DYNAMIC MODELING OF QUADRUPED BIOMECHANISM

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Abstract: In this paper we present the dynamic modeling of a biomechanism which represent the legs of a four legged mammal. The anterior legs and posterior are realized as plane mechanisms, with articulated bars. Each anterior leg has a complex structure with three closed contours, mean while each posterior leg has only two closed contours. Each mechanism is actuated by an electric motor. The dynamic simulation is achieved by means of ADAMS software, considering as basis, the upper platform of each mechanism.

1. INTRODUCTION

In case of four legged animals, the structure of anterior and posterior legs is very similarly by the structure of most majorities of actual four legs quadrupeds [3, 4]. To some quadrupeds, the anterior legs are short that those posterior.

To remark, that at quadrupeds, the anterior legs have the degree of mobility larger than the posterior legs.

By physical modeling of a dog (fig. 1) we obtain a biomechanism (mobile biorobot), in which the legs are realized like plane articulated kinematic chains [4].

Each physically modeled leg is actuated by a continuous current electric motor, powered by an accumulator's battery. The dog body is physically modeled by two parts, front and rear and articulated between them. Also, the dog head is connected by the body with a joint at the head level. We mention that, in the case of this physically model (fig. 1), the foot of the anterior legs has a rotation in vertical plane.

Fig. 1.The picture of the dog as a quadruped biomechanism

2. KINEMATIC SCHEME AND THE MOBILITY OF THE BIOMECHANISM

In frontal plane, the physically model of the dog (fig. 2) distinguish those two complex articulated kinematic chains for the anterior and posterior legs.

Fig. 2.Picture in frontal view of the dog as quadruped biomechanism

The kinematic scheme of the quadruped biomechanism is realized in vertical longitudinal plane (fig. 3), in which are represented the plane articulated mechanisms of those two legs, from rear (fig. 3a) and front (fig. 3b). The booth mechanisms are articulated in the upper side to a horizontal link, which represent the body of the physically modeled dog.

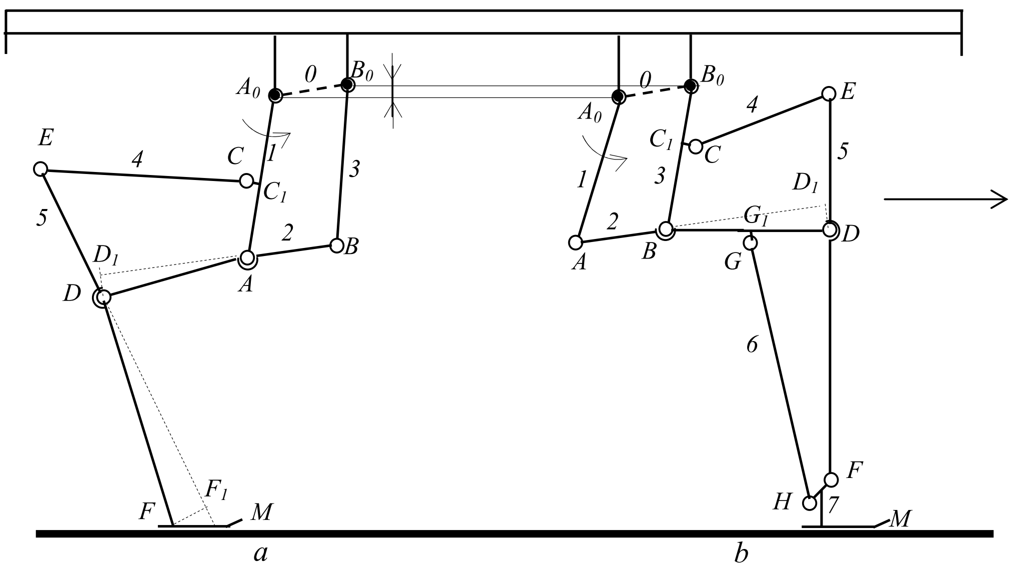

Fig. 3.Kinematical scheme of the mechanisms from posterior legs (a) and anterior (b)

