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THE DESIGN OF THE BASIC STRUCTURE OF A CATAPULTING MACHINE

Abstract: *In this article it will be mainly analyzed the design of the basic structure of a catapulting machine. More broadly, will be presented introductory notions that describe the chosen topic, modeling methods used, the design itself, future research directions and conclusions. The design of the basic structure is illustrated and described in the beginning of the paper, while in the secondary part of the article is approaching the conceptual design of the housing, and of the catapulting system.*

Key words: *design, catapult, structure, concept, modeling, ensemble.*

1. INTRODUCTION

The main topic of this article is the design of the basic structure of a catapulting machine. This type of vehicle means a ground-guided device that has in its arsenal, as its main method of attack, a projectile catapult system. The targeted prototype is equipped with more types of arsenal and built-in functions than an ordinary catapult machine [3]. It is intended to have a strong structure, diversified methods of attack in order to adapt to different situations and useful functions such as video recording.

As a field of use, the described machine will be used both in recognize or shoot down a training target missions, and in direct fights with other such machines, being a remote-controlled vehicle dedicated to leisure activities. In order to be able to incorporate all these requirements, details and features will be taken from two fields.

The necessary armament together with an adequate structure to guarantee both a good defense and a satisfactory offensive will be based on the concept of the machines in the battles from remote-controlled robots arena. Regarding the development of activities in the external environment, i.e. the handling of the product on natural terrain, the rolling and damping systems will take over mechanics from the field of off-road RC cars.

In other words, the basic structure whose finished design will be presented in the first part of the article, will be based on the concept of remote-controlled off-road vehicles [5]. The second section of the paper presents hand sketches that support the future development of a unique design of the exterior structure (housing) and the corresponding catapult system. These aspects are based on arena robots.

Each of these two areas encompasses a wide range of products. However, the applicability does not intersect. Remote-controlled off-road vehicles have the role of navigating many types of surfaces (including rough terrain), not being demanding. An additional function it can have is video recording, performed through a camera mounted on the car [6].

These vehicles are not prone to violent collisions with other bodies, having a vulnerable surface structure, both in terms of design and quality. At the opposite pole are the combat robot vehicles used in arena confrontations. These devices are designed to run only on a smooth surface, i.e. on the arena floor. However, they have a very high impact resistance, their main purpose being to destroy other such vehicles. In an overwhelming weight, arena robots use close-range arsenal, preferring melee combat [7].

The proposed catapulting machine therefore has the potential to combine elements from the two fields in order to obtain the described prototype. The chosen design therefore combines the ability of off-road vehicles to run on various surfaces and the special offensive and defensive structure of arena robots. Moreover, the prototype promotes long-range arsenal by using the catapult as the main method of attack.

The system used is based on the wire-type mechanism twisted around the axis characteristic of the Onager catapult [4]. The improvements consist of the automated launch mode and the adjustable threshold that gives the projectile a variation of the trajectory.

2. MODELING THE BASIC STRUCTURE

2.1 Description of the software program used

To illustrate in a 3D environment the elaborated design requires the use of a dedicated software program. In the detriment of other applications, CATIA V5 was used for this project. One of the great strengths of this program is related to the constraints. On both the 2D drawing side (used for 3D body construction) and the space composition side, CATIA offers the ability to easily put, modify or delete any vital constraint in the construction of a part or assembly. Another very useful function is to add materials. Once the respective parts are made, the corresponding material can be assigned to them. From the moment of allocation, the piece acquires the characteristic texture and most importantly, its mass is calculated.

The difficulties encountered in using the CATIA program lie in its interface. This is very complex and quite difficult for novice users. In this category are also the tools, which can be tangled, lost or deactivated. However, the program in question is a powerful tool in 3D operation but also 2D technical drawings.

