expansion may be absorbed without creating undue stresses that may damage the system, the supports and the equipment to which the pipes are connected.

This is IEEE Text style. Use it for all paragraphs that contain body text. This style matches the appearance of papers in an IEEE conference proceedings but in double-spaced (actually it is 1.5 spaced) format and in a single column. For items not addressed in these instructions, please refer to other documents on IEEE style.

II . CODES AND STANDARDS

In order to satisfy the safety requirements, local regulations, design constraints of Client, piping systems have to be designed and built according to determinate codes and standards.

I. American Society of Mechanical Engineers (ASME)

II. American National Standards Institute (ANSI)

III. American Society of Testing and Materials (ASTM)

IV. Pipe Fabrication Institute (PFI)

American Society for Testing and Materials (ASTM) International is an international standards organization that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services. In the United States, ASTM standards have been adopted, by incorporation or by reference, in many federal, state, and municipal government regulations. The National Technology Transfer and Advancement Act, passed in 1995, require the federal government to use privately developed consensus standards whenever possible.

ASTM A106 seamless pressure pipe (also known as ASME SA106 pipe) is commonly used in the construction of oil and gas refineries, power plants, petrochemical plants, boilers, and ships where the piping must transport fluids and gases that exhibit higher temperatures and pressure levels.

Following are the codes and standards used for Refinery Piping :

Sl. No.	Pipe Code/Standard	Use
1	ASME B31.3	Process Piping
2	ASME B31.1	Power Piping

3	API 610	Centrifugal Pumps
4	API 676	Positive Displacement Pumps
5	API 617	Centrifugal Compressors
6	API 618	Reciprocating Compressors
7	NEMA SM23/ API 612	Steam Turbines
8	API 661	Air Cooled Heat Exchanger
9	API 560	Fired Heaters
10	API 650	Flat Bottom Welded Storage Tanks
11	TEMA/ Vendor Specific	Heat Exchangers
12	Vendor Specific	Vessel/Column

Table 1: Codes and Standards used for Refinery Piping\

III. PROPERTIES

3.1 ASTM A106 Carbon Steel Properties

Carbon steels are an alloy of Iron and Carbon.

Carbon content 0.1 % to 1.5 %

Based on Carbon Content it can be classified into

1. Mild steel - 0.05 % - 0.30 %
2. Medium Carbon steel – 0.30 % - 0.70 %
3. High carbon Steel – 0.70 % - 1.5 %
4. It can withstand up to a temperature of 450^{o}C

3.2Mechanical Properties :-

	Grade A	Grade B	Grade C
Tensile Strength	330	415	485
Yield Strength	205	240	275

Table 2 : Mechanical properties of ASTM A106 Carbon Steel

IV. MATHEMATICAL STRESS ANALYSIS :-

Sl. No.	Insulation material	Density of insulation (kg/m^3)	Thickness of insulation (mm)	Diameter (mm)	No. of Bends	S/A
1	Calcium Silicate	240.28	5	254	2	0.73
2	Mineral Wool	136.16	5	254	2	0.69
3	Styro Foam	28.833	5	254	2	0.56
4	Calcium Silicate	240.28	5	355.6	4	0.63
5	Minearl Wool	136.16	5	355.6	4	0.58
6	Styro Foam	28.833	5	355.6	4	0.42
7	Calcium Silicate	240.28	5	254	4	0.59
8	Mineral Wool	136.16	5	254	4	0.56
9	Styro Foam	28.833	5	254	4	0.45

Table 3 : S/A ratios for different insulations and different number of bends

V. STRESS ANALYSIS IN CAEPIPE

CAD Packages like CAEPIPE have been developed for the comprehensive analysis of complex systems. This software makes use of Finite Element Methods to carry out stress analysis. However they require the pipe system to be modeled before carrying out stress analysis. Due to time constraints it is not possible to model the pipe systems always. Hence it becomes necessary to carryout elementary analysis before going in for the software analysis. Chart solutions, Rules of Thumb and Mathematical formulae are used to serve this purpose. Our project is mainly concerned with the analysis of two anchor problems with different number of pipes using the formula.

