Research Paper

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Structural Concepts for Long (Linear) Bodies Undergoing Thermal Expansion

Engineering

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ABSTRACT

Engineering applications often require working at high temperatures. Most metals undergo a thermal expansion when subjected to high temperatures. Hence, a provision for thermal expansion must be provided in components undergoing thermal expansion in order to reduce or eliminate the stress induction in the body. The present paper presents two structural concepts for linear bodies that undergo a thermal expansion during their work cycle. The concepts suggested are generic in nature and can be used for a wide area application involving linear or long bodies. The first concept involves use of Dovetail arrangement and the other one involves use of Linear Bellows. A short description for the automation of the Dovetail arrangement is also presented.

INTRODUCTION

Molecular motion in any metal body is governed by the average temperature of the body. Higher the body temperature, higher will be the kinetic energy of the molecules and thus a higher degree of movement. This molecular movement is reflected as the thermal expansion of the body. Thus, most metals expand when subjected to a temperature rise. The thermal expansion [1], if prevented, gives rise to thermal stresses in the metal body. The thermal stresses can be detrimental to the functional and safety aspects of the body. Thus, in most cases, especially wherein very high temperature rise is encountered, provision for thermal expansion of the body must be provided. In the present paper, two structural concepts that allow free thermal expansion of a body are presented. The concepts are valid only for long or linear bodies, i.e. the longitudinal dimensions are far greater than the lateral dimensions (at least 10 times). The thermal expansion in lateral direction is neglected.

CONCEPT-1: DOVETAIL ARRANGEMENT

The Dovetail arrangement is quite popular in machine tool guide ways. The Dovetail groove (female part) allows only for the linear movement of the Dovetail male part. All other movements are restricted. The structural concept presented here, is as shown in figure-1. The concept can be used for a variety of long bodies, but here as an example, a pipe subjected to a high temperature is considered. The pipe has to be supported as well as allowed to freely expand. The concept presented here has only a partial Dovetail groove (not through) as shown in figure-1. This prevents the linear movement other than thermal expansion. When the body is cooled the structure returns to its initial default position. The supports can have a provision for height adjustment (nut and screw or rack and pinion) as well.

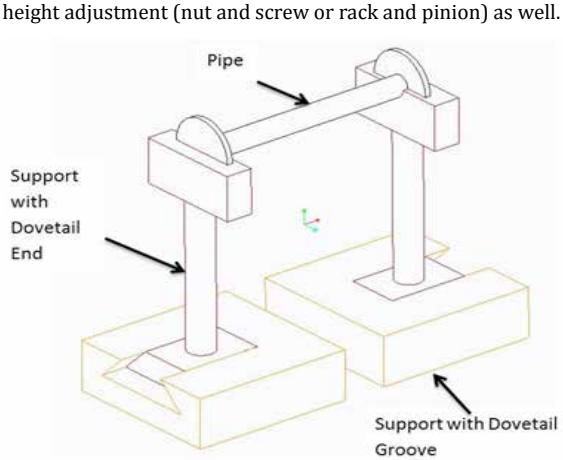


Figure-1: Dovetail Arrangement

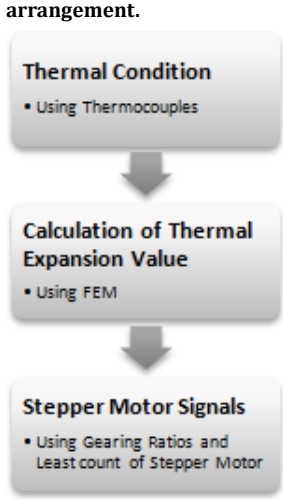
KEY FEATURES

- The key features of the Dovetail arrangement are as listed below:
- The arrangement allows for only thermal expansion.
- The arrangement confines the structure in the vertical plane.
- The arrangement is highly simple and hence robust.
- The provision for height adjustment can be given in the structure.
- The structure must expand parallel to the Dovetail arrangement.