2.2 Description and design of the necessary elements

In order to develop a basic structure of a remote-controlled vehicle, it is necessary to include certain established elements. The part that houses the circuit board (including the microprocessor) and the power supply (batteries) is the one from which the system starts. Having the role of encompassing and protecting these two essential elements, this piece becomes the "center" of the system. It consists of a parallelepiped-shaped object with special slots, profiles and compartments to be able to mount and fix both the two elements specified above and to be able to assemble the other machine parts with which it comes into contact. The chosen design is represented in Figure 1. It is distinguished by an upper cavity (1) and a lower cavity (2). The upper one contains two profiled horizontal ribs (3) and a cylinder in which a threaded hole is drilled (4). This simplistic structure ensures a removable fixed fastening of the circuit board by means of a screw. Also in the upper cavity, there is a rectangular profile hole (5) intended for the passage of power cables from one cavity to another, as well as four threaded holes (6) that serve to place and attach the auxiliary parts in the related spaces (7). Next to these spaces there are also two half-bearings (8) which play the role of articulation with three degrees of freedom for the trees with which it comes into contact. The elements that are mounted in the special spaces (7) also have semi-bearing profiles, meant to complete the joint. Analogous to this principle, on the rear of the part there are eight threaded mounting holes (11), two spaces allocated to the additional parts (9) and four half-bearings (10). Finally, we have four threaded holes (12) that will be used to fix the housing.

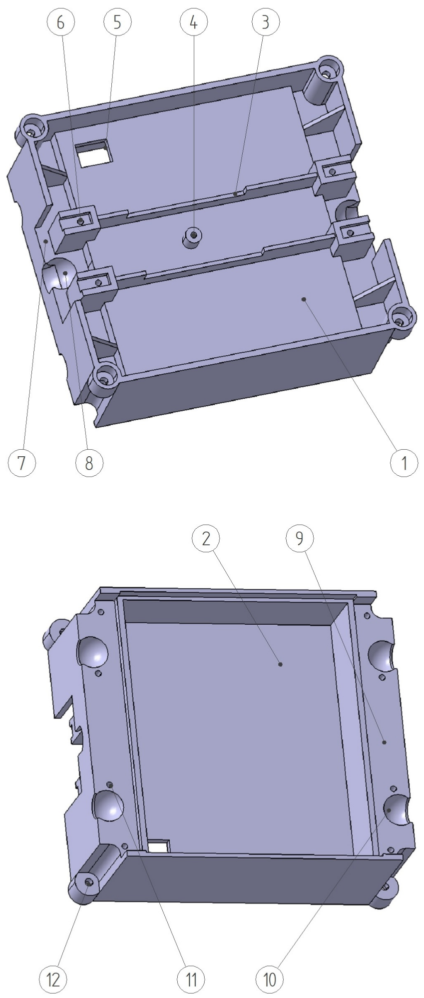

Figure 1 Center piece design (front view and rear view)

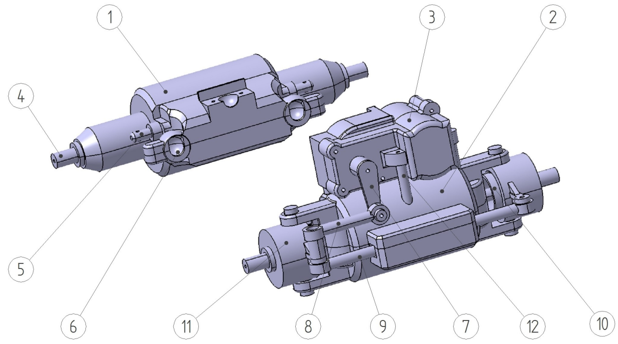

Figure 2 Design of engine housings and steering system

Three other parts with a similar role, namely to house vital elements of the system, are the housings corresponding to the three motors. The operating mechanism of the car benefits from double traction (front-rear), requiring one engine for each axle. In addition, on the front there is also an engine that ensures the turning of the vehicle through a connecting rod-crank system. Figure 2 shows the housings of the two traction motors (1 and 2). They consist of two half-carcasses, each including spherical bearings (6) for shafts and spindles (5) for shock absorbers. In the case of the rear engine, the spindles of the axle (4) pierce the housing, being the final elements for mounting the wheels. For the front engine, bearings (10) are fitted to the ends of the axle by means of special joints. This coupling offers the possibility of rotating the bearing around the axles keeping the moment of the shaft. This bearing is further inserted into a bushing with a single degree of freedom (11). The bearing spindles (10) pierce the bushings and serve for pre-mounting the wheels. Overlapping the engine on the front axle is another that helps control the steering (3). The two motors are connected to each other by a screw-based system (12). The turn is ensured by the mechanism consisting of a crank (7) and two connecting rods (8 and 9). Thus, the torque of the front wheels ensures both traction and steering simultaneously.

