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DESIGN AND ANALYSIS OF PIPING SYSTEM USED IN CHEMICAL PLANT USING CAESAR II

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ABSTRACT

Piping system is a pipe network using pipe fittings like tees, cross, elbows, etc., and other special components valves, gaskets, flanges, filters, etc., to perform the necessary fluid transfer mode (Liquids/Gas/Slurry) from one place to another. The Industrial/International Codes and Standards control the design of piping systems. The specifications for design, manufacture, and use of materials, testing and inspection of piping systems are specified by piping codes, and the standards are more applicable to the concept of application design and construction rules and requirements for piping components. The basic design code used in our project is ASME B31.3. For petroleum refineries, chemical plants, textile plants and paper plants, this code contains the process piping code. Stress in the pipe is also the key concern when constructing any pipe device. Methodologies for the design of pipe systems inside the chemical plant are viewed and analyzed. The analytical study of piping systems is derived by using CAESAR II software.

***Keywords*: Piping, Chemical Plant, CAESAR II, Stress Analysis, ASME B31.3**

1. INTRODUCTION

Piping System design and analysis is a very important field in any process and industry. Piping system is like the blood circulating system in our human body and is necessary for the life of the plant. Design of piping network system meets various Applications which has health and safety for work environment. The performance of the plant depends on the pipe line sizing, Equipment layout, components and fittings used. This paper discusses about the stress analysis and displacement of Process Piping Plants referring to code ASME B31.3. The basic design code used in this paper is ASME B31.3 Process Piping code which includes textile plants, oil and petroleum refineries, chemical plants, paper plant, etc. But the piping system, mentioned in thesis is chemical plant which is used for supplying the chemical for process and treatment Piping stress analysis is a vital part of the Industrial plants condition assessment. At present, there is much software for piping stresses analysis, viz.-CAEPIPE, CAESAR-II, AUTOPLANT, PIPE PACK, check STRESS, PDMS, etc. In our project, Design and analysis of the piping system is done by using CAESAR II Software. The CAESAR II is Computer Aided Engineering Stress Analysis & Routing is a complete pipe stress analysis of piing system subjected to weight, pressure, thermal load, and seismic load, static and dynamic loads. It can Analyses Piping System of any size and complexity

2. PIPING STANDARD& PIPE CODE

The piping standard is the documents prepared by a professional group or committee which are believed to be good and proper Engineering practices and which contain mandatory requirement. It is the application design and construction rules and requirements for piping components as flanges, elbows, tees, etc. there are many type of piping standard available, they are ASME, ANSI, BIS, ISO, ASME B31, CSI, etc. Of these standards ASME B31 is used in this paper.

The pipe code is a group of general rules or systematic procedures for Design, Fabrication, Installation and Inspection methods prepared in such a manner that code can adopted by legal jurisdiction and made into a law. The ASME B13 Piping Codes are:

- ASME B31.1 - Power Piping
- ASME B31.2 - Fuel Gas Piping
- ASME B31.3 - Process Piping
- ASME B31.4 - Liquid Piping
- ASMEB31.5-Refrigeration Piping
- ASME B31.8 - Gas Distribution and Transportation
- ASME B31.9 - Building Service Piping

Among these code ASME B31.3 process piping code is used in our design.

3. PIPING LAYOUT & ROUTING

Piping layout show the overall dimension of the plant/system/unit from where the plants start and ends, which show the all piping, equipment nozzle, Structure, Piping supports instruments tags, piping components used. The piping layout is very important for the installing of pipe in the sites. It shows the piping in the plan view and gives all the information required for preparation of isometric drawings

Piping Routing is the planning of pipeline layout, which includes consideration of neatness, economy and safety. Pipe routing must consider the effects of vibration, corrosion and normal service on the pipe before deciding where to lay them.

