Design And Optimization of Sandwich Pipe For Deep Water Applications

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Abstract:

The application of sandwich pipes related to water depth beyond 1500 m is increases day by day. Efficient sandwich pipe design is a complex problem in the current scenario. The design and optimization of sandwich pipe is a very complex. In the current research Taguchi method is carried out for optimization of the design of the sandwich pipe for deep water applications. Six design parameters to be considered as input factors: Material of the outer pipe and the inner pipe, thickness of the outer pipe and the inner pipe, core material and outer pipe diameter Taguchi analysis is carried out to optimize the design parameters for the output of technological characters. Technological output considered are Vonmises stress, maximum shear stress, and deformation and heat flux. The optimization process will be carried out based on orthogonal array. Modeling and analysis for Vonmises stress, shear stress and heat flux will be done using Catia and Ansys and software's.

Keywords*:* *Taguchi, Optimization, Sandwich, Catia.*

Introduction:

A sandwich consists of three layers which consist of an internal pipe, external pipe and core pipe, in which the external has high strength. Internal pipe is commonly known as the product pipe, which is mostly designed to carry the internal pressure and transfer the products safety. The core layer is thick comparatively. The core layer is designed to provide thermal insulation, to improve the structural performance of the system by conveying the external pressure from the external pipe to the product pipe, or serve as a dual insulation and structural purpose. The outer pipe known as sleeve pipe is the structural part of the system and separates the product, product pipe, and core from the surrounding environment new concepts for subsea pipelines and risers have been proposed to achieve flow assurance in the deep-water environment. Both pipe-in-pipe (PIP) and sandwich pipe (SP) configurations have been considered as alternatives for the single wall pipe (SW).

Sandwich panel concept is recent, and several studies are under development to support its implementation. Numerical studies and experimental collapse tests indicate high structural capacity compared to SW and PIP. Usually, the SP is divided into three layers: two internal and external thin layers and a thick central core as the annular.

Literature Review:

CASTELLO, X. AND ESTEFEN [1], S.F (2005) in his paper stated that the sandwich pipe is suitable for 3000m water depth application and was analyzed for ultimate strength under combined external pressure and bending for several degrees of adhesion between the polymer annular and the outer steel pipe. In his other paper [2] he has an efficient numerical model of the adhesion failure was employed, where the bonding strength of the outer steel pipe and polypropylene interface is simulated by the maximum shear stress supported by the union. Non-linear springs associated with contact surfaces were used.[3]In this work, three Sandwich Pipes employing different annular materials are numerically collapsed by external pressure to be compared to a PIP system.[4] In his another work, after the structural analysis results have indicated good potential, another simulation was performed regarding to the insulation requirement. Two polymers with better thermal properties than polypropylene were additionally selected and employed in Sandwich Pipes designed for a hypothetic oil field. [5] In his work a comparative study between Sandwich Pipes and a Pipe-in-Pipe system for a hypothetical oil field is presented. The pipelines were designed to meet the same thermal insulation and mechanical strength requirements following a simplified design procedure based on those commonly used in industry.

DE.VILLE, F. VAN DEN ABEELE, T.GIAGMOURIS, E. ONYA, J. NJUGUNA[6] 2014 in his work he done experimental study on different numerical approaches to stimulate the structural response of a Pipe-in-Pipe system were reviewed and compared. An equivalent diameter approach was proposed to stimulate fully bonded (complaint) pipe-in-pipe systems, replacing both pipes by one single pipe with equivalent mass and stiffness.

Gap Identified:

Most of the previous work is done on strength analysis and thermal insulation of Sandwich pipe for the given particular input parameters. There is no work is done to find out the optimum combination of input parameters to obtain best strength and thermal properties.

So the present work concentrates on finding the optimum combination of input parameters and the influence of each input parameter on the output parameters (Strength and Thermal Insulation).

TAGUCHI DESIGN:

The following six input parameters with different levels (Table 1) of sandwich pipe is considered for the strength analysis

CORE MATERIALS
INNER PIPE MATERAIL
OUTER PIPE DIAMETER
INNER PIPE THICKNESS
OUTER PIPE THICKNESS
OUTER PIPE MATERIAL

The first two parameters are with four levels and remaining is with two levels so it is mixed level. For the above mixed level we considered orthogonal array of L16. Numerical Simulation is done for all the 16 combinations for Equivalent Stress and Deformation using Ansys (Depth of water 1500 m and fluid pressure inside the pipe is 12 MPa) Taguchi analysis is done using Minitab software.

