SATISFYING PIPING STRESS AND FLEXIBILITY REQUIREMENTS WITH THE IMPLEMENTATION OF EXPANSION JOINTS (TECHNO-ECONOMICAL OPTIMISATION)

Miša Jočić B.Sc. Mechanical and Process Engineering
Principal Engineer Pipe Stress Analysis and Design

PIPETECH Jocic
Baden, Switzerland

SUMMARY

There have been various attempts to deal with the optimization of solutions which involve expansion joints in piping systems where sufficient flexibility can’t be found using suitable pipe routing.

The difficulty of piping designs which involve expansion joints is that they rely upon two engineering expertises: Pipe Flexibility and Stress Analysis on one side and Expansion Joint Design and Construction on the other. Arguably distinctively different, they have been looked upon as totally separate engineering disciplines and it is rarely that companies have two of these experts sitting under the same roof. Pipe Stress Engineers basically relied on the support form Expansion Joint Experts on “as required basis” and called upon their knowledge only when needed. Thus, we have the situation where knowledge related to the design and construction of expansion joints sits with expansion joints manufacturing companies, which are totally separate and often remote entities in the design process.

Even so, the ever present demand for techno-economical optimizations, now days direct us towards the following observations.

The “Traditional method”, where Pipe Stress Engineer defines on his own the requirements for expansion joints and describes them in the technical specification for purchasing is, or should be, a matter of past.

This approach may be used only as a first attempt at finding the solution, but given that it never heads in the direction of achieving optimal techno-economical results, needs to be upgraded with additional steps.
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1 DESIGN AND EVALUATION METHODS

Designing piping systems with expansion joints essentially follows the steps below.

Traditional method of design:

- perform the stress analysis
- define the need for expansion joints
- use [4]CAESAR II expansion joint modeler to define expansion joints
- do the technical specification for expansion joints
- submit the specification to various vendors
- review the bids
- choose the best economical solution and place the order

Good points:
- shortest design process suitable for tight schedules
- least expensive in terms of time spent on engineering
- good for situations where there is a need for only a few expansions joints to be implemented and the cost of engineering is governing

Shortcomings:
- vendors have to bend around the predefined requirements and satisfy whatever is put in front of them
- cost can be significantly higher due to restricted ability for vendors to be creative in their solutions
- extremely cost ineffective where the cost of equipment governs
- could disqualify hi-quality manufacturers and lower the quality of the project

Basically what we get in this approach is a “low cost – low quality” solution, which usually barely satisfies the technical requirements.

For this reason most clients prohibit the use of expansion joints at any cost, knowing that they become a week link in the system which could only cause them problems in exploitation.

Modified Traditional method of design:

In modifying the “Traditional method” attempts have been made to overcome the apparent shortcomings and the following have been added:

- after defining the need for expansion joints
- select two or more reputable manufacturers of expansion joints
- modeling of expansion joints in [4]CAESAR II based on their standard products catalogue, selecting those with the properties closest matching to the requirements
- select those which produce more favorable stress and flexibility results
- do the technical specification for expansion joints defining the specific requirements
- submit the specification to the vendor whose expansion joint has been used to base the piping analysis and request from him to implement the modifications on the standard model or design a new with the required characteristics
- confirm that the special requests have been implemented and place the order

Good points:
- no bid review as such
- focus primarily only on technical aspects
- selection and qualification of vendors not required
- might be suitable where clients demand that designers work with their pre-approved vendors

Shortcomings:
- longer design time
- selected vendor might not have the greatest chance for maneuvering and is pretty much locked in with the requirements
- vendor might have the chance to suggest creative solutions to override the problems in designing and manufacturing but he may not have the capacity to offer the best expertise because of conflict of interest
- the solution still proves to be cost ineffective since the emphasis is placed on technical rather than techno-economical aspect of the design process
- could disqualify the other hi-quality vendor who might be able to offer lower cost through more inventive design

What we get as a result of this approach is a “hi cost – hi quality” solution, which satisfies technical requirements but always with the dose of over design which reflects in higher cost.

