Metal Turbine Exhaust Joints

An analysis of metal and fabric GTX expansion joints

Introduction

Expansion Joint Systems (EJS) does not have a preference when it comes to specifying a Metal or Fabric Turbine Exhaust Joint for an application. It is important, however, to keep in mind that there are differences between the metal and fabric's capabilities. Determining which one to use generally depends on the application specifications.

EJS designs and manufactures both types and has successfully overcome the drawbacks with both designs. Our metal expansion joints are used predominately by Siemens Power Corporation; the largest diameter used is 16'-0" on the V94.3A engine. We have many exhaust joints operating successfully.

The expansion joints, for a large Westinghouse turbine, are used between a hot turbine diffuser and cold HRSG inlet; the internal gas temperature is 1100ºF average. The two fabrics have thermal monitors in 16 locations internally and externally. They are monitored 24 hours a day with 100-hour physical inspections.

This report was originally requested by one of our customers to highlight the positive features of metal turbine expansion joints. EJS feels that there are many good reasons why a metal GTX expansion should be considered over a fabric GTX expansion joint. In order to avoid selling the fabric counterpart short we will examine the features of both types.

Note: With over 20 years experience in the design of both metal and fabric expansion joints, EJS would certainly recommend a metal expansion joint when possible.

History

Metal expansion joints have been successfully used in a wide range of applications since 1940. Their pre-dominant feature is that they are a pressure vessel and they can withstand very high pressures while still absorbing thermal growth.

During the early 70's, the use of elastomeric joints in power plants became popular. They were inexpensive, provided high movement capability with low forces and were not affected by the corrosive media. Because elastomerics were easy to fabricate, many small companies began to manufacture and sell them.

The demand to design fabrics for higher temperatures brought about the multi-layer fabric designs used in industry today. Turbine manufactures became very interested in using fabric expansion joints because it offered lower forces and great movement capability and cost-effective value. The inner layers comprised of insulation to reduce the temperature seen by the outer layers. The theory still holds true today although the new outer layer materials can withstand 500ºF continuous operating temperature. Utilizing pillows and thermal barriers also seems to be effective. A major problem exists today because the complex design of a fabric joint relies on the development of a successful fabric membrane.

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The majority of the failures occur in the metal frames, transitions and liner area. Many manufacturers offer untested products. They may not be unaware of the thermal stress caused by turbine ramp conditions, the deterioration caused by 1100ºF operating conditions, the flow rate and turbulence effects on liners and the transitions. Consequently, over the years fabric turbine exhaust joints have developed a bad name caused by inexperienced companies offering a very poor design. But it was inexpensive!

EJS invests a considerable amount of resources every year in testing and developing high temperature fabrics and frame designs for gas turbine applications. So why would we advise the use of a metal joint? We should probably explain the circumstances we prefer metal joints.

We will look at the drawbacks and pitfalls of the both metal and fabric expansion joint to determine if they solve the problem or if they have negative results in certain circumstances.

Metal Expansion Joints

The following is a series of questions that can help you the user determine the best solution for your application. We also try to offer advice along the way. **Points to consider are highlighted in blue. Questions are in green text.**

Is the unit round or rectangular?

Rectangular metal joints have problems because of corner stress concentrations. They induce high loads and are very susceptible to vibration failure.

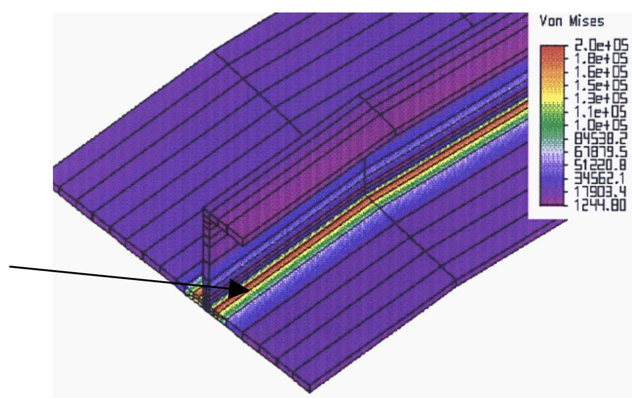
When the joint is rectangular the first option should be fabric. Fabric corners do not have the same problems and the forces do not increase because they are rectangular.

However, on hot fabric flanges the thermal stress is a major problem. The area where the fabric is bolted has to remain relatively cool, therefore, the flange area has to transition from a hot internal ducting to a cool fabric mounting area. On rectangular fabrics the frame corners are high stressed especially during ramp up conditions. If the designer has not addressed this problem, the fabric rectangular will most certainly fail at the corners.

If the expansion joint is round, is there any lateral movement?

On most in-line turbine exhaust applications there should be little to no lateral movement. If the turbine's vertical and horizontal growth is similar to the diffuser or boiler connection, the relative lateral movement is very small. Lateral movements above 1/8" are rare.

Designers often get confused between radial growth and lateral movement. If the unit is supported below it's centerline then the radial growth causes the top of the unit to move upward. This is not lateral movement. Both fabric and metal expansion joints absorb the radial growth naturally, however, with the metal bellows temperature being similar to the internal temperature, the resulting stress imposed on the bellows is lower. If the fabric is supported by stand off flanges that are not properly designed, the resulting radial stress can be catastrophic. As stated earlier, the differential temperature between the fabric attachment point and the internal duct temperature causes significant thermal stress. This is not apparent when the metal bellows is at a similar temperature to the internal duct temperature.