Clause 119.7.1/319.4.1 of the piping code suggests that for a pipe to be safe the value of critical coefficient K where it should be less than 208.3 (in SI units). If according to this formula a pipe is safe, then no further analysis is required.

International Journal of Advanced Technology in Engineering and Science
Vol. No.5, Issue No. 05, May 2017
www.ijates.com
ijates
ISSN 2348 - 7550

5.1 Analysis of stress for A106 Grade B carbon steel pipe with different diameters:

Sl. No.	Length	Diameter(mm)	S/A (CAEPIPE)
1	15	152.6	0.56
2	15	203.2	0.48
3	15	254	0.43
4	15	355.6	0.37

Table 4 : S/A ratios for different diameters in CAEPIPE for 2 bends

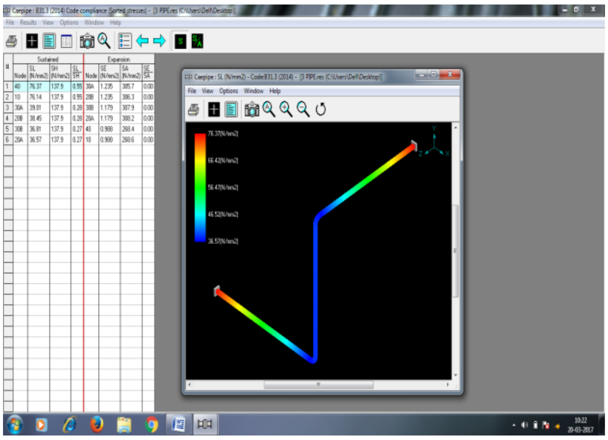


Fig 1 :- A106 GradeB 6" carbon steel pipe with 2 bends

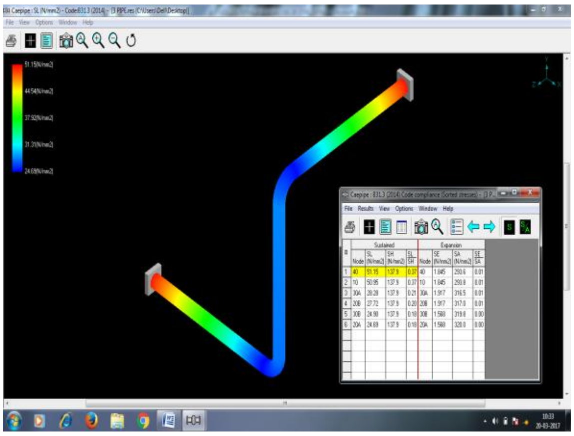


Fig 2 :- A106 GradeB 14" carbon steel pipe with 2 bends

5.2 Analysis of stress for A106 Grade B carbon steel pipe with different bends

Number of Bends: As the number of bends increases, the pipe becomes safer provided the initial and the final point are same. The original formula does not account for the number of bends.

$[2/n]^{0.3}$ is the factor by which the original formula is to be multiplied if the number of bends is less than 4 else we multiply by $[2/n]^{0.6}$

Sl. No.	Length (mm)	Diameter(mm)	No. of bends	S/A (CAEPIPE)
1	15	152.6	0	0.56
2	15	152.6	1	0.48
3	15	152.6	2	0.43
4	15	152.6	4	0.37

