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AIRFIELD EQUIPMENT OPTIMIZATION PROBLEM NUMERICAL SOLVATION WITH SIMULATION PACKAGE USAGE

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Abstract

The paper examines in detail the main functions of the airfield watering machine (AWM) and studies the possibilities of installing various attachments for efficient cleaning of the runway, taxiways and aprons. As a result of the analysis of the dynamic characteristics of the machine's motion, a list of numerical values for the AWM was developed and contact and non-contact forces were calculated using a 3D model of a metal subframe and the ANSYS Workbench 16.2 software package (Static Structural module). The study presents load diagrams and graphs of displacements of structural units during the AWM movement. Numerical values of loads along three axes were determined and hazardous areas capable of compromising the integrity of the structure were identified. Based on the data obtained, a conclusion was made about the need for additional development of the AWM design in order to eliminate possible failures in the power plant and increase its reliability. This work allows to significantly improve the design and operation of airfield watering machines, providing optimal conditions for safe and efficient operation at airfields and airports.

Keywords: Airfield watering machine, design of technological equipment, design strength calculation, car metal structure, runway cleaning

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1. Introduction

AWM provides cleaning of runways and taxiways in winter and summer as a part of the complex of airfield machines (AM) being developed (Gankin et al., 1997; Karelina et al., 2016).

2. Problem Statement

AWM is used for airfield artificial pavement cleaning, applying anti-icing liquid reagents or moisturizing the surface.

3. Research Questions

Figure 1. AWM analog

The research questions concern the problems of using AWM (Figure 01) in different seasons. Cleaning runways and taxiways in summer using AWM allows removing foreign objects and liquids from the surface, whereas in winter it involves treatment of runways with an anti-icing liquid agent (Karelina et al., 2015).

4. Purpose of the Study

The purpose of the study is to overview the functions of AWM consisting of a front blade on the front mounting plate, equipped with the front rail, being installed on AWM (Lipich & Balahura, 2024; Regnerová et al., 2024; Shumilina & Antsiferova, 2024), including a water system, consisting of a tank, a water pump, a piping system and rails with sprayers; central brush; a front dump.

5. Research Methods

The calculation model is used as a research method to show the locations of a subframe, a chassis frame, plastic water tanks and a hydraulic station (Figure 02).

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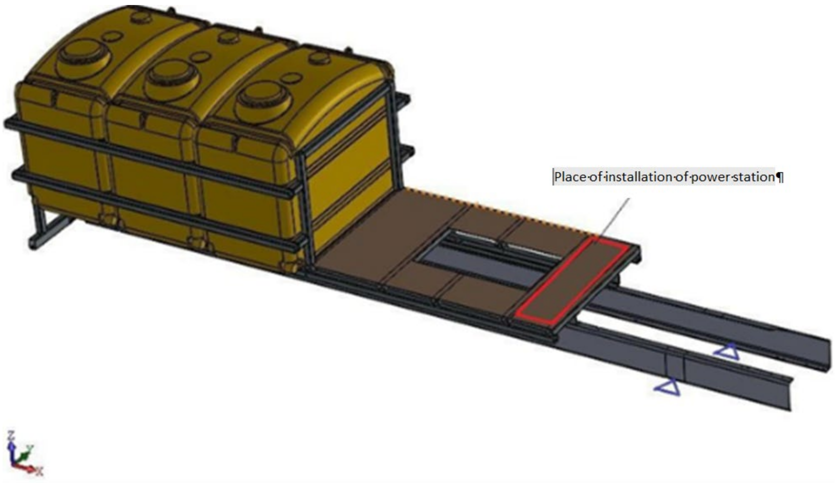

Figure 2. The subframe of AWM with installed tanks, based on the side members, which, in turn, are based on the axles of the chassis

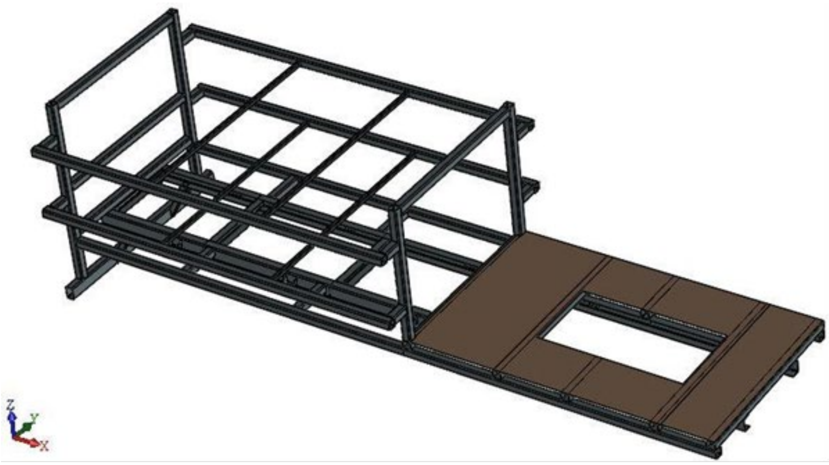

Figure 3. The metal structure of the subframe

The subframe metal structure (Figure 03) experiences gravity (9.81 m/s^2), motion inertia (Table 01), braking inertia (Table 02), rotation inertia, friction force between the bottom of the tanks and the base (Dokuchayeva et al., 2024; Tang & Yang, 2024).

