KINEMATIC ANALYSIS FOR MULTI-COPTER UAV LANDING GEAR

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Abstract: *The multi-copter UAV landing gear is used for ground station and shock damping for landings. The materials used in the construction of landing gears are selected by using a simple criterion: minimal mass versus maxim resistance at shocks. Article contains an evaluation of a kinematics mechanism quadrilateral landing gear is mounted on a multicopter.*

Keywords: *UAV, multi-copter, landing gear, mechanism, kinematic analysis*

Symbols:

n	*The number of elements for the mechanism, including fixed elements*	p	*The number kinematic couplings of the mechanism*
m	*Movement restrictions*	c_i	*Constrain level for kinematic couple*
q	*Number of independent outlines of the mechanism*	b	*The number of free space for the gradations that are used (mobility number)*
b_j	*The number of free space for the gradations used in the closed chain*	f_i	*The connectivity of kinematic couple (the number of free space for the gradations)*

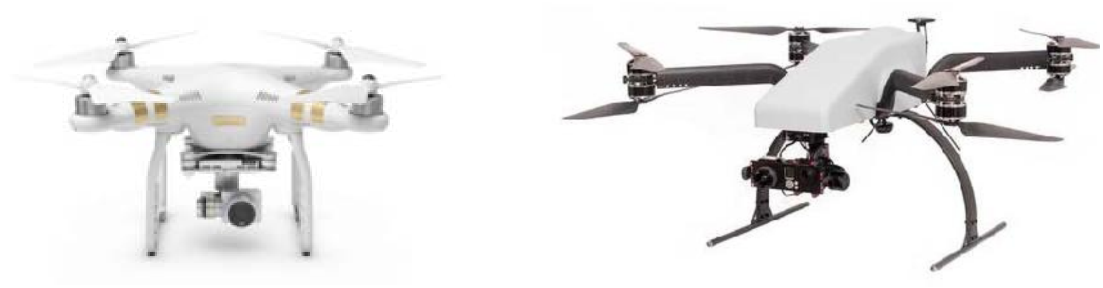
1. INTRODUCTION

The multi-copter UAV's are one of the most stable and fast unmanned aerial vehicles which offers a large applicability in all types of missions, such as: data acquisition, registration, direct transmissions, and flight at low altitude, all at a low cost. The actual development rate proves the fact that they are especially used in data acquisition due the variety of sensors on it. [3, 7].

The imagery sensors are usually mounted in the center of the aerial vector for a wide range in the field vision. Fixed landing gear does not offer an advantage for the sensor mounted, see figure 1, thus the constructors resorted to retractable landing gear which enhanced data acquisition, see figure 2.

The multi-copter UAV landing gear is used for ground station and shock damping for landings. The materials used in the construction of landing gears are selected by using a simple criterion: minimal mass versus maxim resistance at shocks. Some of the materials used are: duralumin, glass fiber and carbon. The elements for the landing gear could have a pipe or rod shape, with a circular or square section [7].

Looking at the landing gear functions (turnover, station and shock damping) we will present a series of data and an analysis of a landing gear for a UAV type multi-copter.



(a) (b)

FIG.1. Multi-copter with fixed landing gear, a.DJI Phantom 3 [1], b.Bird-pilot X8 [2]

FIG.2 UAV type multi-copter with retractable landing gear, a.DJI Inspire 1 [1], b. DJI S1000 [4]

2. THEORETICAL REFERENCES

From the constructor's point of view, the landing gear chosen for analysis is the one with a linkage mechanism (quadrilateral mechanism) which has 4 closed kinematic couples, where the contact between the two kinematic elements is realized through permanent steerage, see figure 3.

