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DESIGN AND ENGINEERING OF MINI VEHICLES

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ABSTRACT

In this paper, methodological foundations regarding the design and engineering of the small-sized three-wheel and four-wheel vehicles were studied, including the selection of promising rational layout schemes, anthropometric modeling of landing circuits, shaping the polymer structure of the body, as well as the approaches used for car design modeling.

1. INTRODUCTION

Small Vehicles (SV) are becoming the most promising segment of the transport dealing with increasing problems of the urban traffic, in particular the acute situation of the environment, traffic jams and low efficiency in case of transporting people and goods (increased waste of time, increasing cost of hydrocarbon fuel and vehicle operation, lack of parking places, social conflicts due to the inequality in the traffic for people, etc.) [1-4].

Today, SVs have been occupied the main niche ,as they are used for different applications such as sports and recreation, tourism, hunting, police, and emergency services and city driving, designed to carry one or two people (mopeds, tricycles, quadric cycles/ATVs, snowmobiles and other alternative individual electric vehicles).

The solution for theoretical and methodological problems of SV design lies in the theory and practice related to the design and engineering of the vehicle. In the context of increased competition in the automotive market, the problems are revealed with respect to the tight time constraints and defects in morphological features of the SV body, the actual use of numerical analysis approaches used for SV body at the design and fabrication stage. Restrictions on the morphological structure of the SV reveal the differences from traditional vehicles, requiring the development of the methodological bases for designing this type of vehicle (including ergonomic and layout design, design modeling of the poly material body structure, approaches used for numerical analysis of the body at the design stage).

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2. RESEARCH METHOD

2.1 Development of SV designs

Methodological foundations for modeling the promising layout schemes have been developed at the stage of SV designs [5-11]. Classification and modeling of modern SV layout schemes (Tables 1, 2; Figure 1, 2) is associated with the following parameters : wheel layout (3-wheel and 4-wheel); type of power-generating installation (ESA) (electric motor (ED), Internal Combustion Engine (ICE), combined ESA (ED + ICE), alternative energy sources (AIE); and the location of ESA (front, central, rear, combined). Given X and Y are the position of the components location in the platform which is shown in Figure 1.

Table 1: Classification and characteristics of SV layout schemes

SV layout schemes				
	Types of ESA and their location		Wheel schemes	
			4-wheel	3-wheel
Power circuits	ED	Front	*X1Y1, X2Y1*	*X1Y6*
		Central	–	*X2Y6*
		Rear	*X3Y1*	*X1Y1, X2Y1*
		Combined	*X4Y1, X5Y1*	*X5Y6*
	Internal combustion engine	Front	*X1Y2*	*X1Y7*
		Central	*X2Y2*	–
		Rear	*X3Y2*	*X2Y7*
		Combined	*X4Y2*	–
	CESU (ED + ICE)	Front	*X1Y3*	–
		Central	*X2Y3*	–
		Rear	*X3Y3, X4Y3*	–
		Combined	*X5Y3-X8Y3*	*X1Y8-X3Y8*
	Alternative IE	Front	–	–
		Central	*X1Y4, X2Y4, X3Y5*	–
		Rear	*X2Y5*	–
		Combined	–	–

Table 2: Conditional graphic symbols of the ESA.

	Electric motor (ED)			Hydrogen
	Internal Combustion Engine (ICE)			Battery/Batteries
	Fuel cells (TE)			Gas bottle

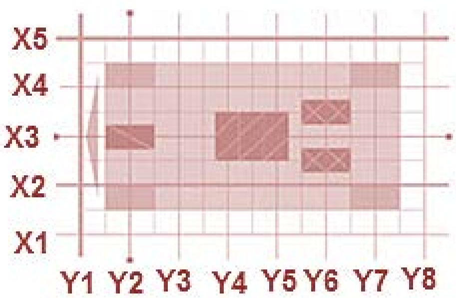

Figure 1: Configuration of components position (X, Y) in the platform.