The joints A_0 and B_0 of each mechanism to the upper mobile platform (fig. 3) are considered as basis joints, by this reason this platform has been noted with 0.
Each from those two mechanisms (rear and front) has a first kinematic chain, the four bar mechanism A_0ABB_0, which is formed from the kinematics chains *0, 1, 2* and *4.*
The second kinematic chain of each mechanism is the four bar articulated mechanism *ACED,* with the kinematic elements *1, 2, 4* and 5 (fig. 3a) or *BCED,* from the elements *2, 3, 4* and *5* (fig. 3b). The mechanism of the front leg contain another kinematic chain *DGHF* (fig. 3b), which is formed from the kinematic elements *2, 5, 6* and 7. The mobility M_b of each from those two plane mechanisms is calculated with the Dobrovolski formula:

$$M_{bf} = (6-f)n - \sum_{k=f+1}^{5}(k-f)C_k \tag{1}$$

which for $f=3$ (plane mechanisms) become the Grübler-Cebâşev formula

$$M_{b3} = 3n - \sum_{k=4}^{5}(k-3)C_k = 3n - 2C_5 - C_4 \tag{2}$$

where the class of the kinematic joint distinguish the imposed restrictions (*k=5, k=4*).
Also, the mechanism mobility can be calculated with the general formula, P. Antonescu [1], [2]

$$M_b = \sum_{m=1}^{5} mC_m - \sum_{r=2}^{6} rN_r \tag{3}$$

where is distinguished the mobility of the kinematical joints $m = 6-k$ and the range of each closed independent contour $r = 6-f$. For plane mechanisms the formula (3) is writhed

$$M_b = \sum_{m=1}^{2} mC_m - 3N_3 = C_1 + 2C_2 - 3N_3 \tag{4}$$

To calculate the mobility of those two mechanisms (fig. 3a, 3b) we use the formulas (2) and (4):

a) $M_{b3} = 3n - 2C_5 - C_4 = 3\times5 - 2\times7 - 0 = 1$; $M_b = C_1 + 2C_2 - 3N_3 = 7 + 2\times0 - 3\times2 = 1$.

b) $M_{b3} = 3n - 2C_5 - C_4 = 3\times7 - 2\times10 - 0 = 1$; $M_b = C_1 + 2C_2 - 3N_3 = 10 + 2\times0 - 3\times3 = 1$.

The characteristics dimensions of each from those two mechanisms are (fig. 3*a* ,*b*):

a) A_0B_0=12 mm; $y_{B_0} = 2mm$; *A_0A=28; AB=13; B_0B=30; A_0C_1=15; CC_1=2,5; AD_1=30; DD_1=4; CE=40; DE=23; DM=66; DF_1=54; FF_1=25;* $CC_1 \perp A_0A$; $DD_1 \perp AB$; $FF_1 \perp DM$.

b) A_0B_0=12 mm; $y_{B_0} = 2mm$; *A_0A=28; AB=13; B_0B=26; BC_1=15; CC_1=4; BD_1=27; DD_1=4; CE=19; DE=17,5; DF=47,5;BD=27,5; BG_1=15; GG_1=0,5; GH=56; HF=10; FM=20; HM=25;* $CC_1 \perp B_0B$; $DD_1 \perp AB$.

In the topological structure of each mechanism we identify the kinematic element 1, as motor element and two or three kinematic chain, dyad type (LD). In this case, starting from the fundamental mechanism $MF(0+1)$, the structural topological equations of the mechanisms (fig. 3*a, b*) have the expressions:

a) MM_p = MF(0+1)+LD(2+3)+LD(4+5); posterior leg; (5)

b) MM_a = MF(0+1)+LD(2+3)+LD(4+5)+LD(6+7); anterior leg. (6)

In the following we analyze the geometry and kinematics of the mechanism which form the anterior member (leg from front) with o more complex structure.

3. DIAGRAMS OF JOINTS CONNECTING FORCES VARIATIONS

We consider the uniform movement of the motor element 1 (fig. 3). With the help of the ADAMS soft-ware we simulate the movement of the anterior leg for the angle φ_1 = 52º.
We realize the mechanism as a 3D structure, on which the kinematic elements are defined as shape, geometry and material property.
We define the kinematic joints of the mechanism with corresponding constraints and mobility's, we define the local and global coordinates systems upon we calculate the

mechanism kinematic parameters. We define the motor element ant the eventually loads (forces or moments which act upon the kinematic elements) upon we process the kinematic analysis.