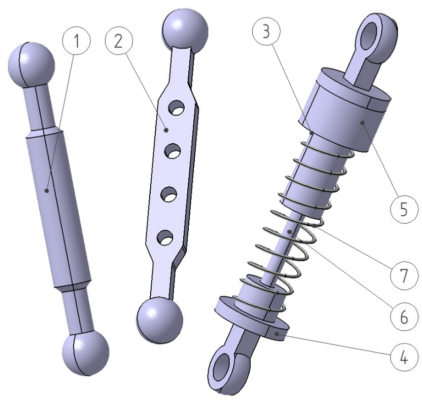

Figure 3 Design of spherical articulated shafts and shock absorber

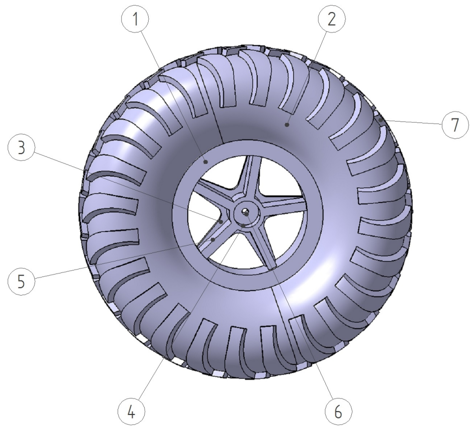

Figure 4 Wheel design

In order to couple the central part with the motor housings through which the axles pass, six articulated shafts and four shock absorbers are used, which can be identified in Figure 3. These symmetrically distributed elements have the role of capturing, homogenizing and stabilizing the whole assembly. Because the central body is designed to have a relative movement to the axles, due the damping system, it is necessary that the shafts used (1 and 2) benefit from joints with three degrees of freedom. Thus, at both ends of them is a ball. They come into contact with the spherical bearings (8 and 10) of Figure 1 and (6) of Figure 2.

The damping system consists of four identical shock absorbers distributed uniformly for each wheel. Relative to the part shown in Figure 3, a shock absorber (3) consists of two gripping elements (4) for connection with the axes of the structure, an element (5) inside which slides the shock absorber shaft, the shaft itself (6) and a spring (7). Having a composition that includes the mechanism presented by the joints and shock absorbers, the vehicle develops a high flexibility that helps to establish balance and dissipate shocks in special situations.

To ensure a rolling even on rough surfaces it is necessary to use appropriate wheels shown in Figure 4. They consist of a rim (1) and a tire (2). The geometry of the central part of the rim (3) is based on a five-cornered star shape. An axle bearing (4) is drilled along its axis. It is supported by ribs (5) distributed around the wheel. The fixing is ensured by a screw passing through the axial hole (6). For a satisfactory grip the tire benefits from a prominent profiling (7). The size of the tire is also considerable, playing a role in shock mitigation.

2.3 The whole structure

All the elements presented, together with additional ones meant to complete the mechanism, form the basic structural assembly of the catapulting machine. All joints are removable, reinforced by screws coupled in threaded holes. This basic structure, presented in Figure 5, represents more precisely the totality of the parts assembled within a unitary assembly, which ensures the operation in nominal parameters of the prototype pursued. Specifically, the basic structure, together with a power supply, a microprocessor integrated on a circuit board, the related motors and an external device emitting commands, guarantees the running in the optimal parameters of the catapulting machine. It has the ability to run face-back, left-right or any combination of these.