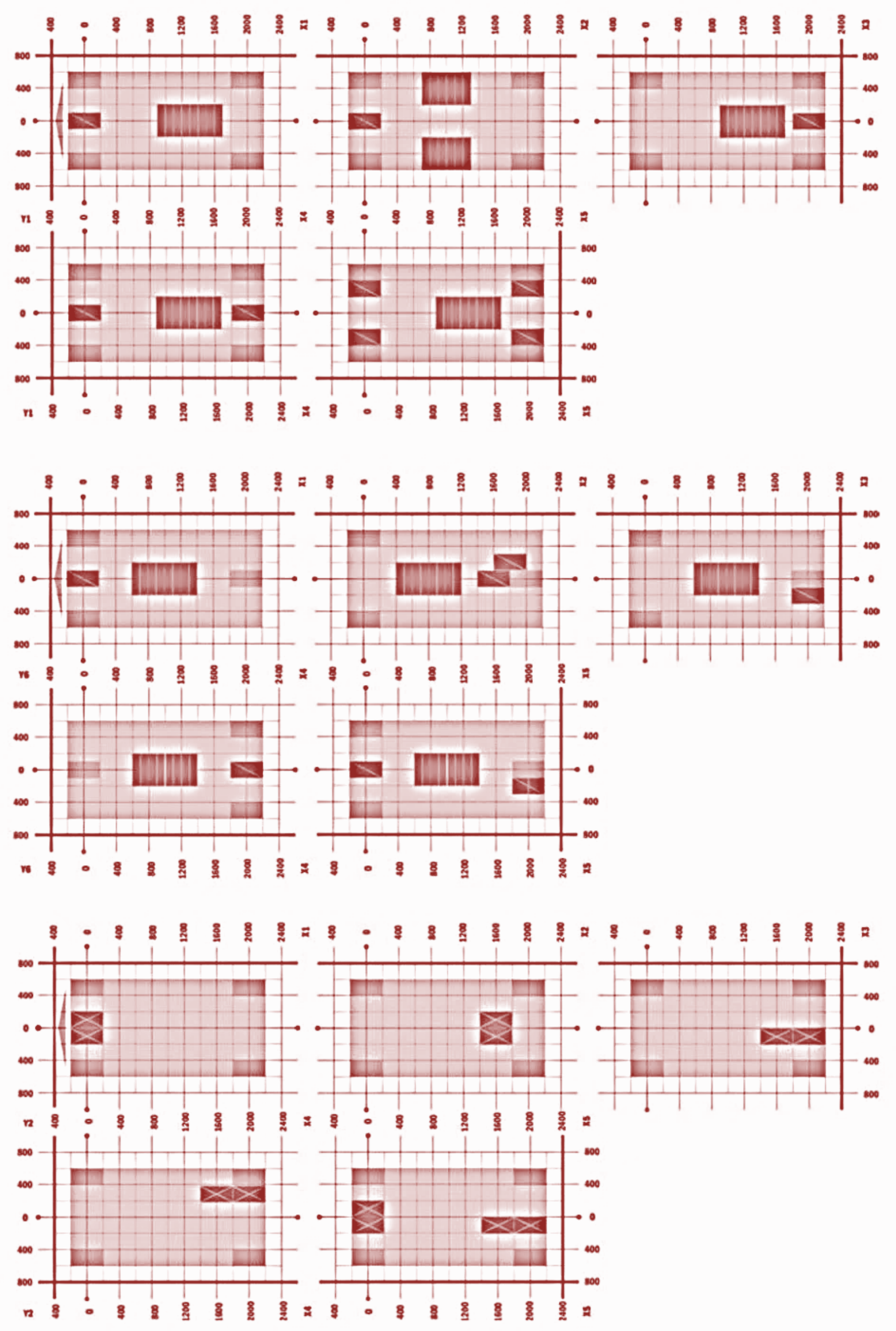

Figure 2: Vehicle layout schemes for three- and four-wheel SV.

