The research into compensatory possibilities of straight pipes in pipeline routes with cambers

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Abstract. In this paper, we studied the current state of the design, manufacture and installation of marine pipelines, and considered the problem of manufacturability improvement marine systems pipelines at the stage of designing, providing the possibility of manufacturing the pipes without taking actual sizes and its solution within the framework of the research of the interrelation of configuration and compensation possibilities of the pipeline routes. The problem of compensatory possibilities of straight pipes on pipeline routes with a camber or with two and more cambers was examined. It was established that at simultaneous rotation of two different pipes with parallel ends, the end point moves along the surface (if the axes of these pipes are not parallel); at rotation of three or more pipes with three non-coplanar axes (i.e. not lying in the same plane) the compensation range is a three-dimensional body. The method of calculating the possible compensation area was improved in order to reduce the amount of computation. As part of the hypothesis about the relationship of the configuration and compensatory capabilities of the design pipeline routing, the idea of using straight pipes to move the pipeline route in order to compensate for errors in the manufacture of pipes and the installation of rigidly fixed connections of equipment, saturation products, etc., was presented, which ensured the collection of the route pipes.

1. Introduction

The development of science and the application of new technologies in the shipbuilding industry has turned the vessel into a complex technological complex, consisting of various types of equipment, mechanisms and structures, which are provided by pipeline systems [1-8]. The emergence of new types of multifunctional vessels, the complexity of the equipment used entail an increase in the number of pipes for various purposes and configurations that need to be placed compactly on the vessel [9-15]. The length of ship systems pipelines and systems of power plants on modern large ships is tens of kilometers [2]. Thus, the length of pipeline systems on the tanker “British Progress” is 81 km [16, 17].

In modern shipbuilding, the share of manufactured pipelines "in reserve" is about 40%. The remaining part of the pipes can be made only after taking the dimensions on the ship, which adversely affects both the term for the construction of the vessel and the final cost of the work performed [16].

In connection with the foregoing, the study of the compensatory capabilities of the project pipeline routing to increase production efficiency by introducing pipe manufacturing technology using design information is one of the most important industry trends of modern shipbuilding.

In the projects of ship pipelines, there are direct routes, routes of parallel sections, and routes with cambers. It has been established that in practice the installation of the routes with cambers is carried out in violation of the requirements provided for by the current standards [17]. In this paper, we consider...
the compensatory possibilities of straight pipes in the pipeline routes with cambers.

2. Ship pipeline route with a camber
In the routes with only one camber, as in the direct routes, there are no parallel sections by definition. When choosing as a fitting pipe with one camber, it is possible, using technological allowances at its ends, to compensate for deviations only in two directions, in the plane of the pipe. At the same time, the deviation in the direction perpendicular to the pipe plane remains uncompensated. It is impossible to compensate for it by installing connections with a skew on one pipe due to exceeding the permissible angle, which was shown when considering direct paths [16-17]. The permissible movement when installing connections with a skew of a pipe with a camber will be less than that of a straight pipe. The expanded length of a pipe with camber, as well as the length of a straight line, will be 1.5–2.5 m, depending on the diameter of the pipe: the larger the diameter, the shorter the pipe. The amount of displacement of the pipe with a camber due to the allowable skew depends on the length of the pipe section adjacent to the straight pipe, which is shorter than the unfolded length by definition.

Using the same approach as in straight routes, deviations can be compensated for using straight pipes with offset connections. Two straight pipes are enough to compensate for any deviation of $\pm (A_1 + A_2)$ in any direction perpendicular to the direction of these pipes. After turning the straight pipes to the angles necessary to compensate for the deviation, it is enough to assign one allowance in the section that coincides with the direction of the straight pipes. The pipe (straight or with one camber), to which the allowance will be assigned, is the “fitting pipe” (figure 1).

![Figure 1](image)

Figure 1. Compensation area of pipeline routes with one camber: $r = A \cdot n -$ cylinder radius ($A$ – offset value, $n$ – number of straight pipes in the route); $l$ – allowance value; $h = 2l$ – cylinder height.

Let us consider the possibility of compensating for deviations in the routes with one camber consisting of two pipes - a straight line and a pipe with a camber.

The most obvious is compensation using the rotation of a straight pipe in combination with a skewed installation of the connection in the area adjacent to the straight pipe and an allowance assigned to this section of the “fitting pipe” (the pipe with camber). The disadvantage of this compensatory method is the presence of a “dead zone”, which will arise in most cases due to the fact that the length of a straight pipe is longer than the length of one section of a pipe with a camber, therefore the permissible displacement of a straight pipe A2 is greater A1 [16]. The values of the displacements can differ significantly, which increases the size of the "dead zone" and makes the application of this compensatory method problematic.

Let us consider the possibility of compensating for deviations by rotating a straight pipe and assigning two allowances on a “fitting pipe” with a camber. With this method, the “dead zone” is absent, but the maximum compensation $r$ - the radius of the cylinder base (figure 1) will be limited by the offset of the straight pipe A, which may not be sufficient to perform the compensation (figure 2). The compensation area is a cylinder cut along its diameter with an inserted parallelepiped (figure 3).
Figure 2. View of the compensation area without moving connections of “fitting pipe”.

Thus, for pipeline routes with a camber, the compensation area is formed when a straight pipe is combined with a second straight pipe or with a pipe having a section not parallel to the direction of the straight pipe.