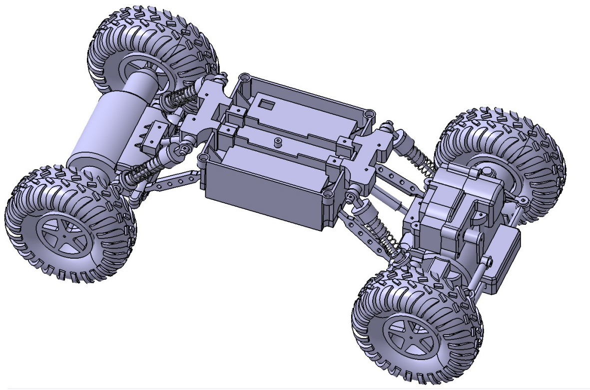

Figure 5 Basic structure design

As for the constraints imposed in 3D using the CATIA V5 program, they are of three types: plane parallelism, axiality or coincidence of surfaces or two-dimensional elements. The first type of constraint is used in most joints, where it is desired that two flat surfaces be joined. Axiality is also a widely used constraint because with its help the axle-hub or hole-screw type couplings are made. The third constraint is used in spherical joints, where the bearing surface must coincide with that of the shaft head. Also, this type of constraint is used to couple the shock absorbers on the related spindles. As their bodies are inclined to the vertical plane, the axis of the gripping ring is not parallel to that of the cylinder on which the shock absorber is mounted. Consequently, the constraint is realized only by the intersection of the axes in the imaginary point that represents the center of the hole of the gripping ring.

2.4 Materials and visual effects

Such a structure can be constructed from a wide range of materials. Most such assemblies are based on plastic parts. The low density of the plastic favors the mass of the whole, and implicitly the force / weight ratio. However, in the present case, the use of plastic is not suitable given the collisions to which the machine is prone. Doing an analysis of the materials used casually in such constructions and trying as much as possible to maintain a reasonable maximum mass, came to the conclusion of using 6061-T6 aluminum class as the predominant material [1]. This one has a very good hardness and a breaking strength of around 270 MPa. Also, its density is a very good one of about 2.7 g/cm^3. 6061-T6 aluminum is frequently used in structural frame applications, where strength and low mass are required.

