Material selection and mechanical behavior evaluation of expansion joints

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Abstract

Based on the elastoplastic theory, the finite element model of the solid expandable pipe joint is established. The nonlinear expansion process of the casing is numerically calculated and simulated. The driving force required for the expansion process of the expansion tube materials 316L and SA106B was analyzed separately. The connection strength of the threaded joint during the expansion process and the change of the thread seal were discussed. The mechanical behavior of the joint part was evaluated. After that, the selection of the material of the expansion tube and the structural optimization of the thread provide a reference basis.

Keywords

Expansion pipe joint; thread; finite element; expansion force; mechanical behavior.

1. Introduction

The expansion tube technology began in the late 1980s. After 20 years of development, it has been widely used in drilling, workover and completion operations, showing great potential [1]. Similar to the connection between the ordinary casings, the expansion pipes are also connected by threads, but there is a higher requirement for the strength and sealing of the threads, which requires the material of the expansion pipe and the corresponding expansion pipe joints. The expansion mechanical behavior of the material was evaluated. In this paper, with the help of finite element software, the threaded part of the solid expansion joint section and the finite element model of the expanded expansion cone are established. The finite element simulation calculation is carried out on the expansion process of the expansion joint of different materials, and the thread connection in the expansion process is analyzed. The state change and the driving force of the expansion cone focus on the joint strength and thread sealing performance of the expansion process. Through analysis, it provides a theoretical basis for the material selection and structural optimization of solid expansion pipe joints quickly and accurately.

2. Finite element basic theory

2.1 Basic theory of elastoplasticity of expansion tube

Since the expansion process of the expansion tube is the plastic forming problem of the metal material, the elastoplastic material appears as a material nonlinearity in the constitutive relationship, and usually needs to be combined with the flow theory and the incremental method. According to the elastoplastic theory of Prandtl.L-Reuss.E: ideal elastoplastic material, when the Mises yield criterion is used, the total strain increment at any point inside the object is the sum of the elastic strain increment and the plastic strain increment, namely:

$$d\varepsilon_{ij} = d\varepsilon_{ij}{}^{e} + d\varepsilon_{ij}{}^{p}$$

Remark: $\varepsilon_{ij}^{\ e}$ is the elastic strain of the object;

$\varepsilon_{ij}^{\ p}$ It is the plastic strain of the object.

The strain of the object in the elastic phase is determined only by the final stress state, and is independent of the deformation process. The elastic strain increment can be written by generalized Hooke's law as: $d\varepsilon_{ij}^{e} = \frac{1+\upsilon}{2} d\sigma_{ij} + \delta_{ij}\sigma_m$ .According to the Levy.M-Mises equation, the plastic strain increment is expressed as: $d\varepsilon_{ij}^{p} = d\lambda\sigma_{ij}$.

Since the plastic forming of the expansion tube is a large deformation process, the elastoplastic constitutive of the small deformation is not applicable, but the time interval in the expansion tube process can be infinitely divided into small time intervals dt, and then the small deformation elastoplastic constitutive is used. The large deformation elastoplastic constitutive model can be obtained by removing the equation at a small time interval dt. which is:

$$\frac{d\sigma_{ij}}{dt} = \frac{E}{1+\upsilon}\left[\frac{d\varepsilon_{ij}}{dt} + \frac{3\upsilon}{1-2\upsilon}\delta_{ij}\frac{d\varepsilon_m}{dt} - \frac{d\lambda}{dt}\sigma_{ij}\right]$$

$$\frac{d\varepsilon_{ij}}{dt} = \frac{1+\upsilon}{E}\frac{d\sigma_{ij}}{dt} - \frac{1-2\upsilon}{E}\delta_{ij}\frac{d\sigma_m}{dt} + \frac{d\lambda}{dt}\sigma_{ij}$$

Remark: σ_{ij} Is the stress tensor; E is the elastic modulus; υ is the Poisson's ratio; ε_{ij} is the strain bias.

2.2 Establishment of finite element model

The main structural parameters of the expansion joint section are Ø194×10mm and the expansion ratio is 9.8%. The taper of the threaded section is 1:16, and the thread taper is 1:16. The API standard is trapezoidal thread.