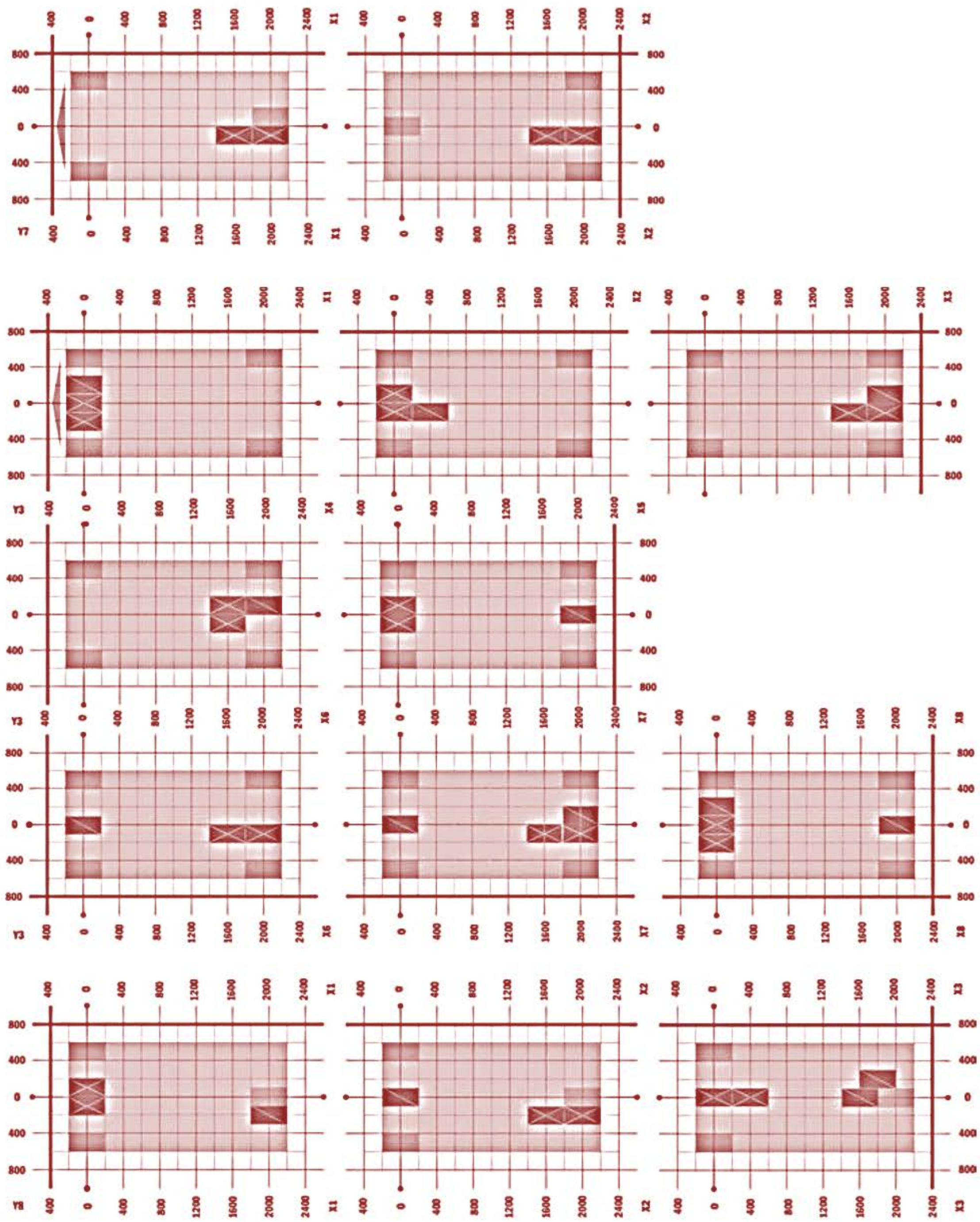

Figure 2: Vehicle layout schemes for three- and four-wheel SV (continued).