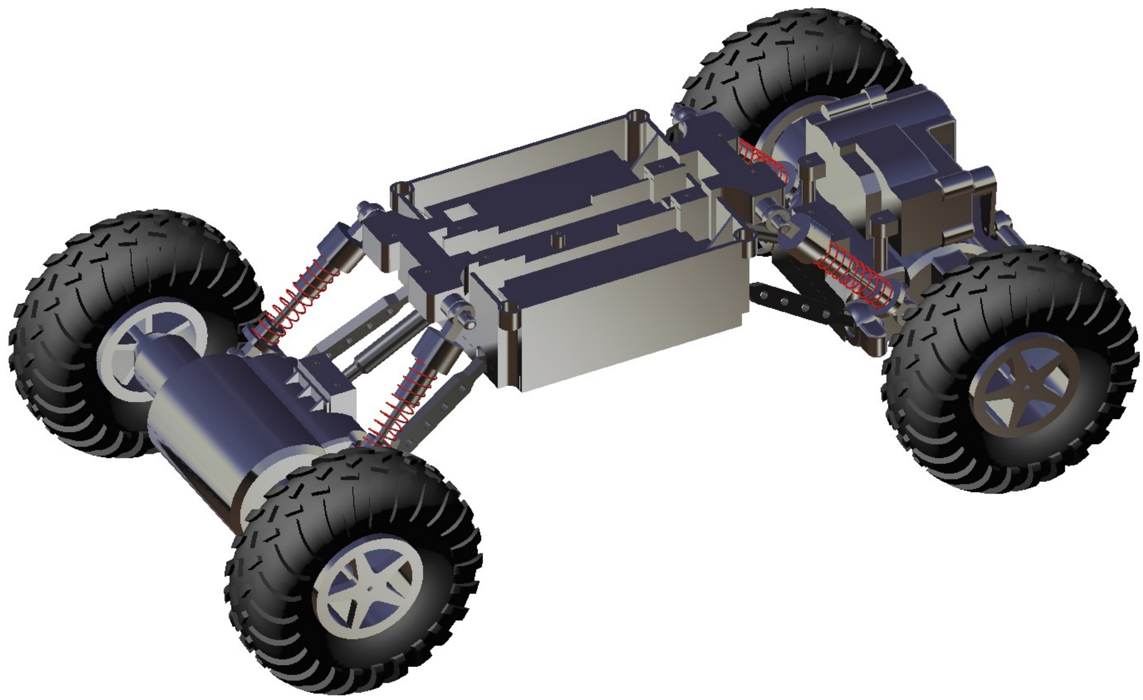

Figure 6 Design of the basic structure with material textures

However, axles and articulated shafts are the most sought-after parts in the event of an impact. As without one of these elements the functionality is compromised, the allocated materials must be much more resistant. Thus, these components will be made of 1.4006 martensitic stainless steel brand [2]. It has a remarkable strength of about 450 MPa, but also a high density of 7.75 g/cm^3. The advantage in these circumstances is the low volume that such parts have compared to the whole. The shock absorber spring is also made of stainless steel.

Lastly, the tires will obviously be made of rubber. The material used for the wheel rims will also be aluminum.

One aspect that needs to be combated very well is the electrical conductivity of aluminum. The power supply together with all the wires through which electricity is transported must be well insulated to avoid carrying current on the entire structure of the machine. The insulations will be made by coating the elements in question with rubber.

As previously mentioned, the CATIA program offers the possibility to assign the corresponding material to each piece. Following this procedure, the assembly acquires the aspect illustrated in Figure 6. You can see how the parts made of aluminum have the characteristic luster, and the steel ones less. Both of course have gray as the basic shade. The rubber on the other hand has the normal color of matte black. For a special look, it was decided that the shock absorber springs be painted red. Therefore, it can be seen how the effects rendered by the texture corresponding to the materials give the structure a completely different look, much more realistic.

3. FUTURE RESEARCH DIRECTIONS

Once the stage of realization of the basic structure is completed, the design of an external structure follows. It will include all the parts needed to give the prototype offensive and defensive properties but also various functionalities. The outer structure together with the basic one, forms the finished product.

3.1 Conceptual design of the exterior structure

The basic assembly created is subdivided, relative to its axles, into two types of structures: fixed and mobile. The fixed ones are represented by the motor housings and everything that is mounted on them (except the spherical articulated parts or the shock absorbers), and the mobile ones the rest. This classification is very important because catching a future piece simultaneously on two elements of the basic structure (one fixed and one mobile) would lead to malfunctions. Moreover, it is necessary to take into account the maximum level difference of the thresholds produced due to the stroke of the damping system, in order to avoid possible unwanted interactions with the ground [8].

As such, the proposed concept consists of four large structures whose design tends to appeal to a theme from the living world: the scorpion. The first two will be connected to the fixed elements of the basic structure and consist of wheel guards. In Figure 7 are shown the sketches for the design of the front wheel guards. Frames (1) and (4) show the guard on both sides. The model consists of a symmetrical piece, equipped at the ends with a guard [9]. It covers about three-quarters of the diameter of the wheel, protecting it from foreign bodies. Its geometry uses beveled edges in order to copy the exact volume of the wheel. A cutout is made on the inner side (4) to provide the space needed for the spindle to enter the wheel. Also, on this side, above the cutout, is a structure that crosses the axle and communicates with the other side guard. In the front part, the wheel guard acquires an offensive character, by profiling in the form of a ramp. Having this shape, when colliding with another object, the catapulting machine will tend to

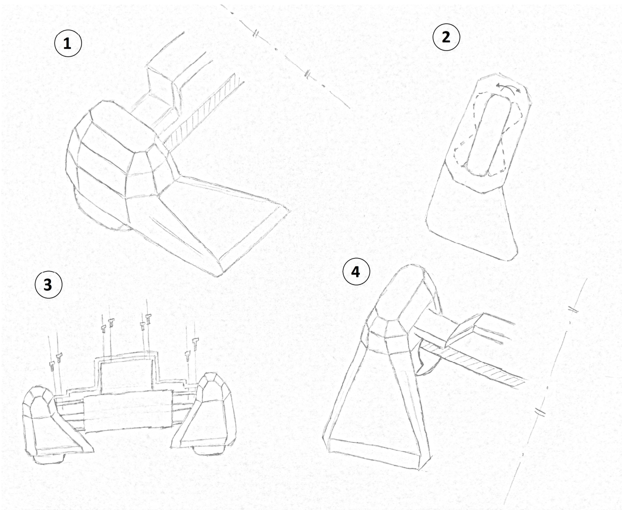

Figure 7 Sketch of the front wheel guards

overturn it. Moreover, this design has in the background the shape of a scorpion tongs.