Table 5 : S/A ratios for different bends in CAEPIPE of 6" pipe

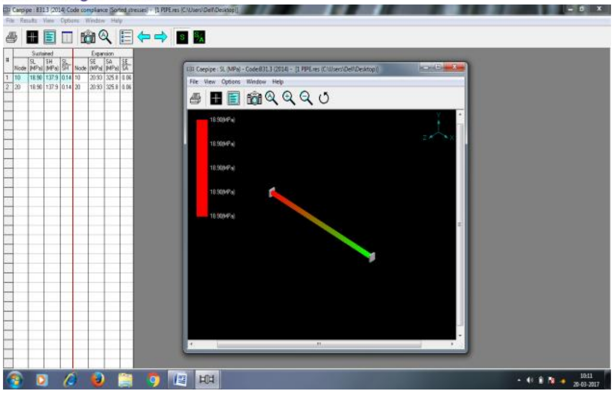


Fig 3: A106 GradeB 6"carbon steel pipe with no bends

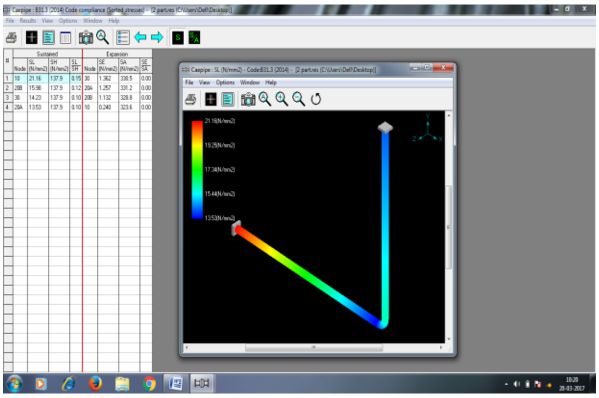


Fig 4 : A106 Grade B 6" carbon steel pipe with 1 bend

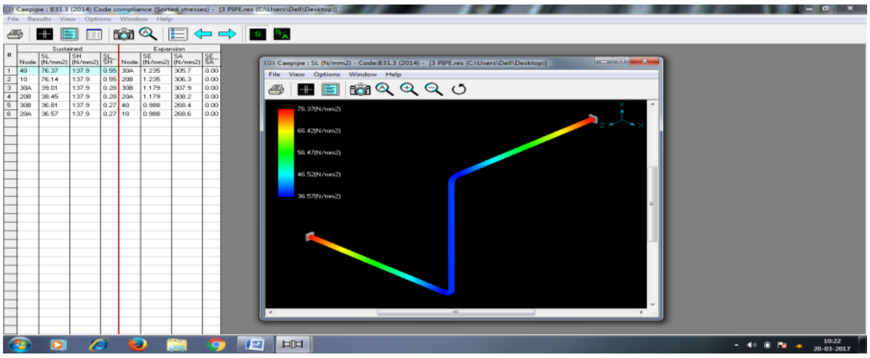


Fig 5: A106 GradeB 6" carbon steel pipe with 2 bends

5.3 Analysis of stress for A106 GradeB carbon steel pipe with different bends and insulations:-

The S/A ratios obtained in CAEPIPE for pipes for different diameters with different bends using insulation materials Calcium Silicate, Mineral Wool and Styro Foam insulations are tabulated below.

Sl. No.	Insulation material	Density of insulation (kg/m^3)	Thickness of insulation (mm)	Diameter(mm)	No. of Bends	S/A (CAEPIPE)
1	Calcium Silicate	240.28	5	254	2	0.84
2	Mineral Wool	136.16	5	254	2	0.80
3	Styro Foam	28.833	5	254	2	0.50
4	Calcium Silicate	240.28	5	355.6	4	0.69
5	Minearl Wool	136.16	5	355.6	4	0.67
6	Styro Foam	28.833	5	355.6	4	0.48
7	Calcium Silicate	240.28	5	254	4	0.43
8	Mineral Wool	136.16	5	254	4	0.42
9	Styro Foam	28.833	5	254	4	0.21

Table 6 : S/A ratios in CAEPIPE for different insulations and different number of bends