Clients, which do not prohibit the use of expansion joints often resort to this method. No doubt with enforcing that the fabrication is done by their pre-approved vendors, clients will assure the quality much needed to avoid expansion joints becoming a week link in the system.
It is obvious however, that by doing this and without having an influence on the above mentioned design process, they end up paying the penalty in higher costs.

Techno-Economical Optimization method

 Begins in a similar manner to the “Traditional method”
- perform the stress analysis
- define the need for expansion joints
- use [4]CAESAR II expansion joint modeler to define expansion joints
- do the technical specification for expansion joints
- submit the specification as well as the complete piping solution to vendors asking them to review the design and propose their expansion joints based on the first attempt on finding a solution
Here we divert from ordinary practice and even make direct contact with vendors, in an attempt to make them fully understand our requirements, inspect and review their manufacturing facilities and convince ourselves in their technological capabilities. What we are trying to establish here, is to assess if vendors design expertise as well as manufacturing processes satisfy and match with our design standards. Once this has been achieved we

- review the bids from two levels, design expertise and manufacturing processes

At this stage it is not required to look for the best-offered price but rather to search for the best-suggested technical solution for expansion joints.

The idea is to:

- choose the right vendor and work with him in a team to arrive at the best techno-economical solution

It is advisable also to bring the Expansion Joint Expert on board and let him work in synergy with the Piping Designers and Pipe Stress Engineer on optimizing the solution and implementing his proposals.

Good points:

There are many ways to solve the complex problem of designing a piping system with implementation of required flexibility via installation of expansion joints. Several types of expansion joints are at our disposal such as Universal, Universal Tied, Pressure balanced, Double and Single Hinged or Gimble etc., as well as many arrangements, but only a few would have the optimal “low cost – high quality” outcome.

After many years of practical research and work on projects involving such applications, we have established that in an effort to achieve the best possible quality at the lowest investment cost, the above-described Techno-Economical Optimisation method has no viable alternative.

Shortcomings:

Some may argue that the process is engineering demanding, costly and time consuming! Certainly this is true, but it is our experience that the final product outweighs all this by producing a cost effective solution while achieving also the highest quality. It is a well known fact that systems designed in this way nearly twenty years ago still operate without any problems and that a so called “expansion joint weak link” could be practically nonexistent.
2 EXAMPLE OF TECHNO-ECONOMICAL OPTIMISATION METHOD

In the example shown in Appendix 1 we have shown the results of the final part of the optimization process on a GAS TURBINE “BLOW-OFF SYSTEM” shown below.

In a confined space around the turbine, preliminary analysis is carried out in [4]CAESAR II pipe stress analysis program and the requirement for expansion joints is established. The location and installation lengths for inserting the joints are being developed in teamwork with Piping Designers and using [4]CAESAR II Expansion Joint Modeler, the proposal for expansion joints manufacturer developed.
This information is then used for the tendering process and to select the preferred Expansion Joints manufacturer. Consequently the selected vendor is brought on board to work together with Piping Designers and Pipe Stress Engineers on a number of technical solutions and cost reductions.

Below are some of the costs saving measures, which have been developed in the process:

Firstly, it was planned where installation length is not limiting, to utilize Double Hinged Expansion Joints for they can take large rotational moments through hinges.

The solution was trailed and found to be producing a satisfactory technical solution but it had two shortcomings: excessive weight, contributing to the cost in the application of required pipe supports and in the higher cost of expansion joints themselves.

However working together with the preferred Expansion Joint Manufacturer a solution was also devised comprising of only Universal Tied Expansion Joints.

The problem here was how to deal with the torsional stiffness. The procedure was established to initially conservatively calculate stiffnesses based on the assumed data and use it in preliminary piping stress analysis runs. However, this would have been responsible for creating high torsional moments on expansion joints and would require piping layout rework. Subsequently by using the data for actual expansion joints from manufacturers design, torsional stiffness was recalculated and torsional moments
reduced to allowable values. Thus in working together with the Expansion Joints Manufacturer we eliminated the need for expensive piping rework. This solution, while satisfying technical requirements, was also providing cost savings in the implementation of pipe supports due to lighter design and also in the cost of individual expansion joints.