S. No	PARAMETERS	LEVELS			
		Level 1	Level 2	Level 3	Level 4
1	Core Materials	CONCRETE	POLY PROPYLENE	HIGH DENSITY POLY ETHYLENE(HDPE)	POLY CARBONATE
2	Inner Pipe Material	STEEL X-60	STEEL X-65	AL 1060	STEEL X-56
3	Outer Pipe Diameter	323.9	355.6	-	-
4	Inner Pipe Thickness	13.3	15.1	-	-
5	Outer Pipe Thickness	26.6	27.7	-	-
6	Outer Pipe Material	STEEL X-60	AL 1060	-	-

Table 1: Parameters & levels considered for Taguchi analysis

Modeling of Sandwich Pipe

Modelling of sandwich pipe is done using the Catia V5 software, for the various combinations that were obtained in the Taguchi Design.

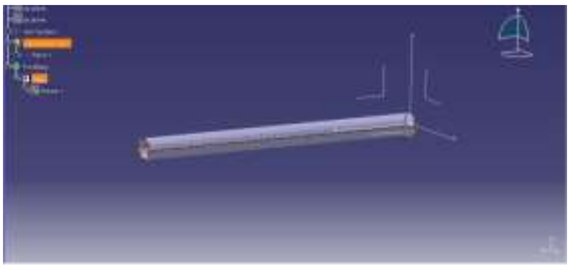


Fig 1: Outer Pipe

Fig 2: Core Pipe

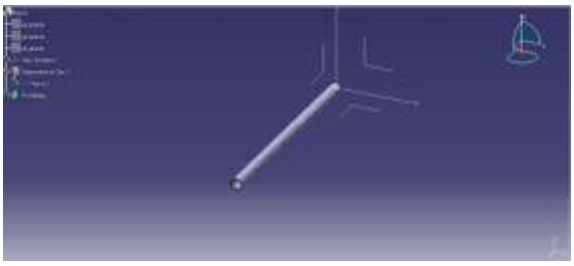


Fig 3: Inner Pipe

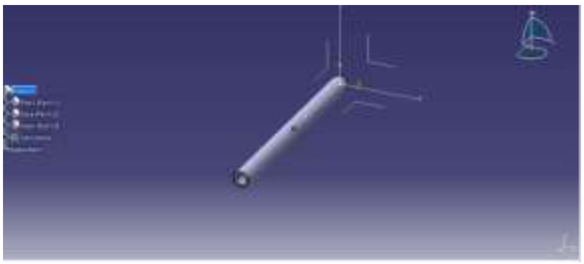


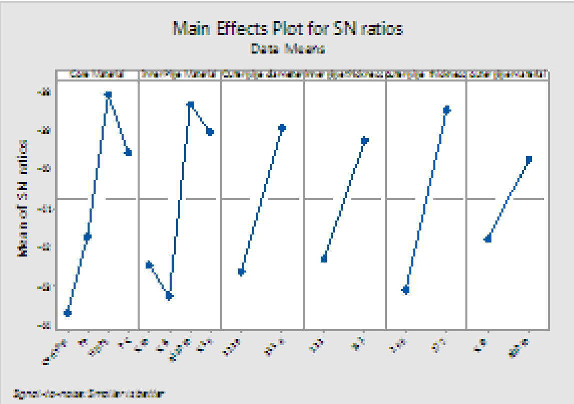
Fig 4: Assembly

The various combinations that are obtained from the taguchi design are tabulated and the corresponding Vonmises stresses are found using Ansys software.

combination No	Core Material	Inner Pipe Material	Outer pipe Outer diameter	outer pipe thickness	Outer Pipe Inner Dia	inner pipe thickness	Inner Pipe Outer Dia	outer pipe material	Deformation mm	Equivalent Stress MPa
1	Concrete	X60	323.9	26.6	297.3	13.3	232.4	X60	0.28356	358.46
2	Concrete	X65	323.9	26.6	297.3	13.3	232.4	Al1060	0.36559	391.82
3	Concrete	AL1060	355.6	27.7	327.9	15.1	234.2	X60	0.050482	75.885
4	Concrete	X56	355.6	27.7	327.9	15.1	234.2	Al1060	0.040464	51.22
5	Polypropylene	X60	323.9	27.7	296.2	15.1	234.2	X60	0.057208	126.58
6	Polypropylene	X65	323.9	27.7	296.2	15.1	234.2	Al1060	0.16528	120.93
7	Polypropylene	AL1060	355.6	26.6	329	13.3	232.4	X60	0.093746	136.31
8	Polypropylene	X56	355.6	26.6	329	13.3	232.4	Al1060	0.14811	106.32
9	HDPE	X60	355.6	27.7	327.9	13.3	232.4	Al1060	0.10823	79.623
10	HDPE	X65	355.6	27.7	327.9	13.3	232.4	X60	0.42534	70.75
11	HDPE	AL1060	323.9	26.6	297.3	15.1	234.2	Al1060	0.07795	66.31
12	HDPE	X56	323.9	26.6	297.3	15.1	234.2	X60	0.047686	109.4
13	Polycarbonate	X60	355.6	26.6	329	15.1	234.2	Al1060	0.10873	85.79
14	Polycarbonate	X65	355.6	26.6	329	15.1	234.2	X60	0.065201	133.52
15	Polycarbonate	AL1060	323.9	27.7	296.2	13.3	232.4	Al1060	0.079179	66.768
16	Polycarbonate	X56	323.9	27.7	296.2	13.3	232.4	X60	0.045474	106.45