Table 1. Dynamic characteristics of car movement (Karelina & Petrovskaya, 2015)

Road section number	RMS* vibration acceleration over the rear axle, m/s 2, no more than			
	Special automatic telephone exchanges based on cars and buses		Special automatic telephone exchanges based on trucks	
	$\tilde{a}_z$	$\tilde{a}_x, \tilde{a}_y$	$\tilde{a}_z$	$\tilde{a}_x, \tilde{a}_y$
Cement concrete road (RWY)	1.00	0.65	1.30	0.80

* RMS values

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Table 2. Coefficients of road adhesion (Grib et al., 2013)

Tire grip coefficient		
Coating type	**Coefficient value**	
	On a dry surface	**On wet surfaces**
asphalt concrete	0.7–0.8	0.4–0.6 (0.5)
cobblestone, rubble	0.6–0.7	0.3–0.5
Ground	0.5–0.6	0.2–0.4
packed snow	0.2–0.3	
Ice	0.1–0.2	

Braking efficiency coefficient j, m/s^2									
Category		Equipped				Full load			
		0.8	0.7	0.6	0.5	0.8	0.7	0.6	0.5
road train	N1	1.66	1.46	1.25	1.04	1.96	1.71	1.47	1.22
	N2	1.60	1.40	1.20	1.00	1.96	1.71	1.47	1.22
	N3	1.56	1.37	1.17	1.00	1.96	1.71	1.47	1.22

The centrifugal acceleration is:

$$c = \frac{V^2}{R}, \quad (1)$$

where V - AWM movement speed; R - turning radius.

Let us assume that the maximum speed of the car when driving around the corner is 20 km/h = 5.55 m/s, the turning radius R = 30 m.

Then c = 5.552 / 30 = 1.027 m/s^2

The design case is considered when all body forces add up and act in one direction:

- along the vertical axis Z (g + a Z);

- along the horizontal axis X (j + a X);

- along the horizontal axis Y (c + a Y). Vertical force from three tanks:

$$F_Z = 3p_{H_2O} \cdot V_{H_2O} \cdot (g + a_Z) = 3 \cdot 1000 \cdot (9,28 + 1,3) = 99990 \text{ H}. \quad (2)$$

The friction force, where f = 0.055 (friction coefficient), is:

$$F_{TP} = f \cdot F_Z = 0,055 \cdot 99990 = 5499 \; H. \quad (3)$$

Horizontal forces are:

$$F_x = 3 \cdot p_{H_2O} \cdot V_{H_2O} \cdot (j + a_X) - F_{TP} = 3 \cdot 1000 \cdot 3 \cdot (1,22 + 0,8) - 5499 = 12681 \text{ H}. \quad (4)$$

$$F_Y = 3 \cdot p_{H_2O} \cdot V_{H_2O} \cdot (c + a_Y) - F_{TP} = 3 \cdot 1000 \cdot 3 \cdot (1,027 + 0,8) - 5499 = 10942 \text{ H}. \quad (5)$$

The vertical force from the power station is:

$$Q_Z = m \cdot (g + a_Z) = 346 \cdot (9,81 + 1,3) = 3844 \text{ H}. \quad (6)$$

The subframe stress-strain state (SSS) using the ANSYS Workbench (Ahmad et al., 2024; Singh et al., 2024; Waite, 2024) 16.2 software package (Static Structural module) was measured during uniform movement, braking, passing a turn (20 km/h), cornering and simultaneously braking (20 km/h).

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6. Findings

The model shows vertical forces acting on the subframe metal structure, the schematic chassis spar, imitating the subframe elastic base (Figure 04, Figure 05).

