Applied Mechanics and Materials Vols. 353-356 (2013) pp 3316-3319
© (2013) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMM.353-356.3316

Bending and Moment Stability in Reel Mechanisms

Zahiraniza Bt Mustaffa[1,a], Mohammed Badri Taufiq[2,b], and Thar M. Badri[1,c]*

[1]Civil Engineering Department, Universiti Teknologi PETRONAS, Bandar Seri Iskandar, 31750 Tronoh, Perak, Malaysia.

[2]Mechanical Engineering Department, Collage of Engineering, the University of Mustansiriyah, Alrosapha, 46007 Almustansiriyah, Baghdad, Iraq.

[a]email: zahiraniza@petronas.com.my, [b]email: moh.badri55@yahoo.com, [c]email:t.albarody@ymail.com,

Keywords: Reel pipe lay, Bending stability, Moment stability, spooling and laying mechanism.

Abstract. This paper is examining the instabilities of reeled pipelines during spooling of initially straight or laying of initially bent pipe and sifting parametrically number of reel lay mechanisms. A combination of composite materials is studied and number of bending stability cases (i.e., ovalization and bifurcation "buckling") is discussed. It is demonstrated that composite pipeline exhibit more stability than Steel pipes. The bending stability of spooled pipeline is examined in detail and, in particular, the case on the diameter drum of the reel lay system. Moreover, results on the strain energy release in the reel lay system are presented, extending the findings of previous works on controlling the spooling or laying mechanism.

Introduction

Reel pipe lay is a conventional method of installing pipelines in the ocean, when the pipeline is wound on a massive reel mounted on the deck of a pipe lay barge [1]. Pipelines are generally spooled into a reel at an onshore spool-base facility. The first commercial application of reeled pipeline technology was available by Santa Fe Corporation in the early 1970s [2]. Reel technology also provides:

1. A safer and more stable work environment, thus speeding pipeline installation.
2. Faster installation "one to two miles per hour" that's up to 10 times than conventional pipe lay.
3. Less weather dependency, pipelines can be spooled off during a short weather window, extending the normal construction season.
4. Spooling pipelines up to 18 inches in diameter.
5. Less labor costs by facilitating; welding under protected and controlled conditions, corrosion coating, x-raying, and testing to be accomplished onshore, which are generally lower than the operating costs of these equipment when carried on the pipe lay barge.

However, the main disadvantages of the reeling method are:

1. Connecting the ends of the pipeline segments.
2. The pipeline is deformed plastically twice, when spooled into a reel and when straightened.
3. Wound pipeline exhibit compression in the positive bending side cause wrinkles and tension in the negative bending side cause some thinning of the wall result in loss of yield strength in localized areas which brought a Bauschinger effect.
4. Spooling of pipeline cause some loss of stiffness result in ovalization may lead to upheaval bifurcation "buckling". Therefore, amount of time require when laid the pipeline, to remove the buckle.

After an evaluation of recently improvement of reeling matters [3-6], it could be said that the literature dealing with computational work in reel pipeline concerning bending phenomena in general and composite pipelines in particular, are rather scarce. In this Paper, new issues elicited by the pipe parameter and common composite materials are addressed.

Problem Statement

Considering a reel lay system consists of an installation reel, rollers and straightener. The installation reel holds the pipe tension e.g., see Fig. 1. Through a set of rollers the pipe will routed. Then the pipe will sent through a tower has a pipe straightener. In fact, to spool a pipeline in large variances in laid angle, the straightener was assumed to be pivoted and mounted to rails which allow the whole straightener to slide. Therefore, examining the plastic-deformation that occurs in reeled pipeline made from different composite materials is ideal in order to design spooling or laying mechanism and need to:

1. Simulate the stress, strain and deformations generated by the rapid release of strain energy that occurs within a material during plastic deformation "spooling or laying" of pipeline.
2. Drawn these stress, strains and deformations, versus drum diameter examining different radius of pipeline, to optimize the reel lay pipeline mechanism.

Three type of materials are used in the current examine and listed in Table 1.

Table 1. The materials properties.