In addition, the Expansion Joints Expert then took care of the construction details and optimized the number of expansion joints flanges, further reducing the cost.

Furthermore we have introduced a piping “Cut Short” in front of one expansion joint, pre-stressing it and halving the required movement, which needed to be absorbed. This in return enabled the use of a shorter expansion joint with fewer flanges, thus also reducing the cost.

3 CONCLUSIONS

Use of expansion joints is usually a last resort solution since expansion joints could present maintenance problems due to their fatigue failure mode if the “Traditional method” of design is followed. Only on some occasions however they may be utilized as an economical solution alternative, in extreme cases such as when the alternative is expansion loops of very large diameter pipe of expensive material such as alloy or stainless steel, or where it is necessary to provide a large amount of flexibility in a small space.

It is a complex and difficult task to accomplish and should be left only to experienced Pipe Stress Analysis Engineers to handle with a competent expansion joint manufacturer providing assistance throughout the design stages. However, if the recommendations outlined here are followed closely, the rewards can be significant. Because Techno-Economical Optimization method always results in “low cost – hi quality” solution the client will be awarded with a safe and reliable system for the lowest investment cost.

4 REFERENCES

[1]  BPVC ASME  SEC VIII, Div 1,2, 2007
[4]  Caesar II, Version 5.10.02, Build 080512; Coade Inc; Houston; Texas; USA

5 APPENDICES

Appendix 1  EXAMPLE OF TECHNO-ECONOMICAL OPTIMISATION METHOD
GAS TURBINE “BLOW-OFF SYSTEM ”
EXAMPLE OF TECHNO-ECONOMICAL OPTIMISATION METHOD

APPENDIX 1

GAS TURBINE “BLOW-OFF SYSTEM”
The location and installation lengths for inserting the joints are being developed in teamwork with Piping Designers and using CAESAR II Expansion Joint Modeler, the proposal for expansion joints manufacturer developed.
APPENDIX 1

GT11N2 - TURBINE
BLOW-OFF SYSTEM

OPERATING CONDITIONS

START UP and SHUT DOWN

NORMAL OPERATION

OPERATING CONDITIONS
APPENDIX 1

GT11N2 - TURBINE BLOW-OFF SYSTEM

OPERATING CONDITIONS NOZZLE DISPLACEMENTS

\[ \text{Coordinates: } X = -1619 \text{ mm} \]
\[ \text{Coordinates: } Y = -905 \text{ mm} \]
\[ \text{Coordinates: } Z = -350 \text{ mm} \]

\[ \text{Displacements: } \Delta X = -1.3 \text{ mm} \]
\[ \text{Displacements: } \Delta Y = +2.4 \text{ mm} \]
\[ \text{Displacements: } \Delta Z = 0.6 \text{ mm} \]
COST SAVING MEASURES, WHICH HAVE BEEN DEVELOPED IN THE PROCESS:

Choosing the correct type of expansion joint:

- satisfactory technical solution
- however
- excessive weight =
  - higher cost of spring supports +
  - higher cost of expansion joints +
  - piping system needs more flexibility

the problem here was torsional stiffness
however

working together with the Expansion Joint manufacturer =

- no need for piping layout rework +
- less expensive piping supports system +
- less expensive design of expansion joints
APPENDIX 1

GT11N2 - TURBINE BLOW-OFF SYSTEM

PIECE SUPPORTS SOLUTION

HTCT423373R4
LISEGA TYPE
295218
Fc = 11.8 KN
Fh = 13.4 KN
c = 1333 N/cm

HTCT423373R5
LISEGA TYPE
296218
Fc = 26 KN
Fh = 24.4 KN
c = 2666 N/cm

MBH32BQ003
SUPPORT-3
LISEGA TYPE
293218
Fc = 3.5 KN
Fh = 3.8 KN
c = 333 N/cm

HTCT423373R2
LISEGA TYPE
293118
Fc = 3.5 KN
Fh = 3.3 KN
c = 666 N/cm

HTCT423373R1
LISEGA TYPE
293118
Fc = 3 KN
Fh = 3.5 KN
c = 666 N/cm

Fz = 1 KN

+Z (PIPE RESTING ON STEEL)
### APPENDIX 1

#### GT11N2 - TURBINE BLOW-OFF SYSTEM

**EXANSION JOINTS DATASHEETS**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EXPANSION JOINT</th>
<th>KGS NO.</th>
<th>HTC439618 R1</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATERIAL</td>
<td>HTC439618 R1</td>
<td>Sheet No: 1</td>
<td></td>
</tr>
</tbody>
</table>