SCOPE OF AUTOMATION

It is easy to automate this concept for a sophisticated purpose. The Dovetail movement can be made motorised. The motors in turn would get signals based on the thermal condition of the component. A conceptual flow-chart is as shown in figure-2. The simple arrangements like nut and screw or rack and pinion can be used for motion conversion from rotary to linear. The reason behind making the system automated is safety and sophistication. In case, the structure fails to expand, it can lead to very high stress induction and thus may prove unsafe in the working condition. Provisions for alarm in case of structural failure can be made. The thermal control can also be governed based on the feedback from the structure. Strain gauges can be mounted on the system and the strain in the body can be monitored. The strain values can be used as feedback values for thermal control. Provision for a total thermal cut-off can also be made, in case the strain value has reached the allowable value.

Figure-2: Conceptual Flow-Chart for Automation of Dovetail arrangement.



CONCEPT-2: LINEAR BELLOWS

Linear Bellows are inherently flexible in longitudinal direction. The structural concept presented here, is as shown in figure-3. The concept can be used for a variety of long bodies, but here as an example, a pipe subjected to a high temperature is considered. The pipe must be made free to expand longitudinally. Various kind of linear bellows are available in the market; one of them is as shown in figure-3. This arrangement is more suitable in complicated arrangements wherein only one part is subjected to high temperature and it is desired not to disturb other components of the system.

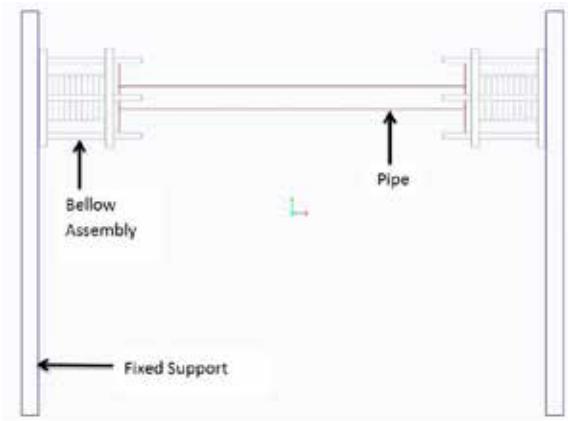


Figure-3: Linear Bellows Arrangement

KEY FEATURES

- The key features of the Linear Bellows arrangement are as listed below:
- The arrangement allows only for thermal expansion.
- The arrangement confines the structure in the vertical plane.
- The linear bellows easily fit in the entire arrangement. If the structure is complex and other components might interfere with the structural changes, then Linear Bellows can come very handy.

APPLICATIONS

The use of the aforementioned concepts is generic for linear bodies undergoing thermal expansion. Typical application area would include the thermal expansion of pipes, trusses, metal-beams, Heat-Pipes [2] etc. In research field, a new concept for particle acceleration, called the Plasma Wakefield Acceleration [3], is emerging. Equipment involving Plasma Wakefield Acceleration uses a Heat-Pipe as one of its components. The suggested concepts can be used in such applications as well.

CONCLUSION

Two concepts for accommodating thermal expansion of linear or long bodies have been presented. The concepts suggested are very generic, in the sense that they can be used for wide variety of applications with slight modifications. The concepts are simpler and hence present a robust solution. An idea for the automation for the Dovetail arrangement has also been presented.

REFERENCE

[1]. A.S. Usmani, J.M. Rotter, S. Lamont, A.M. Sanad, M. Gillie (2001), "Fundamental principles of structural behaviour under thermal effects". Fire Safety Journal, ELSEVIER, 36 (2001) 721–744. | [2]. Reay D, Kew P. (2006); Heat Pipes, 5th edition. Butterworth-Heinemann, U. S. A. | [3]. Presentation on "Quasi-Monoenergetic Plasma Wakefield Acceleration at FACET" by Mark Hogan at SLAC on September 19th, 2013 |