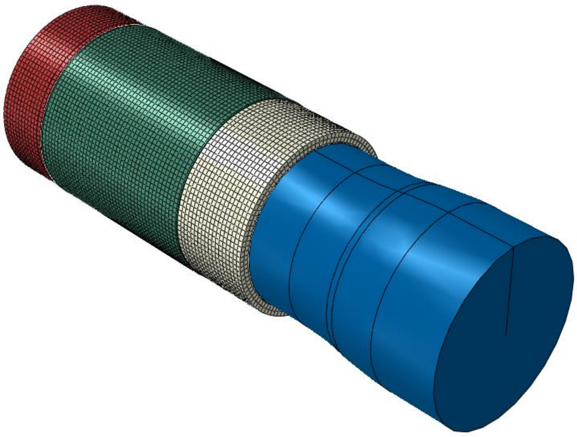


Figure 1 Finite element model of expansion joint and expansion cone

3. Numerical calculation content and result analysis

3.1 Setting of related parameters

The materials of this expansion joint are preferably 316L and SA106B, and the material properties are shown in the following table. With rigid-flex contact, the expansion cone and the joint section are in universal contact with a friction coefficient of 0.1.

Table 1 Preferred Material Attribute Table

Material properties	SA106B	316L
E	2.09×105 MPa	1.93×105
ν	0.3	0.3
σs	295 MPa	229MPa

3.2 Analysis of calculation results

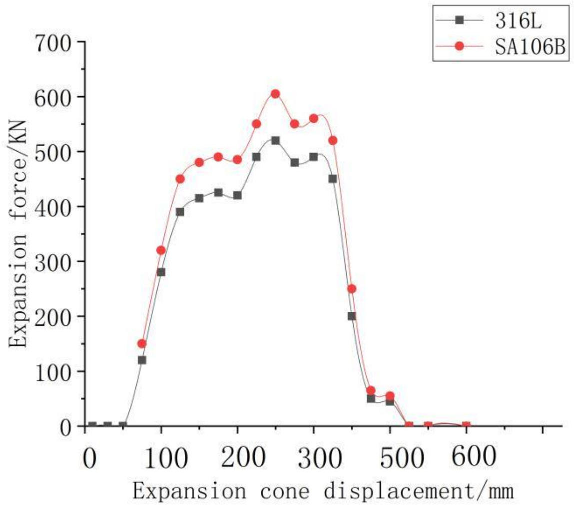
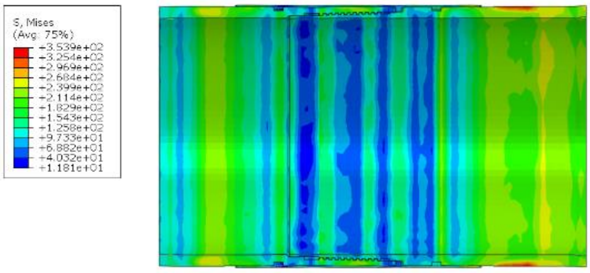
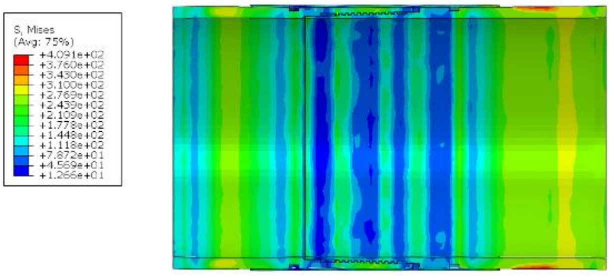


Figure 2 Expansion force required for expansion joints of different materials

It can be seen from Fig. 2 that the maximum expansion force required for the 316L and SA106B materials is 530598N and 609542N, respectively, and the corresponding expansion fluid pressures are 18.14MPa and 20.84MPa respectively. It can be seen that the 316L material has better swellability than the SA106B.