As the result of studies of the compensatory possibilities of the tracks with one death, the following was established:

Figure 3. Compensation area of the route with one camber, consisting of two pipes, without displacement of the connections of the “fitting pipe”: $h_1 = 2l_1; h_2 = 2A + 2l_2; r_3 = A$. 
– a pipeline route with one camber, in which there are two straight pipes and more, can be assembled using the same techniques as the route consisting only of straight pipes;
– a pipeline route consisting of two pipes – a straight pipe and a pipe with a camber – can be assembled using straight pipe turns, allowances at both ends of the pipe with a camber and fitting the connections on this pipe with a permissible skew during the fitting process.

3. Ship pipeline route with two and more cambers
Let us consider the possibility of applying the developed compensation method using straight pipes in ordinary routes — routes with two or more camber. Connections on straight pipes are installed mutually in parallel, but with an allowable skew to the pipe axis, which ensures the displacement of the route during installation.

If there are two straight pipes in the route located on the same line, compensation is carried out, as in straight routes [1]. In the process of turning the straight pipes, it is necessary to control that the directions of all sections of the route located along the course of the installation behind the straight pipes remain parallel to their original position.

If there are two straight pipes in the route, arranged in parallel, the compensation is carried out in stages. At the first stage, the second straight pipe 3 compensates the offset of the route from the straight pipe 1, and the final part of the route takes a theoretical position (figure 4).

![Figure 4. Installation of the route in the theoretical position of the end section.](image)

At the second stage, the deviation $P$ of the mutual position of rigidly fixed connections, limiting the route, is compensated (figure 5). With the help of straight pipes 1 and 3 and the techniques used in straight lines, the deviations in the directions perpendicular to the axes of these pipes are compensated. When turning in the connections of the pipe 1, it is necessary to control that the directions of all sections of the route located along the course of the installation behind the straight pipe 1 are kept parallel to their original position. As a result, the last section of the route will take position I.

After turning the pipe 3 to the required angle to compensate for deviations and turning the pipe 4 to the same angle, but in the opposite direction, the last part of the route will occupy the position necessary for the assembly - the actual position of the route after installation (figure 5).

If we first turn the pipe 3, then after the reverse rotation of the pipe 4, the last part of the route will take position II (figure 5). When turning the pipe 1 and the part of the route located behind it to the angle
necessary for compensation in the opposite direction, the last part of the route will take the position necessary for the assembly - the actual position of the route after installation (figure 5).

**Figure 5.** Compensation for deviations of pipeline route using two mutually parallel straight pipes.

Thus, if there are two or more straight pipes in the route, which are located on the same line or mutually in parallel, then by turning them in the free connections, it is possible to compensate for deviations of the route with any configuration as well as compensate for deviations in direct routes.

4. **Conclusion**

In the course of the compensatory possibilities studies in the pipeline routes of various configurations with two or more kills, it was established:
• during the installation of routes with the cambers when installing pipe connections, it is possible to compensate for the deviation of rigidly fixed connections that limit the route by moving the end of the route by turning the pipes;
• the movement of tracks that do not have parallel sections to compensate for deviations can be accomplished using straight pipes made with offset axes of connections;
• the minimum necessary combinations of pipeline route configuration elements were determined to compensate for deviations when installing systems from prepared pipes - these are two straight pipes, a straight pipe and a pipe with one camber (or with cambers and oppositely directed ends), as well as a straight pipe and pipe with parallel end sections.

References
[1] Ersoy M 2016 Asymptotic Analysis 98(3) 237–55
[2] Endo M and Iwamoto J 1998 Journal of Visualization 1(3) 261–9
[3] Hightower D W 1988 Proceedings of the 25 Years of DAC Papers on Twenty-Five Years of Electronic Design Automation 11–34
[4] Fan X L, Lin Y and Ji Z H 2007 Journal of Ship Production 23(1) 36–45
[5] Fan X L, Lin Y and Ji Z H 2009 Journal of Shanghai Jiaotong University 43(2) 193–7
[6] Fan X N, Lin Y and Ji Z H 2007 Shipbuilding of China 48(1) 82–90
[7] Wang C E and Liu Q 2011 IEEE Transactions on Automation Science and Engineering 8(3) 641-5
[8] Ito T 2002 Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) 2358 547–56
[9] Ren T, Zhu Z L, Dimirovski G M, Gao Z H, Sun X H anh Yu H 2014 Proceedings of the Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering 228(3) 424–33
[10] Jiang W Y, Lin Y, Chen M anh Yu Y Y 2015 Ocean Engineering 102 63–70
[11] Kennedy J 2010 Encyclopedia of Machine Learning Springer US 760–6
[12] Asmara A and Nienhuis U 2006 Proceedings of the 5th International Conference on Computer and IT Applications in the Maritime Industries, Sieca Repro (TUD 06) 269–80
[13] Zhang j Q and Liang Z S 2017 International Journal of Applied Electromagnetics and Mechanics 55(4) 507–22
[14] Dorronsoro B, Danoy G, Nebro A J and Bouvry P 2013 Computers & Operations 40(6) 1552–63
[15] Sui H T and Niu W T 2016 Frontiers of Mechanical Engineering 11(3) 316–23
[16] Ngo G V 2017 Bulletin of Admiral Makarov State University of maritime and inland shipping 9(1) 157–64
[17] Ngo G V 2018 Ph. D. thesis Astrakhan State Technical university 192