The following data were used in this paper:

- Pipe Material - MONEL 67Ni 30Cu
- Pipe Nominal Diameter - 11 cm
- Operating Pressure - 3.7 bar
- Operating Temperature - 90^0-130^0

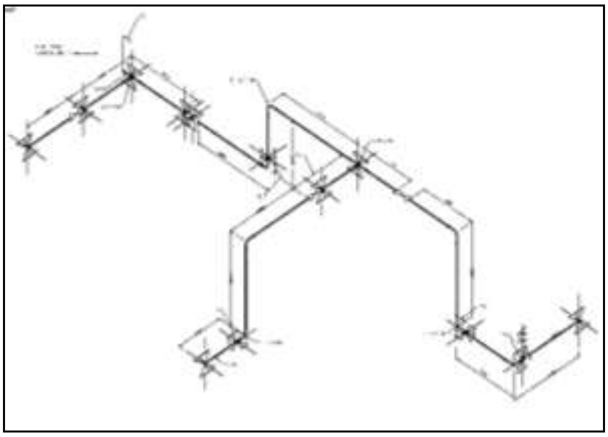

Figure 1: Piping routing view of Chemical plant

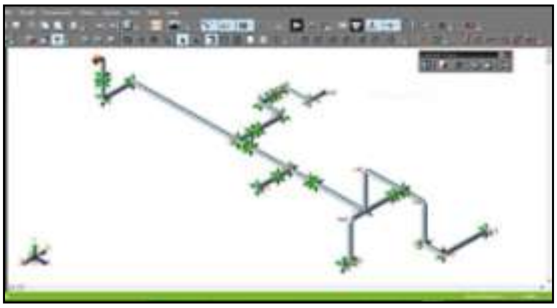

Figure 2: 3D view of piping layout in Chemical plant

4. METHODOLOGY

The methodology of the project is start with Problem identification in the chemical industry followed by design of piping system using code ASME B31.3 and choosing of proper material, finally analyses the piping layout and then concluded the solution, the methodology of any analysis is followed by three steps

- Preprocessing – Create a layout of the piping system by using various component like control valves, bends etc. and choosing pipe material
- Solution – Applying loads, giving supports and then solve the solution
- Post processing – Finally review the result obtained and check the validity of the solution

5. STRESS ANALYSIS

Stress is a measure of the force per unit area is acting on a plane passing through the point of interest in a body. Stress analysis is general term used to describe analyses where the results quantities include stress and strain. The purpose of stress analysis in piping is to calculate the static force in a piping system created by thermal expansion, static pressure, loads, weights, etc. The stress analysis should be perform according to the applicable piping code is ASME B31.3, this code provide calculation for the maximum allowable stress in the piping based on the diameter, wall thickness, and material properties

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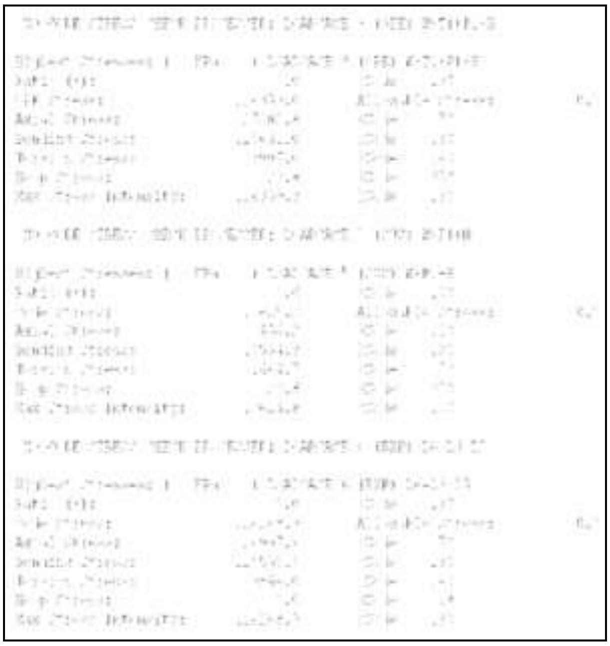

Figure 3: Stress analysis Result

6. FLEXIBILITY ANALYSIS

Flexibility analysis is an analysis of the ability of pipe to change its length and deform elastically. This condition occurs because of load which is affected by high temperature during operation in piping system. Piping system must be enough flexible, so thermal expansion or movement of support or end point of pipe will cause failure on pipe and support due to excessive stress.