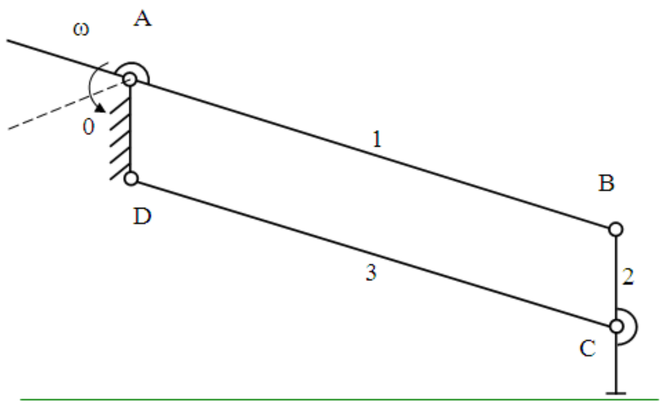


FIG. 3 Kinematics scheme for the landing gear mechanism

A plan mechanism with a high rate of mobility requires four fundamental kinematic couples. The chosen landing gear represents a determined kinematic chain (desmodromic) in which the position of the components depends on the position of one kinematic parameter (angle or movement), and the mobility rate for the plan mechanism (Grubler-Cebîşev-Kuţbah equation) is accordance with the fast calculation method, [11] which is written (equation 1, 2, and 3):

$$M = 6 \cdot (n-1) - \sum_{i=1}^{p} c_i \tag{1}$$

$$M = b(n-p-1) + \sum_{i=1}^{p} f_i \tag{2}$$

$$M = \sum_{i=1}^{p} f_i - \sum_{j=1}^{q} b_j \tag{3}$$

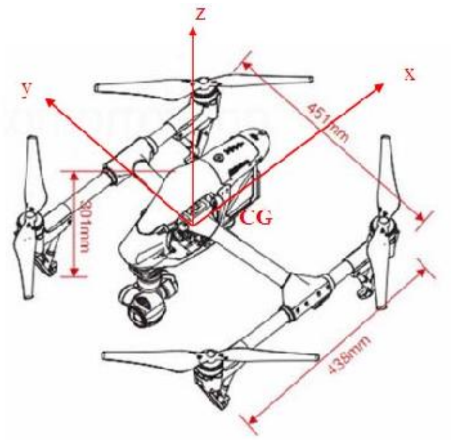
For plane mechanism with b=3 the mobility rate is (equation. 4):

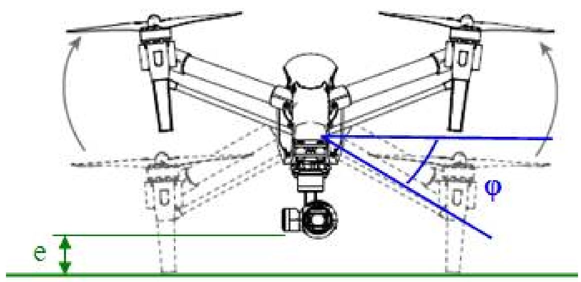
$$M = -3 + \sum_{i=1}^{p} f_i \tag{4}$$

3. THE ANALYSIS OF A RETRACTABLE LANDING GEAR FOR UAV TYPE MULTI-COPTER

3.1. Landing gear type parallelogram with four support points

This type of landing gear could be equipped with wheels for the realization of turnovers or sled, both cases offering a high stability on the ground. The support base on the sole for a light weighted multi-copter is optimized in the following way: components versus a high stability at station on ground, respecting the minimal ground fuselage (e) which will be adopted according to the standard dimensions of the video sensor (see figure 4b)





a b

FIG. 4 Dimensions and the extreme positions of the landing gear

a- base dimensions for multi-copter, b- ground clearance and the semi-angle of the retractable landing gear

The design process includes the conceptual stage where the mechanism of the landing gear is analyzed through a series of parameters: dimensional, positional, angular and kinematic, depending on the mobility rate that it has. For movement element for the landing gear we use a servomechanism with the following characteristics, see table 1.

Table 1. Servomechanism characteristics [6]

Servo model	Futaba 3153	Tension	4.8 – 6 V
Modulation	Digital	Torsion	1.4-1,7 kgcm
Motor type	Brushless	Mass	9,6 g

3.2. The analysis of the quadrilateral landing gear

The kinematic analysis of the mechanism is reduced to the study of the structural groups, so it can determine the trajectories for some points in the mechanism, the position of the mechanism for the know data of the leader element, speed and angular accelerations for head elements, speed and angular accelerations for some random point in the mechanism.

