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Optimal design of a mobil minirobot with locomotion based on the changement of the mass centre position

ABSTRACT

The mobil minirobots development is closely linked to research, education and hobbies. Relating to research areas, the interest is represented by the minirobot capability to navigate and to adapt to an unknown environment. Therefore, mechanical structures optimization and command and control algorithm optimization are still feature research issues.

The walking robots degrade less the environment and have a higher mobility than those that have wheels or caterpillar chains. The paper presents a mobile minirobot, which use modification of his center of gravity for displacement. He is a walking robot.

ISSUES REGARDING THE MODEL DESIGN

DIAGRAMMATIC, THE MINI-ROBOT HAS, AS BASE MOTION, A SLUING motion of a rail, backed on one of the two bearer supports A and B, as can be seen in fig.1. This motion is possible through the displacement of a slide cart with the mass GC [Kg] (see fig. 2, to) on the length direction of the two bearer supports and is positioning outside those, to one end or to the other and of the rail. For example, through the displacement to the left end, when the cart is outside the bearer support A, at a distance from this support, to the open end, if the weight moment towards the support point of the rail on the bearer support, A, is balancing the moments caused by the own weight forces of the rail with the mass GB [kg] and weight forces of the other bearer support, B, with the mass GS [kg], the rail will be in the circumstance of movement starting (sluing). Both the support A and the support B belong to the rail, as long as, in reality, they have joints, every one of them, by a universal joint (cardan) to rail.

Below, is presented a preliminary simple calculus regarding of one part of mini-robot locomotion. It is presented just one cycling sluing movement of one rail, in the vertical plan, on one bearer support. The rail represents the main component of the mini-robot. In the calculus,

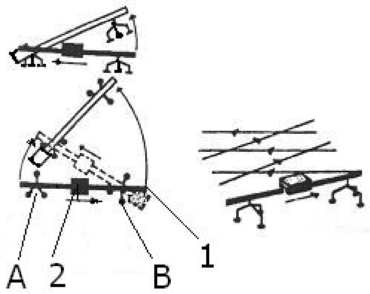

Fig. 1. Modality of displacement for the minirobot.

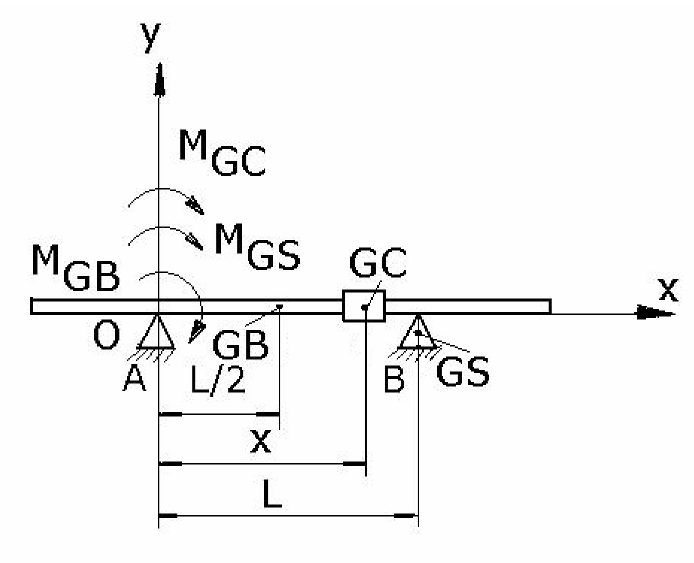

Fig. 2. Calculus schema.

it's take in account only the time when the rail is starting the sluing motion, when the balance is lost. The calculus is a simple one, but, the obtained results allow to appraisal the ratios between the slide cart mass, rail mass and bearer support mass. These ratios are very useful in the actual design phase. Attested with the balance, precisely enough, of the minirobot masses, thing possible in the actual design phase, can be acknowledge the advantages regarding the gear motors, the DC source (storage battery), the control and command interfaces mounting, so that it will be used a minimum supplementary masses of ballast counterweights. Thus, it permits to obtain an active structure, not a passive one, as lightly as possible.

The purpose of this preliminary calculus is a quantitative estimation of the ratio between the rail and the other masses of the parts of mini-robot model (that is, especially, the own mass of the rail and one bearer support mass): $\frac{GC}{GB+GS}$. To calculate, it is necessary to make some issues which will permit to approach very well known calculus methods. This is also the case of simple bar bracing on supports, without take in account the above mentioned joints, between the rail and legs bearer supports. Through sum the three moments M_{GB}, M_{GS} and M_{GC}, which are moments produced by weights GB, GS, and GC, towards the bearer support A, and can be written a static equilibrium linear equation. To this purpose, a reference system, xOy, is attached to the rail horizontal position with origin point O placed in the contact point of the rail with the bearer support A. Toward the origin point, O, the moment produced by the weights GB, GS and GC is:

$$MS = M_{GB} + M_{GS} + M_{GC}$$

The weighs moments GB and, respectively GS, towards the origin point O, are:

$$M_{GB} = \frac{L}{2} \cdot GB \cdot g$$ and

$$M_{GS} = L \cdot GS \cdot g$$

They have constant value. L represents the rail length between the bearer supports and g – gravitational acceleration.