As shown in (2), it is necessary for the guard to have an inner width greater than the thickness of the wheel in order to allow it to change direction. This whole structure is mounted on the motor housing by eight screws, similar to the representation in frame (3).

Figure 8 shows the structure of the guard on the rear axle. Its concept is very similar to the previous one, however there are some differences. According to the frame (1) the wheel is protected in a smaller percentage, because the front cannot be hit, given the fact that in front of it will be placed a side of the housing. You can also see a cutout on the side, which gives the whole piece the appearance of two parallel legs of scorpion.

Analogous as in the front case, on the inner side, the wheel guard benefits from a cutout for the axle spindle and above it is coupled the structure that crosses the engine housing. In frame (2) the mounting scheme is illustrated. The fastening is secured by four screws.

For complete protection against frontal attacks, a mask will be attached to the front of the catapult machine. Obviously, this will protect the two engines together with the steering system and even the damping system. The design of the mask is represented in Figure 9 and appeals to features of a scorpion's face. In frame (1) there is a front view of the part, and behind it can be seen the bare axle. In frame (2) it can also be seen a side view of the piece, together with the wheel guard, having the role to highlight the level of protection, but also the offensive one.

Similar to wheel guards, the mask is attached to fixed parts of the base structure. For a better perception of the assembly method, a section by part is shown in frame

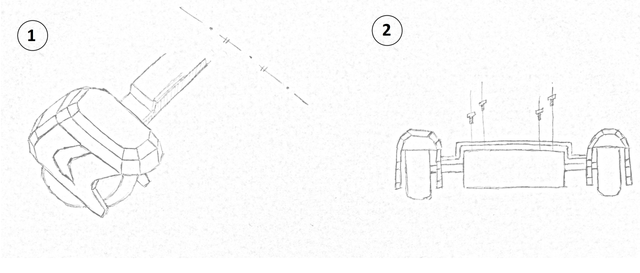

Figure 8 Sketch of the rear wheel guards

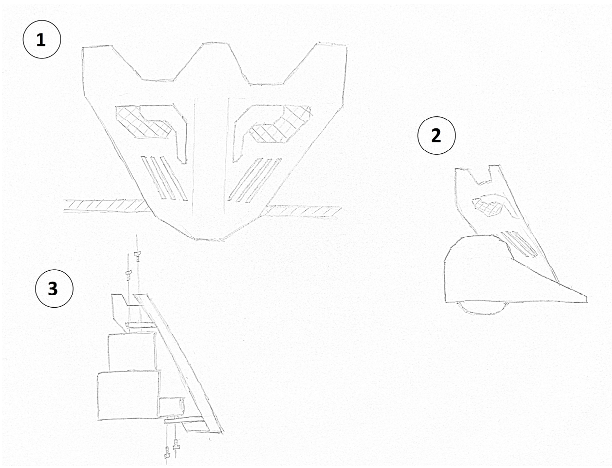

Figure 9 Sketch the front mask

(3). The fixing is done with four screws: two at the top and two at the bottom.

The last piece, part of the outer structure, is the housing. This on the one hand has the role of protecting the basic structure (the microprocessor and the rest of the vital components), and on the other hand it includes the catapulting system. Figure 10 outlines the concept of this housing, together with the catapulting system and the video recording system. The frame (1) captures a side view of this part. The design is obviously structured around the idea of resembling the body of a scorpion. Thus, a sharp segment can be seen at the bottom, which represents the fourth pair of legs. In the extremities the threshold is higher to allow the installation of wheel guards. The catapult system is located inside this structure, and the camera is mounted above it. The footprint of the housing, relative to the wheels of the machine, is outlined in (4). The mounting of the housing on the basic structure will be done by four screws, as in frame (5). These screws will enter the threaded holes (12) noted in Figure 1.