We will take into consideration the fact that the balance mechanism contains a RRR diode, with the geometry presented in figure 5, and the analysis data in table 2. The kinematic mechanism has three mobile elements (m=3) and four inferior kinematic couples (i=4), see figure 5. The mechanism is analyzed with the help of a software, SAM 6.1 [5, 9, and 12], and the values are from table 2. This software allows design, analysis and optimization of simple and complex plan mechanisms.

Table2. Parameters for kinematic mechanism

Training element 6	30 mm	Execution Element 4	49 mm
Element 2	49 mm	Element 3	230 mm
Element 1	230 mm	Actuation lever angle	60^0
Analysis time	6 sec		

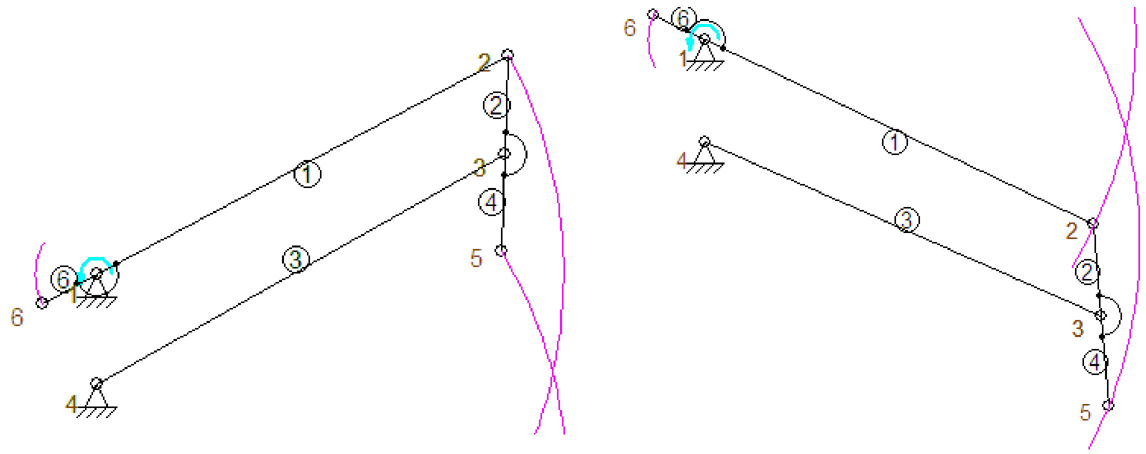
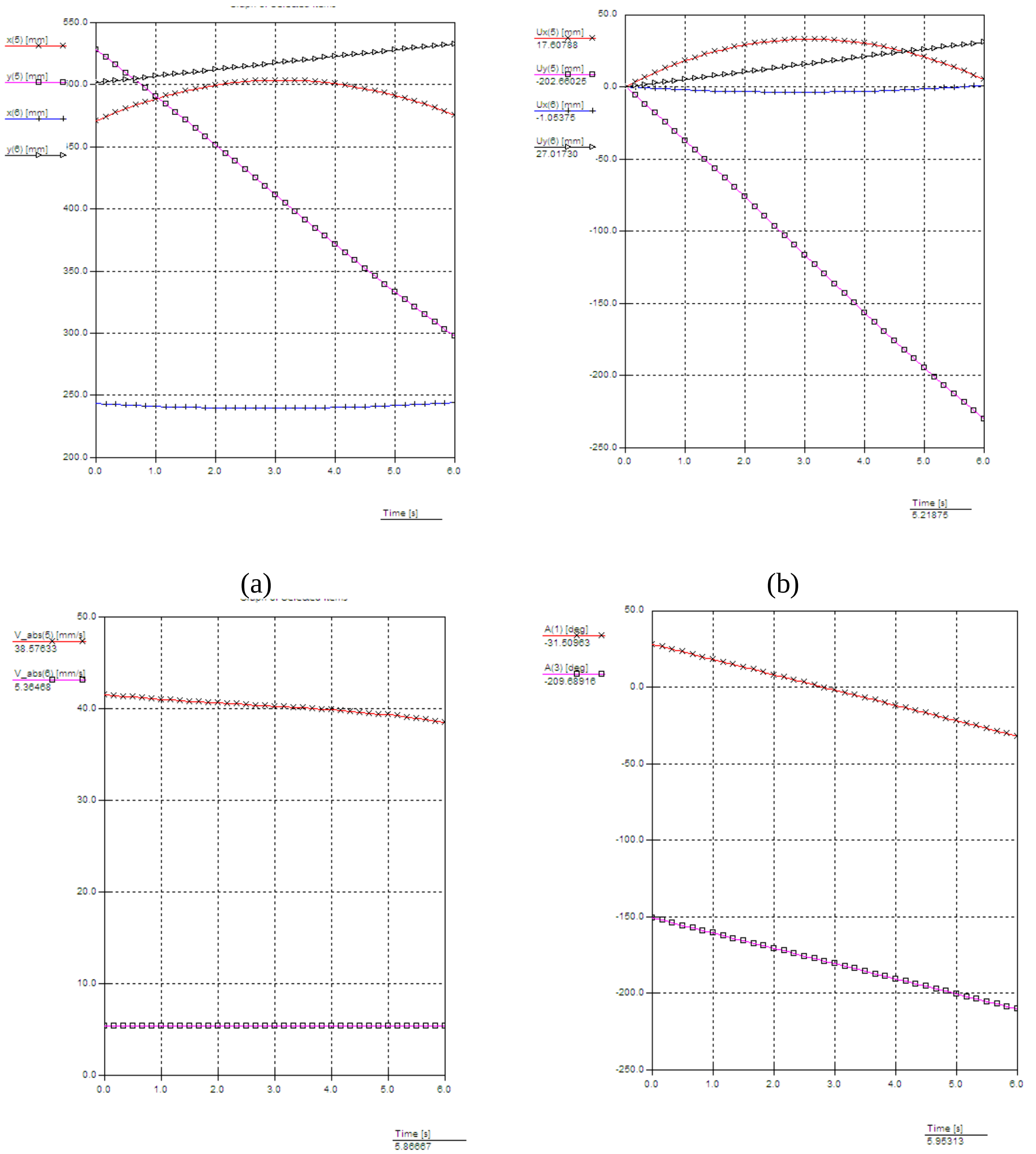