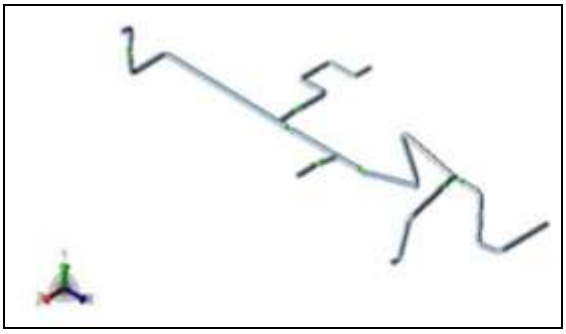

Figure 4: Flexibility analysis

7. DISPLACEMENT ANALYSIS

Piping Flexibility analysis in accordance with the basic assumptions and requirements of B31.3 is concerned with two types of stress called sustained stress and displacement stress. Both of these stress must be considered separately because sustained stress are associated with sustained force and displacement stress is associated with fixed displacement.

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Node	DX mm.	DY mm.	DZ mm.	RX deg.	RY deg.	RZ deg.
10	0.000	0.000	0.000	0.0000	0.0000	0.0000
18	-0.000	0.066	-0.037	0.0311	0.0001	0.0000
19	-0.000	0.121	-0.089	0.0252	0.0002	0.0000
20	-0.000	0.113	-0.128	0.0052	0.0003	0.0001
30	-0.000	-0.012	-0.000	-0.0000	0.0008	0.0000
40	0.000	-0.068	0.000	0.0000	0.0008	0.0000
48	0.009	-0.166	-0.220	0.0594	0.0012	-0.0004
49	0.005	-0.134	-0.360	0.0727	0.0012	-0.0030
50	-0.000	-0.000	-0.447	0.0659	0.0018	-0.0069
58	-0.045	0.172	-0.677	-0.0196	-0.0006	-0.0394
59	-0.031	0.100	-0.703	-0.0207	-0.0028	-0.0431
60	-0.000	0.000	-0.707	-0.0203	-0.0053	-0.0448
70	0.426	-0.000	0.000	-0.0005	0.0214	0.0057
80	0.462	0.000	-0.000	-0.0001	-0.0000	-0.0000
90	0.519	-0.000	-0.000	-0.0001	-0.0000	-0.0000
100	0.708	-0.000	-0.000	0.0024	-0.0490	0.0007
110	0.821	0.000	0.000	0.0202	0.0000	-0.0000
120	0.878	-0.000	-0.000	0.0202	0.0000	-0.0000
128	1.136	3.282	-0.136	0.0608	0.0119	0.3810
129	0.821	4.067	-0.111	0.0635	0.0136	0.4261
130	0.000	4.436	0.000	0.0657	0.0158	0.3967
138	-1.605	4.740	1.403	0.0604	0.0360	-0.1417
139	-1.304	4.645	1.465	0.0572	0.0377	-0.1627
140	-1.144	4.333	1.456	0.0529	0.0394	-0.1776
150	-0.789	0.000	-0.000	-0.0005	0.0949	-0.1284
160	-0.771	-0.150	-0.113	-0.0045	0.0898	-0.1172
170	-0.714	-0.600	-0.457	-0.0045	0.0898	-0.1172
178	-0.663	-1.260	-1.040	-0.0289	0.0684	-0.0624
179	-0.692	-1.371	-1.139	-0.0349	0.0643	-0.0495
180	-0.767	-1.419	-1.118	-0.0394	0.0600	-0.0374
188	-0.272	-1.561	-0.101	-0.0455	0.0108	0.0862
189	-0.093	-1.500	-0.024	-0.0416	0.0059	0.0988
190	0.000	-1.307	0.000	-0.0364	0.0021	0.1101
198	0.054	-0.333	0.011	-0.0169	-0.0029	0.1350
199	0.069	-0.087	0.011	-0.0124	-0.0024	0.1365
200	0.078	-0.000	-0.000	-0.0101	-0.0015	0.1366
210	0.000	-0.000	-0.186	0.0076	0.0050	0.1366
220	-0.000	0.000	0.048	-0.0023	0.1173	-0.1254