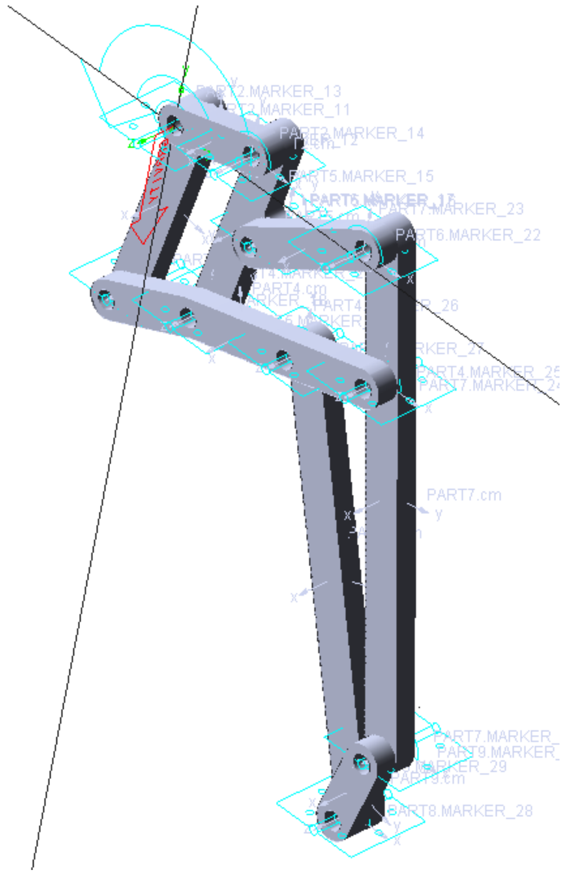

Fig. 4. 3D Model of anterior leg mechanism with plane articulations

With the help of ADAMS software we represent the joints connecting forces diagrams of variation, in figures 6…10.