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The thermal stress caused by the temperature difference at the root of a badly designed standoff frame is far too high. Metal bellows usually see a similar temperature to the internal duct temperature, this reduces or eliminates the thermal stress. Metal bellows is able to withstand extremely high temperatures and fast ramp rates without the thermal stress that causes yielding. If lateral movement is present and a rectangular shape is required, a fabric unit should be considered.

On round units with little or no lateral movement, a metal joint will function well. If lateral movement is a requirement on a round application, the metal joint will require more length to accommodate the lateral deflection.

If the expansion joint is round with a small lateral movement, which joint is the least expensive?

The big question, EJS can only answer from our point of view. We design and build both types.

We also feel that we are one of the few manufactures that are successful with both types. Our fabrics are not inexpensive because of the complex design to avoid thermal stress.

In a typical hot to hot application, approximately 14'-0" diameter, a metal expansion joint from EJS will be less expensive. In the long term it will be less troublesome and its life expectancy will be longer than its fabric counterpart. Notice that we selected a 14'-0". A 14'-0" joint can be shipped in one piece and does not require field erection. When field erection is required, the fabric overall costs may be less than a metal joint, as a field erected metal bellows will require factory personnel to weld the bellows together. However, a well-designed fabric is still complex to field erect and if it is not done correctly the chance of early failure is high.

Metal bellows are susceptible to erection damage?

This is true. EJS packages our units in wood containers for safe transportation and field storage. We include adjustment bars on most units, lifting shackles, and a construction cover over the bellows area. We also include complete installation instructions and can provide on site supervision during installation at reasonable rates. Thousands of metal bellows are installed every year without damage. If reasonable care and guidance is used, a metal bellows can be easy to install.

Metal bellows have high compression forces?

As experts in both metal and fabric expansion joints, this comment always raises a smile at EJS because most fabric manufactures do not know what their spring rates are. Lets examine the 14'-0" diameter unit. A typical hot spring rate would be 1460 lb./in, and cold spring rate would be 1824 lb./in. This equals 2.8 lb. of force per inch of circumference for a 1" movement. When requesting a fabric spring rate, ensure it includes the compression resistance of the pillow. Metal bellows spring rates in the axial direction are usually lower than high temperature fabrics with pillows.

Fabric bellows have higher cycle life?

Another frequent comment made by many people. Fabric bellows never failure due to cyclic loading; they fail due to high temperatures that deteriorate their outer layers. The answer is yes-fabric bellows on cycle test equipment last longer than metal bellows. If we now introduce 1100ºF to the test and time at temperature we have a fair comparison.

The metal bellows will outlast the fabric in 100% of the tests. A good fabric will only last 5 - 7 years exposed to 1100ºF.

How many cycles is this on a typical power plant?

100 cycles would be conservative. The 14'-0" unit we have used for the comparison will complete 225,698 cycles with a minimum of 3" axial compression before cyclic failure occurs. This figure is also corrected for creep effects based on a 15-year operational schedule. EJS continually runs in house hot testing of both metal and fabric bellows.

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We speak from experience and actual test results. EJS is a active member of EJMA (Expansion Joint Manufacturers Association). The analysis methods and equations developed by EJMA are used as standards for the design of most bellows manufactured today.

What advice can EJS give for specifying Metal Gas Turbine Expansion Joints?

Use SS 321 for the bellows membrane and SS 321 or 347 for the connection hardware.Continually heating and cooling SS 304 through its sensitization range can lead to intergranular corrosion. SS 321 and 347 are stabilized with titanium and columbium respectively.

Annealing the bellows after forming. This puts the bellows in its best condition to attain high cycle life and reduce the effects of creep fatigue.

Ensure the length allowed to fit the metal bellows is enough to keep the bellows from becoming heated when being welded into the ducting. Welds ends, at least 4" long (preferably 6" to 8" long), should be used to prevent the heat during welding from affecting the bellows during installation.

Always have bellows larger than 60" in diameter shipped with spiders to maintain roundness during site installation. The spiders are left in during installation to ensure the field welding does not cause distortion to an extent where the bellows life will be affected.

Liner thickness and design should be determined based on flow condition including turbulence correction factors. EJS uses liner stiffeners welded to the liner and internal ducting. Experience has shown that the liner welds are susceptible to thermal shock and turbulence stress.

Insist on installation instructions and lifting instructions from the manufacturer. Asking the manufacturer to be present during installation is an added guarantee that the unit will be installed correctly.

- Ensure that the packaging is adequate for transportation and subsequent field storage.
- Construction protection covers are a small cost to ensure the bellows are not damaged during installation. They are removed before operational service begins.

Adjusting the bellows to accommodate field alignment problems should not be allowed. If you suspect that the field will have alignment problems, utilize a simple landing bar to accommodate any adjustments.

The adjusting bars on the expansion joint are to hold pre-set tensions or accommodate axial adjustments only.

We hope this has helped you to consider your choice in using metal bellows in turbine exhaust conditions without reducing the value of fabric bellows. Deciding of which type to use still lies within in each individual application. Nevertheless, quality of design and manufacturing go a long way towards overall success of the expansion joint. The effect of a shut down due to an expansion joint failure needs to be incorporated into the original purchase price evaluation.

Please contact one our product specialist to discuss your specific application. We can evaluate your specification and make the best recommendation for your system.

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"Committed to Quality"

Metal GTX Expansion Joints

Bellows for 140" (406 cm) ND Metal GTX Single Tied Expansion Joint Transition Assembly

Typical internal spider for metal gas turbine exhaust joint

140" (406 cm) ND Metal GTX Expansion Joint Transition Assembly with Tie Rods

Completed Metal GTX Transition Assembly for Siemens Turbine V84.3A

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