The moment:

$$M_{GC} = x \cdot GC \cdot g$$

can be positive or negative, if x is on the right side or on the left side of the origin O. If the moment MS is positive, the second bearer support B has contact with the floor and is working with the force $\frac{GS + GC + GB}{2}$ on this. When the moment M*S* is zero, the bearer support B don't develop any force on the floor. When the moment MS becomes negative, the rail and the bearer support B (bearer support joints with the rail through a universal joint - cardan, as is mentioned hereinbefore) is sluing with an angle round the origin point O of the bearer support A, toward left. The rotation angle will have a dependent value with the position on the rail and the mass of the slide cart. At the direction changing of the slide cart, the rail will come back in position homologous with the case when the bearer support B is in contact with the floor, this case is identified with the time when the moment MS is becoming, again, positive. So, the rail it will be braced on both bearers supports. Through the alternately displacement of the slide cart to one or to the other ends of the rail is assured the cycling of the rail, the rail will up one end, after that the other end will be up (cycling movement of the rail ends) and so the end will throw-away toward the floor, to make possible the performing of the second part of the mini-robot structure displacement, similar with the biped being gait, just a little different from the movement known in the nature. The specific characteristic of this movement is the sluing, cycling, on each leg, which stays in contact with the floor, to backed the slide cart, which is different from the human gait.

In fig. 3 is presented a software routine window developed in Delphi environment, used to find solutions of the calculus presented in the hereinbefore equations. To facilitate the preliminary evaluation of the part dimensions of the mini-robot structure will be used the following ratios:

$$KB = \frac{GB}{GC} \qquad \text{and} \qquad KS = \frac{GS}{GC}$$

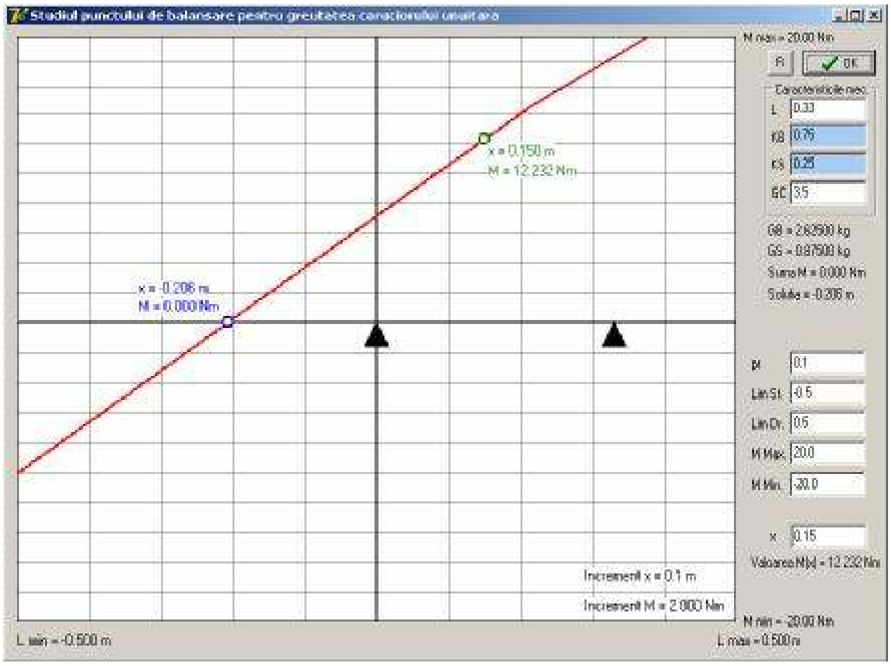

Fig. 3. The graphical interface of the Delphi software routine.

In the up-right zone of the window, aside from the coefficients KB and KS, must be defined: L length of the rail, between the bearer supports, GC [Kg]- the slide cart mass. The values L, KB, KS and GC can be modified through the control button window. The GC and GS masses have been defined also in Kg. in the instant, in the base zone of the window, in the right part the GB, GS, Suma M (moment) and "Soluția =", have been indicated, after the L, KB, KS and GC choosing. „Soluția =" represents the moment equation solution toward the O origin point and is indicated the moment when the rail is sluing (the moment M = 0). Her value is, in fact, the x value, of mass GC vector mass of the slide cart at the bearer support A. In this case the moments sum towards the origin point O becomes zero. If the slide cart mass is on the right side of the bearer support A: $x > 0$, and if $x < 0$, the mass is on the left side of the bearer support. On the diagram is marked with a blue circle, on abscissa axis, which represents the x value when the moments round O origin point are zero that means the value is equal with “soluție”. The red line represents the linear variation of sum moment, M, in terms of Nm. On the diagram is presented, on moment variation line, with a green circle, the current values *x* and the moment M(x). Also, is represented the rail bearer supports, the rail isn’t shown (because the rail lines can be confused with the variation moment line).