**GENERAL**

One end of expansion joint must have a flange size, as ASME B16.5, 100 lb, fl. ASME.

Other end of this exp. joint must have a butt-welding end 2-1/2 diam. in acc. with ASME B16.25.

Nominal length of expansion joint including flange must be 974mm.

The compensator must be possible to cast to a final length of nominal 250mm (field tolerance).

A tie rod direction has to be marked.

**DESIGN CONDITIONS**

- **MATERIAL**: All material must have provisions for CORR.

**TECHNICAL DESIGN REQUIREMENTS**

- **MAX. COMPRESSION EXPANSION**: 2-1/2 IN

**MANUFACTURER INFORMATION FOR TENDER**

**ITEM NO.** | **GT20**
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MANUFACTURER</strong></td>
<td><strong>PIPETECH</strong></td>
</tr>
</tbody>
</table>

#### EXPANSION JOINTS

**MOTIVATION**

- **EXTERNAL PIPE LOADS**
- **STIFFNESS**
- **CONSTANT LOAD**
- **PRESTRESS**

<table>
<thead>
<tr>
<th>MOVEMENT IN COMPENSATION LOCAL COORD. SYS.</th>
<th>EXTERNAL PIPE LOADS</th>
<th>STIFFNESS</th>
<th>CONSTANT LOAD</th>
<th>PRESTRESS</th>
</tr>
</thead>
</table>

### APPENDIX 2

#### GT11N2 - TURBINE BLOW-OFF SYSTEM

**EXANSION JOINTS DATASHEETS**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>EXPANSION JOINT</th>
<th>KGS NO.</th>
<th>HTCCT439618 R2</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATERIAL</td>
<td>HTCCT439618 R2</td>
<td>Sheet No: 2</td>
<td></td>
</tr>
</tbody>
</table>

**GENERAL**

One end of expansion joint must have a flange size, as ASME B16.5, 100 lb, fl. ASME.

Other end of this exp. joint must have a butt-welding end 2-1/2 diam. in acc. with ASME B16.25.

Nominal length of expansion joint including flange must be 974mm.

The compensator must be possible to cast to a final length of nominal 250mm (field tolerance).

A tie rod direction has to be marked.

**DESIGN CONDITIONS**

- **MATERIAL**: All material must have provisions for CORR.

**TECHNICAL DESIGN REQUIREMENTS**

- **MAX. COMPRESSION EXPANSION**: 2-1/2 IN

**MANUFACTURER INFORMATION FOR TENDER**

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<td><strong>PIPETECH</strong></td>
</tr>
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</table>

#### EXPANSION JOINTS

**MOTIVATION**

- **EXTERNAL PIPE LOADS**
- **STIFFNESS**
- **CONSTANT LOAD**
- **PRESTRESS**

<table>
<thead>
<tr>
<th>MOVEMENT IN COMPENSATION LOCAL COORD. SYS.</th>
<th>EXTERNAL PIPE LOADS</th>
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<th>CONSTANT LOAD</th>
<th>PRESTRESS</th>
</tr>
</thead>
</table>

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**Note**: The data provided is a summary of expansion joint specifications and design requirements, including material types, design pressures, and expansion allowances. The tables and figures illustrate various parameters such as compression expansion, maximum pipe loads, and quality tests. The document appears to be a technical manual for expansion joints, providing detailed information for engineering consultants and manufacturers.
APPENDIX 1

GT11N2 - TURBINE BLOW-OFF SYSTEM

MANUFACTURERS SOLUTION