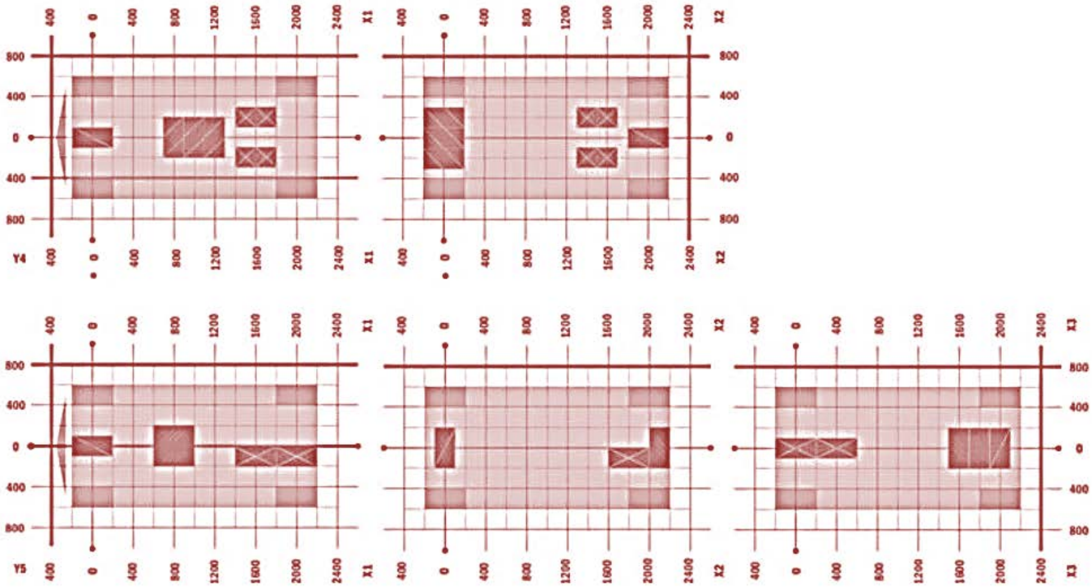

Figure 2: Vehicle layout schemes for three- and four-wheel SV (continued).

2.2 ANTHROPOMETRIC MODELING

Anthropometric modeling of the SV landing scheme [5-11] depends on its type: automobile or motorcycle. Regarding the simulation of the automotive landing scheme (APS), there are two main approaches for the anthropometric organization of the SV interior space [12-16]: from the perspective of a given space to a person, and from the respective of a person to the design of a space, see Figure 3. In the first approach, the space is organized on the basis of the specified parameters, due to standards, technical tasks, safety standards, etc., then the subject area associated with the person is fitted into the space, and is adjusted based on the conditions set out above. In the second approach, the parameters related to a person and his workplace is considered as a point of reference in the design of the space. Theoretically, these two approaches have the right to exist independently from each other. In practice, the two approaches are used in parallel, but the first approach takes precedence. This approach has obvious disadvantages since the convenience of the person is sacrificed in favor of the specified requirements.

For each landing SV scheme, a number of proportional relationships are provided, according to which the main composite elements related to the interior and exterior of the vehicle are connected. The preliminary landing scheme is selected according to the purpose of designing the vehicle and is determined by the regulated landing and landing dummies. The following models are used for modeling: 1) linear dimensions of the dummies of 5-50-95 percentiles, adjusted for clothing and footwear (DIN 33408); 2) distances from the shoulder and pelvic girdles to the steering wheel, pedals, gearshift knob and other controls within the available range, as well as the distance between the dummy and partitions, ceiling, doors, front seatbacks, etc.; 3) admissible angular mobility parameters (kinematics of extremities) and visibility, including the dashboard and rear-view mirrors; 4) standard sizes of cargo and luggage compartments.

