USE OF ZERO MOVEMENTS FOR ADJUSTMENT OF REDUNDANCY STRUCTURES

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Introduction. Vessels with a dynamic positioning system operate in conditions of increased risk, so they are subject to increased requirements for reliability, accuracy and maneuverability. To meet these requirements, the control systems of such vessels are equipped with high-precision means of measuring absolute and relative position, which allow to determine with high accuracy the absolute position of the vessel (DGPS systems), or position relative to another vessel (Reference systems), redundant control structures, on-board computer system and automatic control system software [1]. These vessels have the highest degree of automation of traffic control processes. Excessive control is a very important characteristic of the vessel, as it improves not only reliability but also maneuverability and quality of control, reduces the risks of occurrence and development of adverse situations. The use of automatic control modules in automated systems was considered in articles [2-12], in particular the control of redundant structures in articles [7, 12]. As can be seen from the study [7, 12], the same control forces and torque can be created in redundant structures by different sets of control parameters, among which you can find the optimal according to the selected function of control quality. Changing the control quality function leads to readjustment of the structure, as a result of which disturbing forces and moments may occur, which is unacceptable when performing dynamic positioning operations.

The relevance of research. In connection with the above, there is a need to reconfigure redundant structures without creating disturbing forces and moments, and therefore, the development of methods and mathematical software that would allow such a reconfiguration is an urgent scientific and technical task.

Problem formulation. The redundant structure of stern ACD (Azimuth Control Devices) with a nasal steering device is given.

$$\begin{cases} P_x = P_1\cos\alpha_1 + P_2\cos\alpha_2, \\ P_y = P_1\sin\alpha_1 + P_2\sin\alpha_2 + P_3, \\ M_z = P_1 b\cos\alpha_1 - P_2 b\cos\alpha_2 - P_1 a\sin\alpha_1 - P_2 a\sin\alpha_2 + P_3 c. \end{cases} \tag{1}$$

$$|P_1| \le P_1^{\max},\ |P_2| \le P_2^{\max},\ |P_3| \le P_3^{\max},\ |\alpha_1| \le \pi,\ |\alpha_2| \le \pi$$

It is necessary to transfer this redundant structure from the initial position $(P_1(0), P_2(0), \alpha_1(0),\ \alpha_2(0),\ P_3(0))$ to the final position $(P_1(T), P_2(T), \alpha_1(T),\ \alpha_2(T),\ P_3(T))$ so that during the readjustment the vector of control forces and moment is equal to zero $(P_x, P_y, M_z) = (0,0,0)$.

Research results. Differentiate the system (1). System (2) has five control parameters $\mathbf{v} = (\dot P_1, \dot P_2, \dot\alpha_1\, \dot\alpha_2,\ \dot P_3)$, which are subject to three constraints in the form of system equations (2), ie there are two independent controls $\mathbf{v} = (\dot P_1, \dot P_2, \dot\alpha_1\, \dot\alpha_2,\ \dot P_3)$ that provide an infinite number of sets of solutions. Among these solutions we will look for those that transfer the redundant structure (2) into a given final position $(P_1(T), P_2(T), \alpha_1(T),\ \alpha_2(T),\ P_3(T))$:

$$\begin{cases} 0 = \dot{P}_1 \cos\alpha_1 - P_1 \sin\alpha_1 \dot{\alpha}_1 + \dot{P}_2 \cos\alpha_2 - P_2 \sin\alpha_2 \dot{\alpha}_2, \\ 0 = \dot{P}_1 \sin\alpha_1 + P_1 \cos\alpha_1 \dot{\alpha}_1 + \dot{P}_2 \sin\alpha_2 + P_2 \cos\alpha_2 \dot{\alpha}_2 + \dot{P}_3, \\ 0 = \dot{P}_1 (b\cos\alpha_1 - a\sin\alpha_1) - (P_1 b\sin\alpha_1 + P_1 a\cos\alpha_1)\dot{\alpha}_1 - \\ - \dot{P}_2 (b\cos\alpha_2 + a\sin\alpha_2) + (P_2 b\sin\alpha_2 - P_2 a\cos\alpha_2)\dot{\alpha}_2 + \dot{P}_3 c. \end{cases} \tag{2}$$

We introduce the quality control function:

$$\begin{gathered} Q_3 = (P_1 - P_1(T))^2 + (P_2 - P_2(T))^2 + (\alpha_1 - \alpha_1(T))^2 + \\ (\alpha_2 - \alpha_2(T))^2 + (P_3 - P_3(T))^2 \end{gathered} \tag{3}$$

and find its derivative in time

$$\frac{dQ_3}{dt} = \frac{\partial Q_3}{\partial P_1}\dot{P}_1 + \frac{\partial Q_3}{\partial P_2}\dot{P}_2 + \frac{\partial Q_3}{\partial \alpha_1}\dot{\alpha}_1 + \frac{\partial Q_3}{\partial \alpha_2}\dot{\alpha}_2 + \frac{\partial Q_3}{\partial P_3}\dot{P}_3 = < \mathbf{grad} Q_3, \mathbf{v} >,$$

$$\frac{\partial Q_3}{\partial P_1} = 2(P_1 - P_1(T)), \frac{\partial Q_3}{\partial P_2} = 2(P_2 - P_2(T)),$$

$$\frac{\partial Q_3}{\partial \alpha_1} = 2(\alpha_1 - \alpha_1(T)), \frac{\partial Q_3}{\partial \alpha_2} = 2(\alpha_2 - \alpha_2(T)),$$

$$\frac{\partial Q_3}{\partial P_3} = 2(P_3 - P_3(T)).$$

Write the law of control in the form

$$\frac{dQ_3}{dt} = < \mathbf{grad} Q_3, \mathbf{v} > \ \to \ \max \tag{4}$$

which will provide the maximum speed of approximation of the objective function (3) to the optimal (minimum) value $Q_3 = 0$. It is necessary also consider the limits on the maximum values of control parameters $\mathbf{v} = (\dot{P}_1, \dot{P}_2, \dot{\alpha}_1 \dot{\alpha}_2, \dot{P}_3)$

$$\left|\dot{P}_1\right| \le \left|\dot{P}_1\right|^{\max}, \left|\dot{P}_2\right| \le \left|\dot{P}_2\right|^{\max}, \left|\dot{\alpha}_1\right| \le \left|\dot{\alpha}_1\right|^{\max}, \left|\dot{\alpha}_2\right| \le \left|\dot{\alpha}_2\right|^{\max}, \left|\dot{P}_3\right| \le \left|\dot{P}_3\right|^{\max}.$$

Conclusions. There was developed a method and mathematical support for automatic transfer of the redundant structure from the initial position to the given final position without creating disturbing forces and moments, which allows adjusting the redundant structure to a new quality control function during the main functional task.

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