Below, is indicated another group of active buttons: pr, represents the grid step dimension on abscissa; Lim St., Lim Dr., represents the abscissa limits on the left side of the origin and, respectively on the right side of the origin, that means graphical limits on abscissa axis. These admeasurements are in terms of meters. M Max. and M Min. are the moment values toward the origin point O, limited by the graphic presentation on ordinate axis. All the moments’ values are in terms of Nm. Another active button modifies x [m] value, which represents the distance between the center of mass of the slide cart and the active bearer support (round is rail cycling get occur). So, these value, can be modified after the placement in an active window, in contract with „soluția” which represents the moment equation x value written toward the origin point O and is presenting the rail cycling starting point (when the moment M = *0*). In an inactive “window” is presented the actual moment value M(x), toward x, of all masses of the rail structure parts. Also, are presented, as redundant parameters, on the drawing limits of the diagram the limits value of the length L: L min and L max, of the moment M: M min and M max.

In the upper side of the window are two buttons: „OK”, for calculus validation after the data value insertion in the active windows and „R”, for the case of the data values coming-back used before the insertion. This permits the using of the previous good data set, if this data set wasn’t saved before.

The software routine was converted in an executable, to be executed on other machines with Microsoft Windows operating system, even when the Delphi environment is not present on that machine.

It can be inserted values for: length L, slide cart mass GC, coefficients KB, K.S. Thus, these last coefficients can be modified in opposed directions, one to go up, and the other to go down, to observe the influence on the rail dimensions, which represents the main part of the mini-robot. The slide cart mass can be modified, to go up or to go down. The length L value between the bearer supports can be, also, modified directly proportional or inverse proportional with the slide cart mass.

THE MODEL OF THE MINIROBOT

THE CONCEIVED AND MANUFACTURED MODEL HAS O BEAM STRUCTURE, materialized into a translation guide made of two cylindrical bars 1 and 1’ (fig. 4). On this structure, a cart 2 is sliding, which bears two servomotors: one used for translation motion cart driving through the gear pinion 3 and rack 4, and another used for actuating a shaft with the rollers 5 and 6, placed on the ends of the beam structure.

The shaft 11 cross the slide cart and is bear in the revolution movement on the bearings mounted in the parts 7 and 8. These shaft has a longitudinal riffle into a worm gear wedge can slide. The worm gear has the bearings inside the slide cart. The worm gear is engaged with a spiral gear mounted on the servomotor shaft 12.

The parts 7 and 8, placed on the two ends of the guiding beams are identical and are joined through the intermediary plates 9. On every intermediary plate is placed a circular retaining holder 10 with cardan joints. The beam structure retaining has been achieved through these holders. When the cart is outside of the retaining holder, it tilts in the vertical plane of the beam structure. The end beam roller 6, where the cart is displaced, it’s holding on the horizontal plane and therefore is the structure swinging with an angle, which can be controlled by the second gear motor. The structure pitch angle is controlled through the cart position, outside of the holding zone through the special structure conceived for this issue. The elements 9 permit this, because they are retained in a preferred position face to the parts 7 or 8, through the actions of some elastic parts, which are not shown in the figure. A horizontal displacement of the minirobot is obtained through similar actions at the opposite end (7) of the beam structure. In this manner, the displacement of the beam structure is obtained; implicate action is presented in fig. 1.

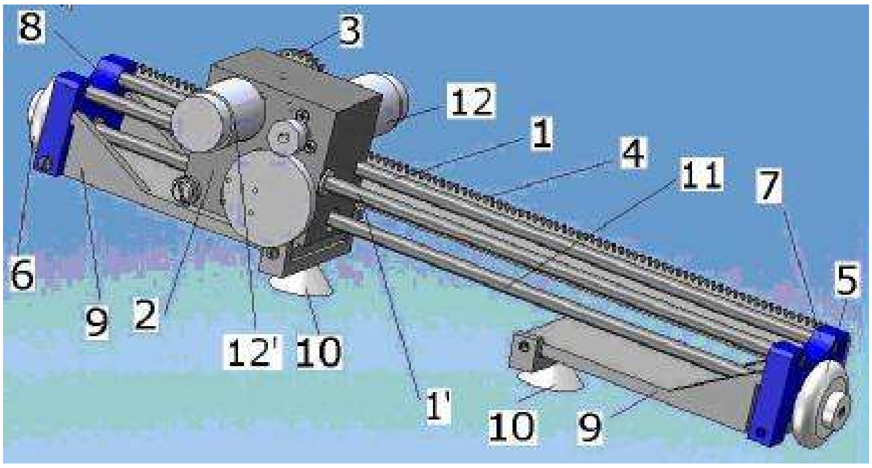

Fig. 4. The model of the minirobot.

CONCLUSION

In the minirobot design process an optimal ratio of the main parts masses was traced, to obtain a minimal loading gauge and a minimal total mass. Also, it was using a additional passive mass avoided, their roles have been take over by the servomotors masses, which are acknowledged like active mass, in this particular case, because they have main functional roles. The adopted solution brings in some structural entanglement, but, through the loading gauge point of view and through the loading mass point of view an optimal was achieved.

It's a fact that the maladjustment between the motors and the driving structure used for command and control is hard to correct, a PIC microcontroller Basic Stamp programmable was used, which control the Parallax servomotors.

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