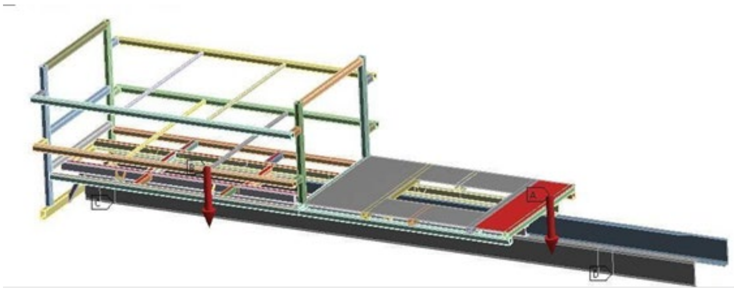

Figure 4. Boundary conditions imposed on the subframe model (Load 1)

It follows from these diagrams that the maximum displacement of the model nodes of 4.65 mm is observed in the side pipe (section 80x80x6 mm) of the tank installation base, the maximum stress of 253 MPa is observed in the pipe – cross member (section 80x80x6 mm) at its junction with the overframe spar (Politkovskaya & Zhidkova, 2020).

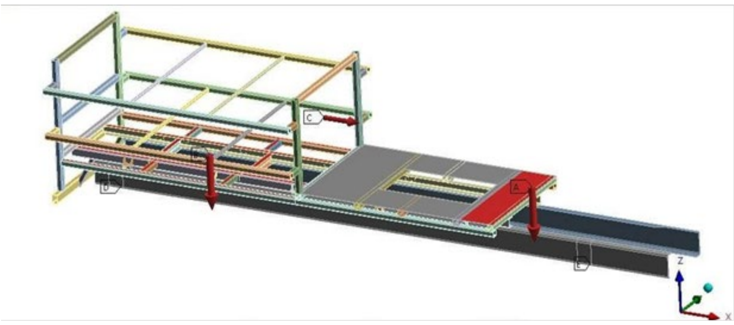

Figure 5. Boundary conditions imposed on the subframe model (Load 2)

The maximum displacement (6.6 mm) is in the front pipe; the maximum stress (278 MPa) is in the pipe at its junction with the overframe spar, when turning at speeds of up to 20 km/h.

FZ, QZ and the horizontal force FY act on the subframe metal structure (Figure 06).

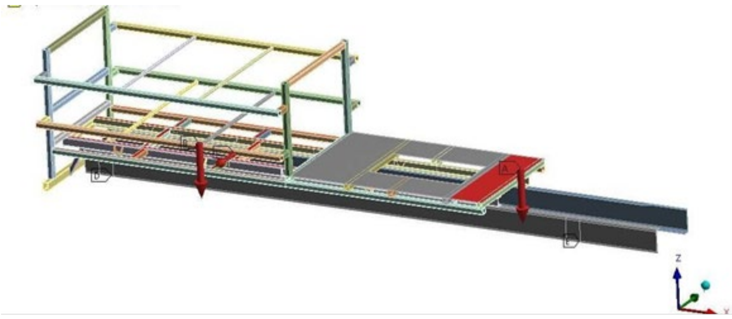

Figure 6. Boundary conditions imposed on the subframe model (Load 3)

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The maximum displacement (8.27 mm) is in the side pipe; the maximum stress (301 MPa) is in the subframe bracket at its junction with the side member, when turning at speeds of up to 20 km/h while braking on the runway.

FZ, QZ and horizontal forces act on the subframe metal structure FY and FX (Figure 07).

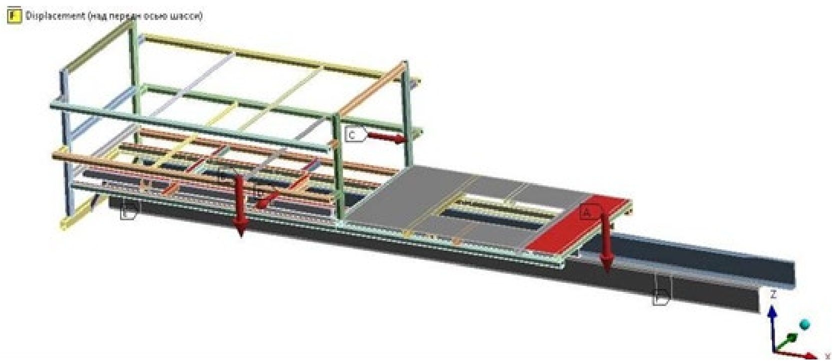

Figure 7. Boundary conditions imposed on the subframe model (Load 4)

The maximum displacement is in the side pipe and in the front pipe; the maximum stress is in the subframe bracket at its junction with the spar.

7. Conclusion

Technical solutions for AWM design individual components were reviewed and analyzed, involving a detailed three-dimensional model of the subframe installation, specifying mass-dimensional and functional characteristics, calculating the structure operability, allowing for the subframe metal structure meeting the strength requirements for loading, considering maximum displacements in the tank piping and maximum stresses in brackets for attaching the subframe to the chassis spars.

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