Material	E_1 GPa	E_2 GPa	E_3 GPa	G_{13}, G_{12} GPa	G_{23} GPa
Gr−Ep[a]	137.9	8.96	8.96	7.2	6.2
Br−Ep[a]	206.9	20.6	20.6	6.9	4.1
Steel[S97]	206.0	206.	206.	7.9	7.9
	Y^b MPa	υ_{12}	υ_{13}	υ_{23}	ρ kgm−3
Gr−Ep[a]	1500	0.30	0.30	0.49	1450
Br−Ep[a]	1420	0.30	0.25	0.25	1950
Steel[S97]	990	0.27	0.27	0.27	7850

a; At (120°C Cure) and $V_f = 60\%$ (fabric). b; Y= Ultimate strength

Analytical model

If we consider the pipe behave as rope "a negligible flexural stiffness, and inertia", it would take up the dashed straight form shows in Fig. 1. It's obvious that the rope imply a step change on bending moment at the point of contact (c) between the pipe and the reel. However, if the configuration taken up as linear elastic pipe with flexural rigidity EI, reeled into a drum of radius R under a tension T, the spooling bending moment be as

$$M_{\text{spooling moment}} = EI \times 1/R,$$

But the bending moment on the lever arm side equal to:

$$M_{\text{lever arm}} = T \times \delta$$

where δ is the offset. While the bending moment must be continuous at the contact point (c); $M_{\text{spooling moment}} = M_{\text{lever arm}}$, and the offset is:

$$\delta = EI/RT,$$

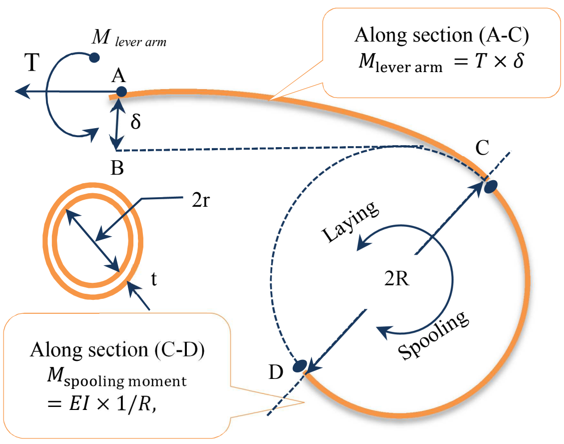

Fig. 1, Schematic of pipeline reeling mechanism.

Result and Discussion

An examination on stresses, and strain, of reeled pipeline made of common composite materials and subjected to tension load is accomplish first. Then Table 2, displays the maximum reel drum diameter that pipeline to be bend plastically "beyond the elastic zone but before the ultimate point". In Table 2, it is clearly seen that composite materials appear more applicable to be reeling into drum of small diameter, than steel. That's obvious, because the ratio of yield to ultimate strength of the nominated composite materials are higher than steel.

Table 2. Maximum reel drum radius (R) in (m)[a].

Type of materials	Radius of the reeled pipe (r)		
	150mm	100mm	75mm
Gr–Epb	13.789	9.193	6.894
Br–Epc	21.855	14.570	10.927
SteelS97	31.212	20.808	15.606

a; calculations obtaind based on: $r/R > Y/E_1$

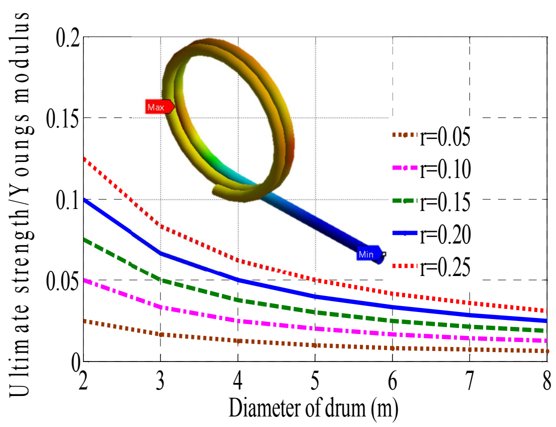

Fig. 2, The maximum drum diameter that composite pipeline could reel into.