ijates
ISSN 2348 - 7550

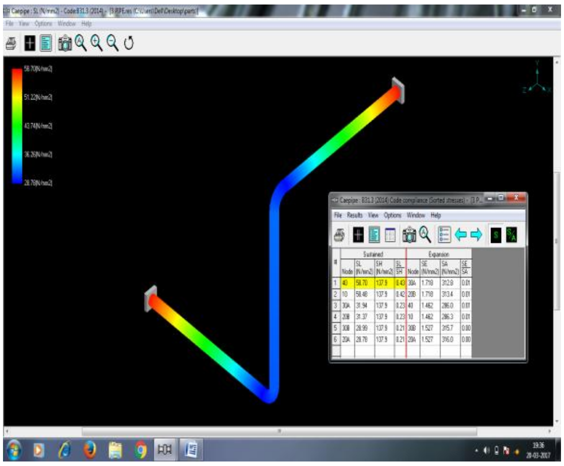


Fig 6 : With calcium silicate insulation-10"& 2 bends

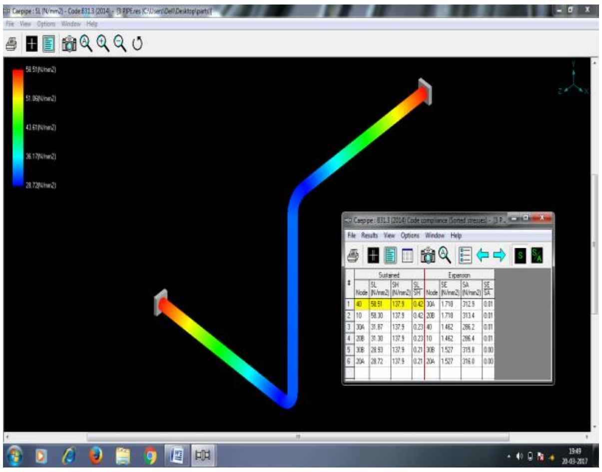


Fig 7 : with mineral wool insulation-10" and 2 bends

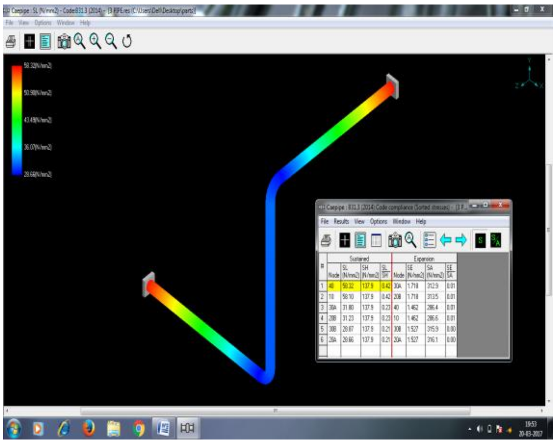


Fig 8: with styro foam insulation-10" and 2 bends

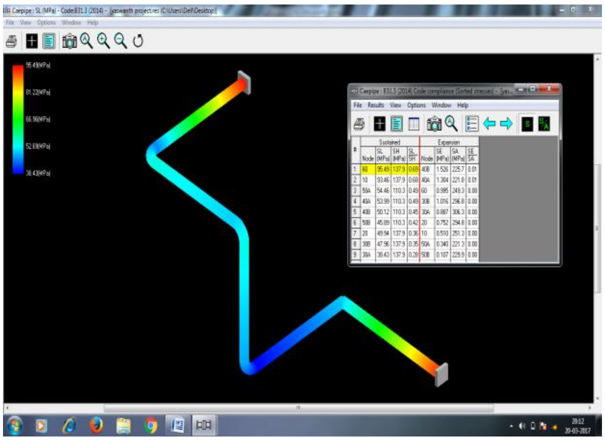


Fig 9 : with Calcium Silicate Insulation -14" and 4 bends

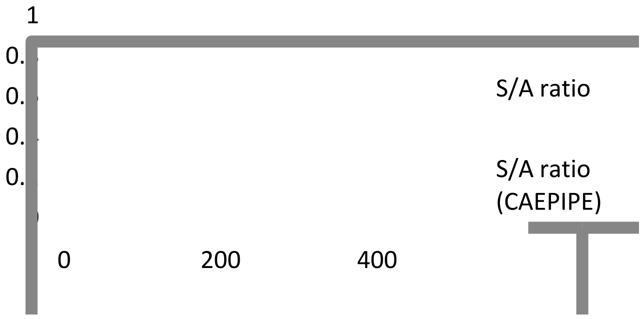
VI . RESULTS AND DISCUSSION

Comparison of S/A ratios for different diameters:

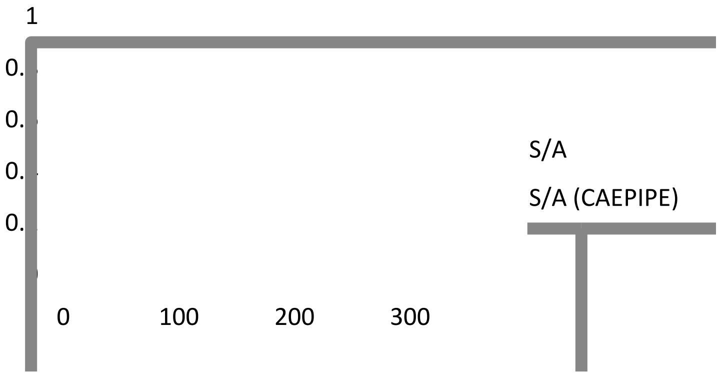
The S/A ratios obtained in manual calculations and CAEPIPE for pipes for different diameters with 2 bends are tabulated below.

Sl.No.	Length	Diameter(mm)	S/A	S/A (CAEPIPE)
1	15	152.6	0.88	0.56
2	15	203.2	0.72	0.48
3	15	254	0.69	0.43
4	15	355.6	0.65	0.37

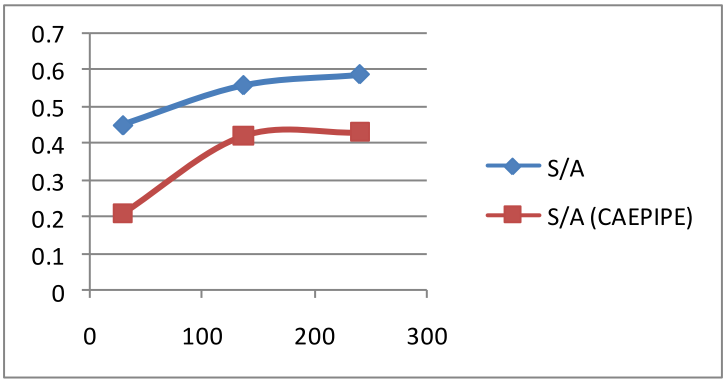
Table 7: S/A ratios for different diameters in manual calculation and CAEPIPE with 2 bends



Graph1 : S/A ratios for different diameters in manual calculation and CAEPIPE for 2 bends



Graph2 : S/A ratios against densities of insulations for 14" with 4 bends



Graph 3 : S/A ratios against densities of insulations for 10" with 4 bends

VII . CONCLUSION

- As the diameter of the pipe is increased from 6" to 14", the normal stress to allowable stress ratio decreased from 0.88 to 0.65 (mathematical calculation)and from 0.56 to 0.35 (CAEPIPE). Hence it can be concluded that with increasing diameter, the pipe becomes safer.
- As the number of bends of pipe are increased from 0 to 4, the normal stress to allowable stress ratio decreased from 0.88 to 0.65 (mathematical calculation) and from 0.56 to 0.35 (CAEPIPE). Hence, with the increase in bends the pipe becomes safer. Anchor lengths do not have a considerable effect on the value of stress in pipe Therefore, they are not taken into consideration.

- The normal stress to allowable stress ratios obtained in manual calculations and CAEPIPE for pipes for different diameters with different bends using insulation materials Calcium Silicate, Mineral Wool and Styro Foam insulations are performed. It could be concluded that Calcium Silicate can be used for insulation at high temperature areas, Mineral Wool for insulation at medium temperatures and Styro Foam at low temperature areas.
- The software is quick and easy check for pipe configurations. The formula gives results in conformance to CAEPIPE results in most of the simple standard configurations.
- Comparison of manual calculations and CAEPIPE is justified as it ensures double safety.