3.2 The concept of the catapult system

As can be seen in Figure 10, the arm of the catapult is curved forward, just like a scorpion tail. This serves not only as a design, but also to obtain a favorable trajectory of the projectile. Since the range is not a parameter of interest, the coverage given by the curvature of the catapult arm implies a straighter and more grounded trajectory of the projectile (which increases the accuracy) to the detriment of a long-distance vault. Detail (2) symbolizes the launch mechanism. It is automated and consists in withdrawing an obstacle formed by two lateral teeth, thus releasing the catapult arm, profiled in turn.

The catapult tensioning mechanism is the one used in the past on Onager [4]. Specifically, it is an elastic cable wrapped around the shaft and attached to the end of the arm. Once the arm is folded, the wire is tensioned and energy is stored. This system is presented in detail (3). An automatic mechanism for adjusting the trajectory is also included in the design of this concept. It consists of a lever attached at one end by the camera that has a degree of freedom (on automatic control the camera has a rotating motion, changing the recording altitude), and at

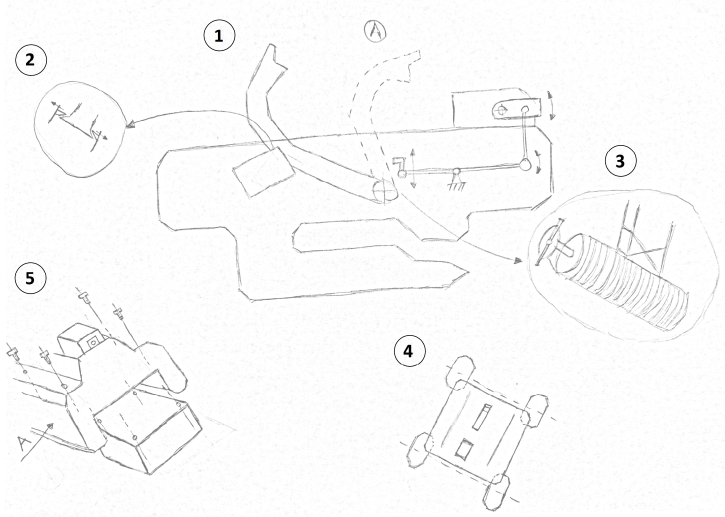

Figure 10 Sketch of the housing

the other one by a threshold. Changing the threshold altitude it modifies the length of the arc described by the catapult arm, from the moment of rest until the projectile detaches. Thus, if the recording target have to be moved ascending, the camera is operated upwards. With this movement, through the lever, the threshold is lowered, and the arc of the circle described by the arm decreases. As the trajectory of the projectile is tangent to the arc of the circle at the moment of detachment, it acquires a greater slope and therefore the catapult aims higher. Analogous to this process, when the camera is dropped the projectile is thrown down.

3.3 Possible developments

Taking into account the current stage of the prototype, but also the concepts presented above, in the future it is aimed to concretize the external structures. The 3D modeling of these parts involves the consolidation of the approached theme, i.e. the realization of the finished design of a catapult machine. Starting from the sketched concepts, the modeling can be performed, similar to the basic structure, in a dedicated software program (CATIA).

Other aspects that can be addressed in this topic are 3D model animation and its implementation in a virtual gaming environment. These two directions of research are linear, the latter involving the former. Once the wheel rolling and projectile launch processes are animated, the entire project can be transposed into a controlled virtual environment for use on various platforms. In any case, the total modeling of the machine is an essential step in developing these procedures.

4. CONCLUSIONS

Following the elaborated stages, the current stadium of the project which consists in the development of the design of a catapulting machine is well outlined. Thus, the functionality in terms of running the machine is ensured by achieving its basic structure. As for the design of exterior structures, it currently remains at the concept level. However, the elaborate sketches provide the details necessary for the concrete modeling of the respective parts.

By concretizing the above, the article manages to cover the design elements of the entire product. Moreover, the paper describes an innovative catapult system that is incorporated into the main exterior structure of the car.

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