230	0.451	0.009	0.074	-0.0023	0.1173	-0.1254
238	2.701	0.187	0.233	-0.0024	0.0757	-0.1155
239	2.750	0.183	0.246	0.0013	0.0714	-0.1142
240	2.591	0.169	0.245	0.0051	0.0661	-0.1131
248	0.276	0.026	-0.005	0.0073	0.0120	-0.1097
249	0.077	0.009	-0.011	0.0039	0.0068	-0.1093
250	-0.000	0.000	0.000	0.0012	0.0024	-0.1088
260	0.000	-0.000	0.018	-0.0001	-0.0001	-0.1088
270	0.000	-0.000	0.060	-0.0003	-0.0423	0.0007
280	-0.162	0.001	0.087	-0.0003	-0.0423	0.0007
290	-0.000	-0.000	0.159	0.0001	0.0423	0.0007
300	0.000	-0.000	-0.068	-0.0000	0.0000	0.0039
310	-0.000	-0.000	-0.095	-0.0000	0.0000	0.0039
318	0.047	0.000	-0.194	0.0007	0.0064	0.0012
319	0.025	0.001	-0.199	0.0008	0.0128	0.0009
320	0.000	-0.000	-0.173	0.0008	0.0183	0.0007
328	-0.068	-0.002	0.020	0.0005	0.0064	-0.0004
329	-0.080	-0.001	0.018	0.0004	-0.0035	-0.0006
330	-0.069	-0.000	-0.000	0.0002	-0.0112	-0.0006
340	-0.000	0.000	-0.036	-0.0000	-0.0069	-0.0006
350	0.000	-0.000	-0.054	-0.0000	0.0021	-0.0006
358	-0.018	0.001	-0.094	0.0003	0.0001	-0.0006
359	-0.012	0.001	-0.102	0.0003	-0.0035	-0.0006
360	-0.000	-0.000	-0.098	0.0004	-0.0073	-0.0007
368	0.079	-0.002	0.018	0.0003	-0.0014	0.0006
369	0.088	-0.001	0.013	0.0003	0.0038	0.0007
370	0.082	-0.000	0.000	0.0002	0.0085	0.0006
380	0.000	-0.000	-0.000	0.0000	0.0000	0.0000

Figure 5: Displacement analysis Result table

8. FLANGE CHECK

A Flange is a method of connecting pipes, valves, pumps and other equipment to form a piping system. It also provides easy access for cleaning, inspection and modification in case of any problem in the pipe line. Flanges are usually welded or screwed. Flanged joints are made by bolting together two flanges with a gasket between them to provide a seal. The sum of the operating pressure and effective pressure is then compared with allowable pressure specified in ASME B31.3 or ASME B16.5.The flange loading calculation method outlined is used to determining the effective pressure in the flange due to

- External Moment
- External Force

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Node	Axial Force N.	Bending Moment N.m.	G/C mm.	P Equivalent KPa	Rating Temperature C	Allowable Pressure /Stress	Ratio %
200							
210	0	0	135.00	101.00	-17.78	0.00	0.00
250							
260	0	0	135.00	101.00	-17.78	0.00	0.00
280							
290	0	0	135.00	101.00	-17.78	0.00	0.00