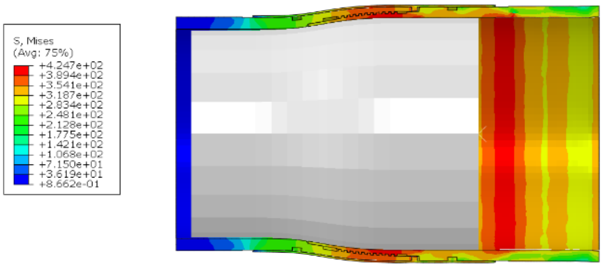


(a) 316L

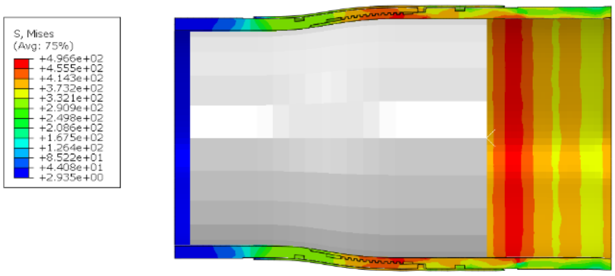


(b) SA106B

Figure 3 Residual stress distribution after expansion of different materials



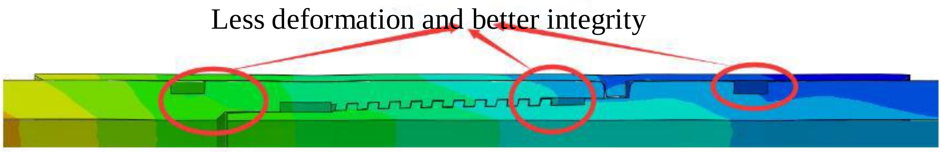
(a) 316L



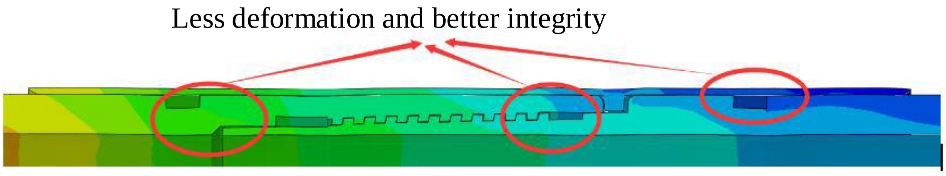
(b) SA106B

Figure.4 Mises stress distribution during expansion molding of different materials

It can be seen from Fig. 3 and Fig. 4 that the maximum Mises stress of the 316L and SA106B materials is 353.9MPa and 409.1MPa respectively after the thread expansion of the Ø194×10mm expansion casing; during the expansion molding of the expansion casing, 316L and The maximum Mises stress of the two materials of SA106B is 424.7MPa and 496.6MPa respectively; the maximum Mises stress formed in the expansion molding of the two materials is less than the tensile strength of the corresponding material, but in the actual engineering, if the safety factor of 1.3 is considered, then SA106B The maximum Mises stress during the forming process will be as high as 645.6 MPa, which is close to the corresponding material tensile strength of 670.7 MPa, and the safety is low. It can be seen that the above two materials can satisfy a given expansion molding condition, but from the viewpoint of work safety, it is better to select 316L material.



(a) 316L



(b) SA106B

Figure.5 Deformation of different materials after expansion molding

It can be seen from Fig. 5 that after the thread expansion of the Ø194×10mm expansion sleeve, the threaded joint and the nose end of the 316L and SA106B materials are less deformed and have better integrity, which satisfies the structural integrity of the expanded thread after expansion. Requirement; compared with SA106B material, 316L material has less deformation and better structural integrity; in addition, according to the rubber seal ring, it has self-sealing characteristics after assembly, and the radial size of the sealing ring placement position is relatively changed after expansion. Small, therefore, the sealing performance after expansion is further enhanced, both of which meet the requirements of sealing integrity after expansion of the expanded thread.

4. Conclusion

1) The model established by the three-dimensional limit element method is used to simulate the expansion process of the threaded joint of the expansion joints intuitively and accurately. The analysis results are basically in line with the data in domestic and foreign literatures.

2) The expansion tube adopts 316L material with less required expansion force and better expandability.

3) Both 316L and SA106B pipes can meet the requirements of sealing integrity after expansion expansion.

References

[1] Hou Ting, Ning Xuetao, Wang Bin et al. Application of expansion pipe technology in drilling and completion engineering [J]. Sino-foreign Energy. 2015, 20 (6): 48.

[2] Fu Shengli, Gao Deli. Three-dimensional finite element numerical simulation of expansion process of expandable tube [J]. Journal of Xi'an Shiyou University, 2006, 21(1): 54~55.

[3] Guo Huijuan, Yang Qingbang, Xu Binggui. Numerical simulation of solid expansion tube and optimization design of expansion cone cone angle[J].Petroleum Machinery.2010,38(7):30~32.

[4] Yuan Guangjie, Lin Yuanhua, Yao Zhenqiang, et al. Study on contact stress field of API trapezoidal casing thread connection[J].Iron & Steel,2004,39(9) : 35-38.

[5] Yang Dongping, Wang Deyong, Gao Xueshi, et al. Oil casing expansion simulation and expansion cone angle design [J]. Pipeline Technology and Equipment. 2007, (2): 27~28.