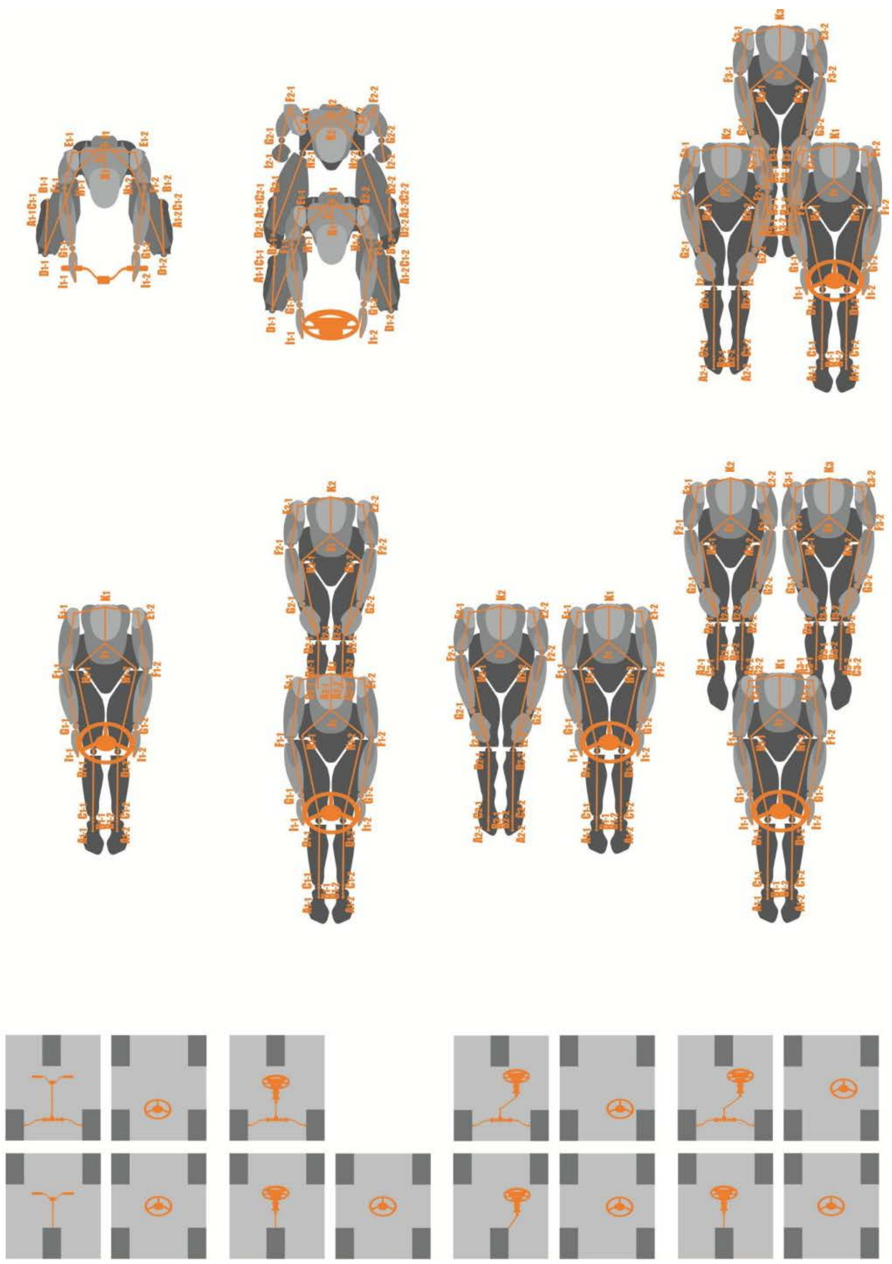

Figure 3: Classification of the landing schemes for three- and four-wheel SV

Due to the large number of requirements, the space of the driver and passengers fits into the layout created by the designers, so that in practice and at global level, while developing the exterior, if there is a compromise between designers, then the designers may reach a consensus in favor of the design, as a result the car's interior would follow the established schemes. Schemes are designed depending on the purpose of designing the vehicle, its wheelbase and price category. Approaches to solving the problem of developing the interior of the SV are as follows: revision of decision on the layout, the position of the driver and passengers relative to each other; detailed identification of the purpose and conditions regarding the use of the vehicle; expanding the functionality of the interior (versatility); shaping other components related to the interior and controls; the use of advanced propulsion (compact units); new options; interior transformation; using new materials.

2.3 EXTERNAL POLYMER STRUCTURE

The formation of the external polymer structure of the SV is carried out according to the developed methodological foundations [17], allowing the designer to rationally model the polymer structure of the vehicle, including panels or segments, taking into account the design and technological requirements to increase the efficiency of the design activity, reducing the number of methodological errors, improving the quality of the shape of the polymer structure in the SV.

The design and technological support for the design of the external polymeric structure of the SV are based on using the methods of modeling the polymeric panels of the SV body. Selecting the type of principal solutions for butt joints of polymer panels is carried out according to the purpose of the panels, their location in the general structure, the need for movement or, on the contrary, stationary fixed fastening relative to each other. Designing the lines of the joints in the parts not only must follow a constructive and technological substantiation, but also must observe the overall compositional style decision, which additionally makes the vehicle's image more expressive and complete. Connectors organizing the joint of the panels into a single surface require a higher quality of manufacturing, assembly, and fitting of the panels. Vice versa the problems occur due to the difference in surface level, on the contrary, they may lead to the smoothing and masking inaccuracies in manufacturing and assembly.

2.4 GEOMETRIC PARAMETERS

The geometric parameters of the frame, panels, and shell of the SV body allow the designer to carry out a preliminary numerical analysis (geometric, strength and aerodynamic calculations) of the body already at the design stage [18–20] using modern finite element calculation software systems (CAD / CAM / CAE). This possibility is provided by the use of finite element models (CEM) for frame and surface. The wireframe FEM is generated simply containing a small number of nodes, the number of which is smaller compared to the surface FEM used in modeling the shell body of the SV. The core elements in the CEM model provide the opportunity to easily change the geometric parameters of the model with respect to the physical characteristics of the materials, which is important when it comes to search for a satisfactory combination of compositional characteristics of the form, strength and aerodynamic characteristics of the structure. The purpose of numerical analysis in the SV body design is obtaining preliminary geometric, strength and aerodynamic characteristics of the body using parametric and finite element modeling methods at the design stage [20].