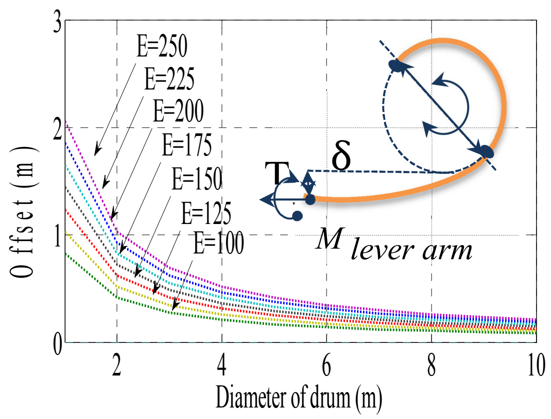

Fig. 3, The offset analysis for wide range of stiffness (e.g., E in GPa) of composite pipeline.

However result in Fig. 2, and Fig. 3, shows a rabid release of strain energy that induced into the composite pipeline during spooling process or laying installations of composite pipeline. In additional, composite pipeline found could lay without strain energy relaxation, which speeds up the insulation process.

Conclusion

In this paper, a composite pipeline that spooled by reel lay system consists of an installation reel, rollers and straightener are solved theoretically. Thus far, the accurate treatment of strain energy "the plastic-deformation" that induced into the reel pipeline yielded rather sophisticated displacement and stress resultant. A supplement digression on the implication of the effects of pipeline parameters, composite properties, and reeling scheme on the offset and drum diameter are investigated. The following features can be concluded;

1. Even though steel reel pipelines are flexible enough when reeling, but not stabile enough as Gr-Ep(AS) and Br-Ep reel pipelines.

2. Although Gr-Ep reel pipeline shows a rigid behavior, it's required higher spooling loads. But it is found reeled into small drum diameter, better than Br-Ep with less spooling effort.
3. It is found that Gr-Ep(AS) and Br-Ep composite pipeline should be spooled or laid with large offset differing from Steel pipeline.

The previous features are considered of particular interest in designing of composite reel pipeline, or may serve as a reference in developing the wounding pipe. In additional, the presented simulation can improve the benchmark solutions for judging the existence of imprecise models and other numerical simulation.

Acknowledgments

The authors would like to acknowledge University Technology PETRONAS for sponsoring this work.

References

[1] Technology. Pipelay Vessels and Techniques. PetroMin Pipeliner Jan 2012; Available from: http//www.pm-pipeliner.safan.commagppl0112t50.pdf.
[2] Guo, B., et al., Offshore Pipelines. 2005: Elsevier Inc.
[3] Lyle Stockstill, B.C., Reel pipeline laying ship and method, in United state Patent. Apr. 29, 2003, Torch Offshore, Inc., Gretna (US): LA (US).
[4] Karamanos Spyros A., Bending instabilities of elastic tubes International Journal of Solids and Structures, 2002. 39: p. 2059-2085.
[5] Karamanos S. A., Stability of elastic tubes under in-plane bending. , in Internal Research Report,. 2000, University of Thessaly: Volos, Greece.
[6] Karamanos S. A., Tassoulas J. L., Tubular members I: Stability analysis and preliminary results Journal of Engineering Mechanics ASCE 1996a 122 (1): p. 64-71.
[7] Karamanos S. A., Tassoulas J. L. , Tubular members II: Local buckling and experimental verification. Journal of Engineering Mechanics ASCE, 1996b 122(1): p. 72-78.
[8] Karamanos S. A., Tassoulas J. L. , Stability of inelastic tubes under external pressure and bending. . Journal of Engineering Mechanics, ASCE 1991. 117 (12): p. 2845-2861.
[9] Corona E., Kyriakides S., On the collapse of inelastic tubes under combined bending and pressure. International Journal of Solids and Structures 1988. 24 p. 505-535.
[10] Shaw P. K., Kyriakides S. , Inelastic analysis of thin-walled tubes under cyclic bending. International Journal of Solids and Structures 1985 21(11): p. 1073-1100.
[11] Badri, T. and H. Al-Kayiem, Free Vibration Analysis of Structronics Shell, in Trends in Intelligent Robotics, Automation, and Manufacturing, S.G. Ponnambalam, Editor. 2012, Springer Berlin Heidelberg. p. 322-330.
[12] Al-Kayiem, H. and T. Badri, Transient Analysis of Structronics Shell, in Trends in Intelligent Robotics, Automation, and Manufacturing, S.G. Ponnambalam, Editor. 2012, Springer Berlin Heidelberg. p. 313-321.
[13] Reddy J.N., Mechanics of Laminated Composite Plates and Shells. 2004, New York: CRC Press.