FIG.5. Extreme positions of the kinematic mechanism for the landing gear [9]

The analysis shows a series of position and speed parameters in figure 6 and figure 7 and table 3.

Table3 Kinematic characteristics

Time [s]	x(6) [mm]	y(6) [mm]	x(5) [mm]	y(5) [mm]
0	243	501	470	527
3	239	517	503	411
6	244	532	475	297



(c) (d)

FIG. 6 Theoretical position parameters for the landing gear

Absolute speeds of input nodes (N6) and output (N5) can be seen in Figure 6c (node 6 constant speed, node 5 having quasi-linear variation). It is seen in Figure 6d a development parallel angle (A1 and A3) of the two arms (1 and 3) of the mechanism to be analyzed.

3. CONCLUSSIONS

SAM 6.1 integrates pre-processing, numerical analysis, post-processing and optimization mechanisms (only professional module) in an easy to use software environment, mechanisms can be designed free or module wizard.

To minimize errors and optimize kinematics mechanisms shaping plane and spatial systems in UAVs composition may require a dimensional study developed at the spare parts or assemblies.

The software kinematics analysis of the mechanism is the base of dimensional design of the chain command for a landing gear (for UAV). A complete analysis would be realized in a further research where we will optimize mass and kinematics for the landing gear using a minimal time for retraction.

ACKNOWLEDGMENT

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