Means of the design are formed based on the outer shell of the SV, its overall parameters, and then the compositional harmonization of the form is made, as well as the choice of surface quality [18]. Determining the overall geometric parameters of the surface structure is made taking into account the compositional shaping. Selecting the level of quality of the surfaces in the SV structure is based on the purpose and topology of the structure — a large-sized specific surface, a surface with complex geometry, a small-sized surface, and a surface of a connector. The overall surface structure of the SV is initially modeled as a single shell, subsequently divided into surface panels.

Depending on the influence of modeling factors, the surface modeling class is selected (“A”, “B”, “C”). Species with large-sized surfaces and surfaces with complex geometry are modeled as class "A”, in which visually smooth surfaces are obtained with a single highlight, without refractions and defects. The surfaces of small parts and connectors are modeled in class “B” as they are less visible and consequently less important in the overall composition of the SV surface structure.

Selecting the class of surfaces in modeling the external structure of the SV must begin with an analysis of the purpose and objectives of the simulation, the subsequent application of the model, and the assignment of electronic geometric models [18].

3. CHECKING THE QUALITY OF ELECTRONIC GEOMETRIC MODELS IN PANELS OF THE SURFACE POLYMER STRUCTURE OF THE SV

The epyure and isophote analysis allow us to determine the class (quality) of the polystyrene surface of the SV structure, and to exclude visual surface roughness. In an epyuronal analysis, in the case of a class "A" surface (the coordinates are continuous, as well as the first, second and third derivatives), the appearance of the reflex lines is smooth, sloping; the curvature plot coincides and has no kinks. This means that the curvature changes continuously and smoothly. Isophot analysis allows one to check the geometry of the surfaces in the panels, and eliminate possible defects violating the overall integrity of the structure. To speed up the design of the SV structure with the ability to quickly make changes to the structure, it is effective to carry out a numerical aerodynamic analysis for an electronic high-quality surface model of the SV structure for determining the resistance, flow fields and measures to improve the flow (STAR-CD, AVL - Advanced Simulation Technologies) [21]. These types of analysis allow us to eliminate possible errors made on behalf of the designer under the influence of time, which makes them return to the previous stage of designing.

4. RESULTS AND DISCUSSION

1. Considering the system approaches in modeling layout schemes, the use of modules formed in standard frame sizes is justified in detail: 1) it is associated with the anthropometric data: controls, seats, handrails, etc.; 2) and it is related to the design: power modules (the number of modules depends on the class of vehicle), battery packs (the number of packages depends on the power of the power modules and the type of fit).

2. The ergonomic solution of the SV is presented in four directions: 1) motor transport; 2) motorcycle; 3) combined (auto and motor transport); 4) the formation of a new alternative ergonomic solution. Motor transport direction: it includes the ergonomic characteristics of easy-to-car and cargo-to-car landing scheme for driver and passenger; and the characteristics of automotive type control. Moto transport direction (borrowing from the characteristics inherent in motorcycles): it is referred to the ergonomic characteristics of the moped and motorcycle boarding scheme for the driver and passenger; the characteristics of moped and motorcycle control of the vehicle; and tandem landing for the driver and passenger.

3. The system of factors shaping the external polymer structure (panels) of the SV body includes design factors; factors related to the division of the general structure into separate elements with a certain geometry for lines of joints in elements; factors related to the selection of butt joint; factors related to selecting the quality indicators; as well as factors concerned with selection of technologies and materials.

4. Carrying out a numerical analysis of the SV body allows the designer to make a scientifically-based decision regarding the geometric parameters of the body shape of the SV, determined by the compositional characteristics based on the results of the estimated numerical studies on the SV body

structure. Integrating the aesthetic and technical approaches in choosing the geometric parameters of the SV body reduces the number of structural and technological shortcomings at the design stage, increasing the overall efficiency of the design for subsequent design works, reducing the time and material costs at the time of the implementation.

5. CONCLUSION

This work deliberates over the design and engineering of the SV includes design modeling of the promising layout schemes and polymer body structure based on using modern digital principles. Relevant factors have been discussed, particularly vehicle layout, ergonomic consideration, geometric of the model.

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