Table 2: Vonmises stress results for the various combinations

SN Ratio Curve: From S/N ratio graph the optimum combination is determined.



Graph 1: SN Ratio curve

OPTIMUM COMBINATION RESULT

- **Core Material:** High Density Poly Ethylene
- **Inner pipe material** :AL1060
- **External Pipe Diameters:** 355.6 mm
- **Inner pipe thickness** :15.1 mm
- **Outer pipe thickness: 27.7** mm
- **Outer pipe material**: Al 1060

For this optimum combination we have done the modelling and numerical simulation for strength and deformation. Thermal analysis is also conducted and heat flux is determined.

Analysis:

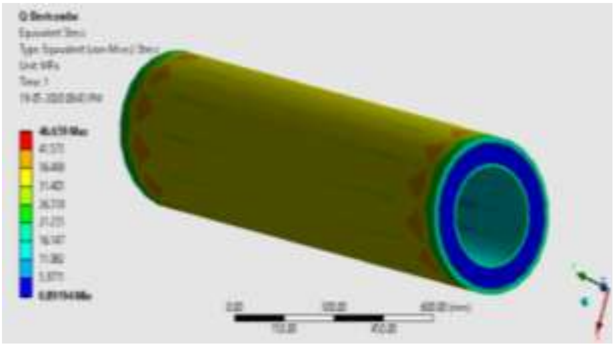


Fig 5: Equivalent Stress

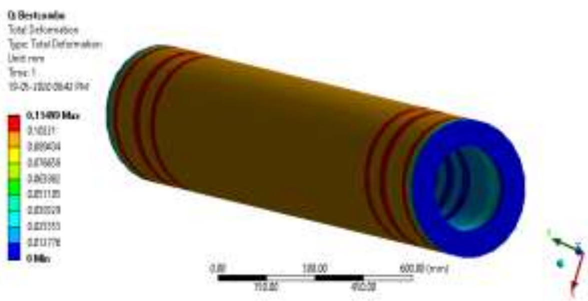


Fig 6: Shear Stress

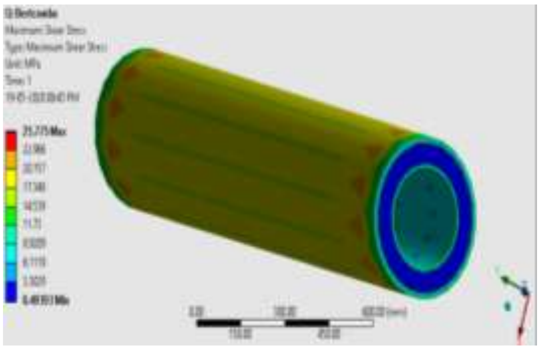


Fig 7: Total Deformation

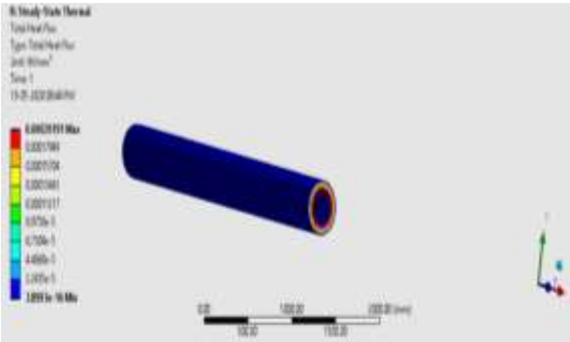


Fig 8: Heat Flux

Conclusion:

In this work, we have considered the basic dimensions and materials for the pipe and Taguchi optimization technique is used to find the best combination (i.e., geometric dimensions & materials) for the outer, core and inner pipes. Equivalent stress, shear stress and heat flux are found out for the best combination that is obtained in the taguchi analysis.

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