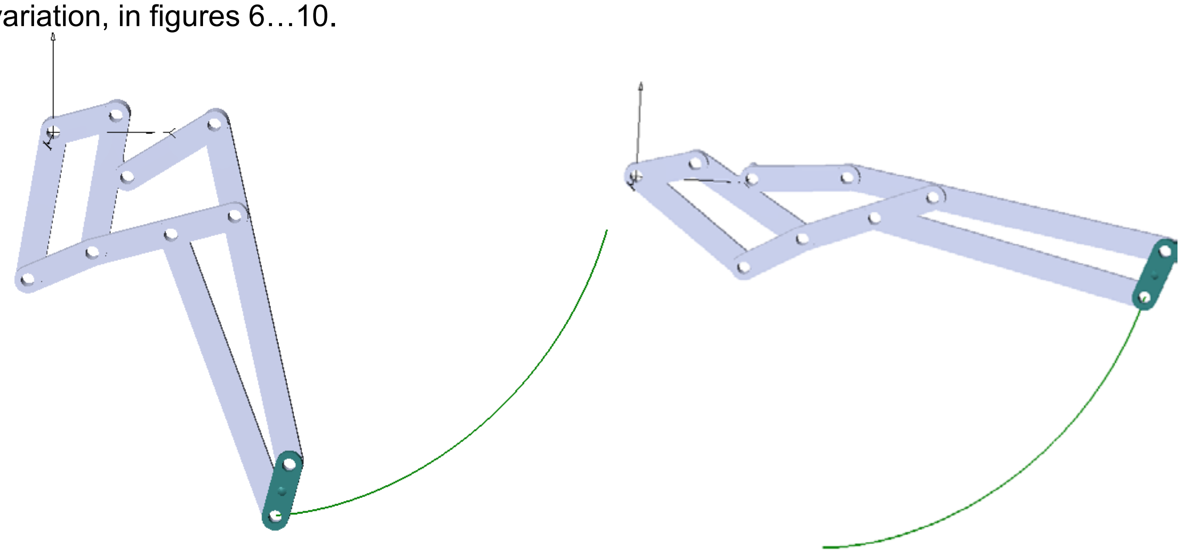

Fig.5.Trajectory of F joint between elements 6 and 7

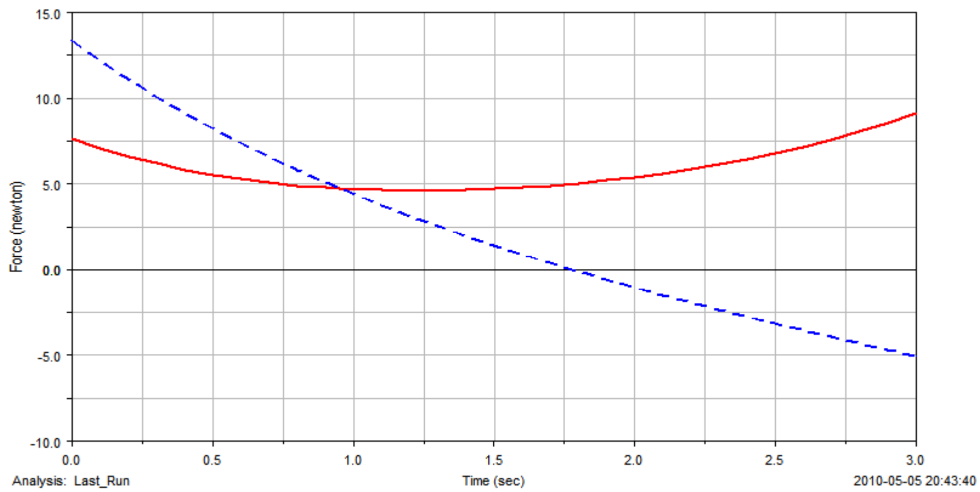

Fig.6. Variation of the components of the connecting forces from the joint B

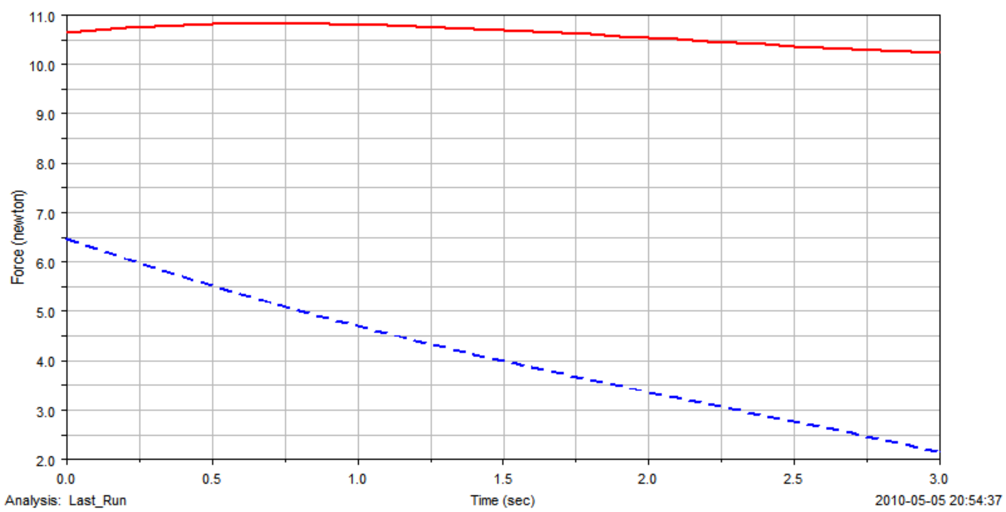

Fig.7. Variation of the components of the connecting forces from the joint C

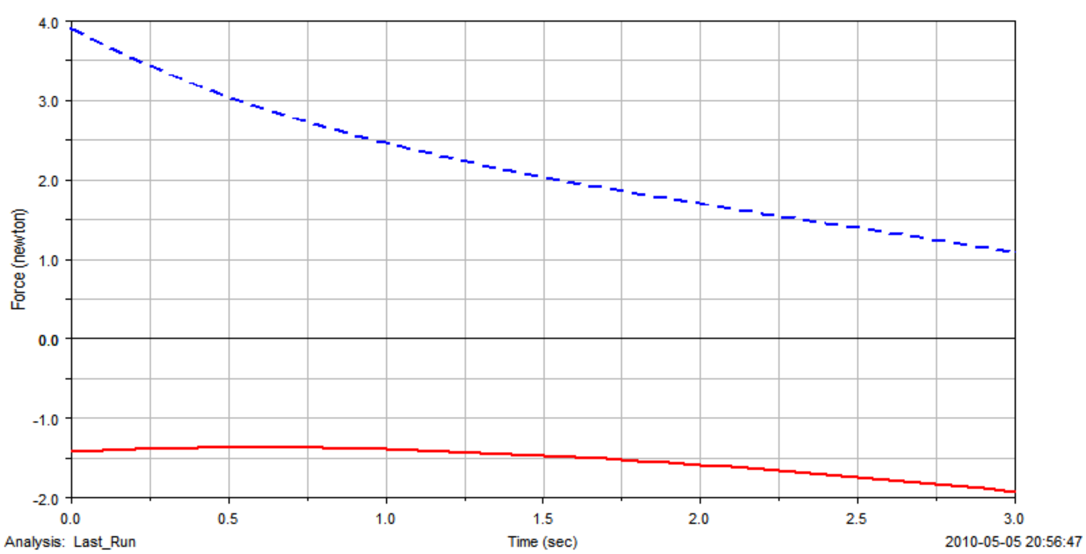

Fig.8. Variation of the components of the connecting forces from the joint G

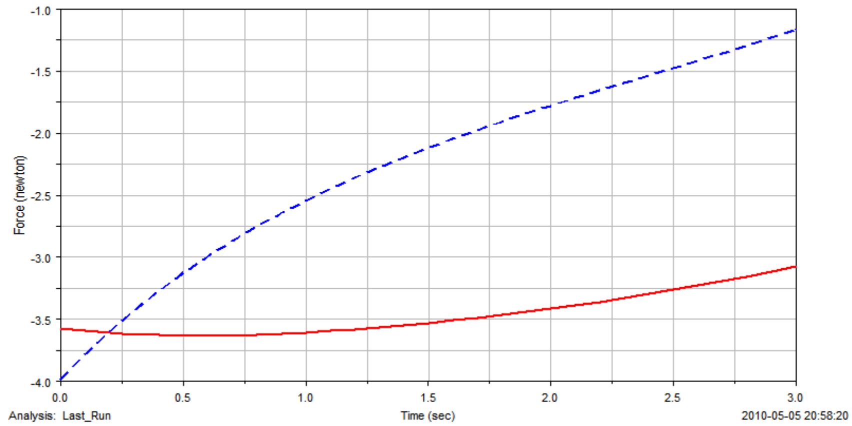

Fig.9. Variation of the components of the connecting forces from the joint F

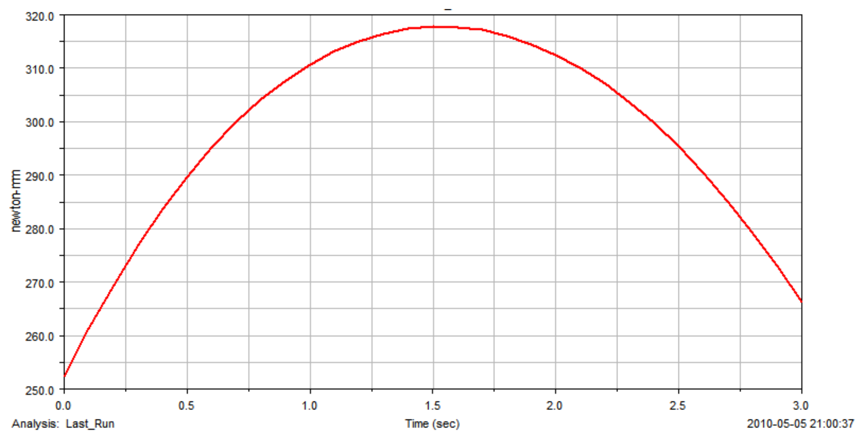

Fig.10. Law of variation of the motor torque

4. CONCLUSIONS

In this paper we have presented the dynamic modeling of the kinematic chain (with three closed contours) which composes the anterior member of a dog robot. For modeling and simulation we have used the ADAMS software.
In figure 5 we present the trajectory of the characteristic point F (fig.3) and simulation in two positions of the plane articulated mechanism of the anterior member.
In figures 6-10 are presented the laws of variations for the joints connecting forces.

5. REFERENCES

[1] Antonescu, P., Mecanisme, Ed. Printech, Bucureşti, 2003;
[2] Antonescu, O., Antonescu, P., Mecanisme şi Manipulatoare, Ed. Printech, Bucureşti, 2006;
[3] Buzea, E.M., Antonescu, O., Modelarea şi simularea geometro-cinematică a biomecanismului tetrapod (patruped), Revista Mecanisme şi Manipulatoare, Vol. 7, Nr. 2, p. 39 – 44, 2008.
[4] Micu C., Geonea I., Kinematic modeling and simulation of quadruped biomechanism, International Conference of Mechanical Engineering, 27-30 aprilie, Craiova.
[5] *** Documentație de firmă: www.smart-toys.ro