Figure 6: Flange load Analysis

9. RESTRAINT LOAD ANALYSIS

The Restraint produces that make it possible to quickly and safely restrain fittings at bends, dead ends, tees, valves, and reducers without the need for concrete thrust blocks or tie rods. These joint restraint products turn the pipeline into its own thrust block. The key to utilizing these new products is to understand the proper application of pipeline restraint. The first step in any pipeline restraint design is to define the force to be restrained: the resultant thrust force. Defining this force at a particular fitting requires isolating the piping section containing the fitting restraint

Node	FX N.	FY N.	FZ N.	MX N.	MY N.	MZ N.	Restraint type
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	0	0	0	0	0	[illegible] Rigid X
[illegible]	0	0	[illegible]	0	0	0	[illegible] Rigid Z
[illegible]	0	0	[illegible]	0	0	0	[illegible] Rigid Z
[illegible]	[illegible]	0	0	0	0	0	[illegible] Rigid X
[illegible]	[illegible]	0	0	0	0	0	[illegible] Rigid X
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	[illegible]	0	0	0	0	0	[illegible] Rigid X
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	0	0	[illegible]	0	0	0	[illegible] Rigid Z
[illegible]	0	0	[illegible]	0	0	0	[illegible] Rigid Z
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	0	0	[illegible]	0	0	0	[illegible] Rigid Z
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	0	0	[illegible]	0	0	0	[illegible] Rigid Z
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	0	0	[illegible]	0	0	0	[illegible] Rigid Z
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	0	0	[illegible]	0	0	0	[illegible] Rigid Z
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	0	0	[illegible]	0	0	0	[illegible] Rigid Z
[illegible]	[illegible]	0	0	0	0	0	[illegible] Rigid X
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	0	0	[illegible]	0	0	0	[illegible] Rigid Z
[illegible]	0	0	[illegible]	0	0	0	[illegible] Rigid Z
[illegible]	1	0	0	0	0	0	[illegible] Rigid X
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	0	0	[illegible]	0	0	0	[illegible] Rigid Z
[illegible]	0	[illegible]	0	0	0	0	[illegible]
[illegible]	[illegible]	0	0	0	0	0	[illegible] Rigid X
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	[illegible]	0	0	0	0	0	[illegible] Rigid X
[illegible]	0	0	[illegible]	0	0	0	[illegible] Rigid Z
[illegible]	[illegible]	0	0	0	0	0	[illegible] Rigid X
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[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	[illegible]	0	0	0	0	0	[illegible] Rigid X
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	[illegible]	0	0	0	0	0	[illegible] Rigid X
[illegible]	[illegible]	0	0	0	0	0	[illegible] Rigid X
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	[illegible]	0	0	0	0	0	[illegible] Rigid X
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	[illegible]	0	0	0	0	0	[illegible] Rigid X
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[illegible]	0	0	[illegible]	0	0	0	[illegible] Rigid Z
[illegible]	[illegible]	0	0	0	0	0	[illegible] Rigid X
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	[illegible]	0	0	0	0	0	[illegible] Rigid X
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	[illegible]	0	0	0	0	0	[illegible] Rigid X
[illegible]	0	0	[illegible]	0	0	0	[illegible] Rigid Z
[illegible]	0	[illegible]	0	0	0	0	[illegible] Rigid Y
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 7: Restraint load analysis result

10. RESULT

By changing the different material for pipe and applying stress under different load condition, the results of stress developed in the pipe node is shown in Figure 3. For the same pressure the flexibility occurs in the pipe is shown at Figure 4. The flange load was applied on the particular node and the result was shown in the Figure 6. By using various materials for the same piping layout, MONEL 67Ni 30Cu material shows the good stress intensification factor, which has load withstand capability. From the above results we conclude the piping layout having high life span and good efficiency.

11. CONCLUSION

The analytical results of this piping layout describe the stress analysis and flexibility analysis of piping system in the chemical plant is found to be good and economically value. The design and analysis of this piping layout is carried out by the CAESAR II Software. Thus, the objective of our project were attained

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