VIII . FUTURE SCOPE

Usage of Carbon steels has been proved to be economical as well as safe. But there is a growing need for insulation in the places of extreme temperature variations. For this purpose, stresses over the pipelines are to be carefully analyzed. Insulations are to be varied to discover the best insulation material required. Different varieties of insulation materials may be found useful at different piping systems. The economics and safety are to be taken into consideration and research is to be carried in this field. Usage of software in this field reduces the difficulty in analyzing the stresses and provides a huge variety of conditions that are to be varied. Software like CAEPIPE not only allows us to find the stresses, stress ratios but also vary the insulation material with respect to the densities. It also indicates the failure in the design regarding the diameter and number of bends. More insulation materials are to be tested in this field considering the stresses over the pipes and thus better efficiency in economy and better safety could be achieved.

REFERENCES

1. Knowledge-based collaborative engineering of pipe networks in the upstream and downstream petroleum industry by Leonid Sheremetov, IldarBatyrshin, Manuel Chi, Armando Rosas, Mexican Petroleum Institute (IMP), Distrito Federal, Mexico.
2. Stress Analysis of Steam Piping System byYogita B Shinger and Thakur AG, Mechanical Department, Sir Visvesvaraya Institute of Technology, Kopargoan, Maharashtra, India.
3. ASSESSMENT OF MATERIALS TECHNOLOGY FOR GASIFIER AND REACTION PRESSURE VESSELS AND PIPING FOR SECOND GENERATION COMMERCIAL COAL CONVERSION SYSTEMS by D. A. Canonico, R. H. Cooper, R. W. McClung, D. P. Edmonds, R. K. Nanstad, B. E. Foster, G. C. Robinson, J. W. McEnerneyandG. M. Slaughter.
4. A general paper on optimization of fuel and energy(cost saving) by insulation (calcium silicate) in boiler by Manish Kumar Soni1 , Gireeshkumar, Post graduate student, Jagannath University, Jaipur, Rajasthan, INDIA
5. Stress Intensification & Flexibility in Pipe Stress Analysis GauravBhende, GirishTembhare, Department of Mechanical Engineering, VJTI, Mumbai, India.
6. THERMAL INSULATION HANDBOOKby THE THERMAL INSULATION ASSOCIATION OF SOUTHERN AFRICA.

7. Stress Analysis of Process Pipe Line Systems (ASME B 31.3) In a Plant Using Caeser-II by A.sivanagaraju, S.Krugon, Dr.M.Venkateswararao, M-Tech Student, Assistant Professor, Professor and Head of Mechanical Department, Bapatla Engineering College, Bapatla, Guntur, India.
8. 3D Modeling and Stress Analysis of Flare PipingbyNavathRavikiran, V. Srinivas Reddy, G. Kiran Kumar, Mechanical Department, Malla Reddy Engineering And Technology, Hyderabad, India, Sr.Stress Engineer, SJK India Ltd, Hyderabad, India.
9. Frequency Spectrum Method-Based Stress Analysis for Oil Pipelines in Earthquake Disaster AreasXiaonan Wu, Hongfang Lu1, Kun Huang1, Shijuan Wu1 and WeibiaoQiao, College of Petroleum Engineering, Liaoning Shihua University, Fushun, Liaoning, China.
10. The Electrochemical Investigation of the Corrosion Rates of Welded Pipe ASTM A106 Grade B TrinetYingsamphancharoen, NakarinSrisuwan and AphichartRodchanarowan Department of Materials Engineering, Faculty of Engineering, Kasetsart University, Chatuchak, Bangkok.
11. Stress Analysis of Steam Piping System by Yogita B Shinger and Thakur AG ofMechanical Department, Sir Visvesvarayya Institute of Technology, Kopargoan, Maharashtra, India.
12. THE COMPRESSIVE STRENGTH PROPERTIES OF MINERAL WOOL SLABS: INFLUENCE OF STRUCTURE ANISOTROPY AND METHODICAL FACTORS by AndriusBuska, RomualdasMačiulaitisDept of Building Materials, Vilnius Gediminas Technical University, Vilnius, Lithuania.
13. THERMOPHYSICAL PARAMETERS OF CALCIUM SILICATE INSULATION MEASURED BY GUARDED HOT PLATE AND PULSE TRANSIENT METHODSby Olga Koronthalyova, Peter Matiasovsky of Institute of Construction and Architecture, Slovak Academy of Sciences, Slovakia.