DINAMIC BALANCING SYSTEM and ITS CONTROL

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ABSTRACT

In order to use lift counter-mass logic effectively and commonly in vertical load transporting, an electromechanical system was designed and introduced in this study. The system can make it easy for the loads to be soft started, soft stopped and hanged without break equipments by using extra counter masses in it.

I INTRODUCTION

We all know that if we put equal weights on both sides of the scale there will be a balance created without any energy consumed and that with wery little force applied this balance could be upset causing the movement of the scale.

In this study, it was shown whether the same logic could be applied to the vertical load transport systems.[1] The similar logic has been used in the lift systems. But The applications are limited and specific depending on the lift structure. In order to apply this logic (counter masses) commonly, it is necessary to use variable counter masses so that it would be possible to balance the load even if its weight is changed.[2] For these conditions to be provided, a special electromechanic system based on the variable counter masses was designed.[3]

This system, called Dinamic Balancing System(DBS), works in vertical position and has got 8 arms with 45^0 degree space among them. And there is a mass (weight) on each arm controlled with electric motor. Loads, which are not connected to any electric motor but to DBS, can be balanced and hanged without energy cunsumption by controlling the position of masses on each arm. Due to the masses' effect, starting and stopping operations can be performed easily. So, energy consumption will be lower too .[4] The system control is one of the most important part of the study. The mass position must be changed constantly to balance the load. The fuzzy control system is preferred as a control method.[5-6]

During the control system development an animation program built for this purpose was used, which contains mathematical modelling of the system.[7-8-9] By using this program on the computer over a hundred control tests have been carried out. Finaly, a prototype was made which works along with the animation program and some application results were obtained.

II STRUCTURE OF DINAMIC BALANCING SYSTEM AND ITS WORKING PRINCIPLES

For the DBS's normal applications its arm length can be changed from 1m to 5m and masses' weights which are moved on arms can be changed from 100kg to 1000kg. DBS is similar to a proppeler which works slowly in vertical position. There is the DBS's prototype shown in fugure 1,

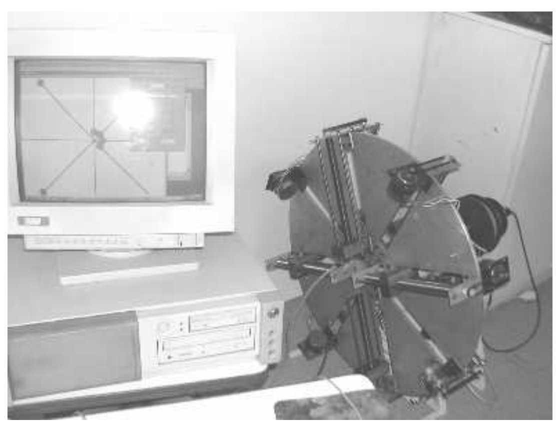


Figure 1

Every reciprocal two arms(stick) represent a scale. Each arm has got a mass which is controlled with an electric motor. All masses are equal in weight.

If the load is removed and all the masses are located at an equal distance from the DBS center, the system will be in balance.

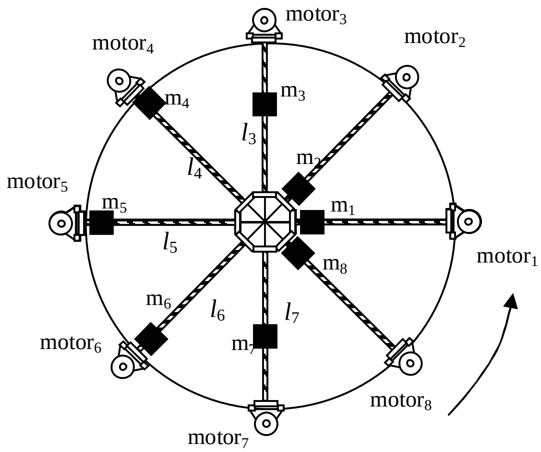


Figure 2

During the loaded working all the masses must be located in proper positions if the system is to be balanced. In the same way, load can be moved by constantly controlling the location of the masses.. l_1-l_8, represent the distance of masses to the center of DBS. m_1-m_8, represent weight of masses (Figure 2).

Figure 3 shows a vertical representation of the system which rotates in inverse clockwise direction. The load is moved up when the right side masses' effect is bigger than the left side masses' one. The speed of the movement is determined by the force difference between the both sides.

These characteristics of the DBS make it possible to use DBS in vertical load movement systems. The System starts rotating right to the direction in which the masses torque direction is bigger.

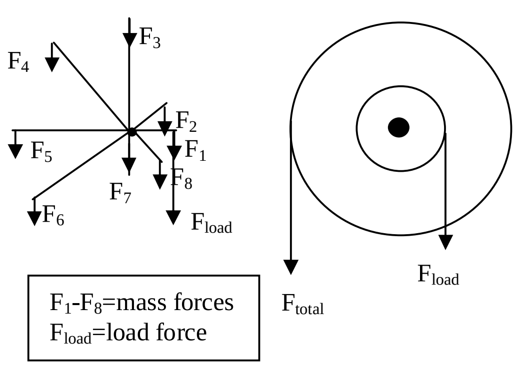


Figure 3

III MAIN FACTORS WHICH EFFECT THE WORKING OF THE DBS

Under the ideal conditions, if it is accepted that all masses' weights are 1 kg each, the left side masses are at the arms'ends (1 m away from center) and the right side masses are right at the center (their affects are zero), the torque curves can be obtained, which is shown in fugure 4. Each cosinus curve represents one mass effect. So, the maximum rotating force for each mass is found to be 1kgm. When we direct all the arms torques into one single torque, the system total torque is obtained. Figure 4a shows each mass torque separately.

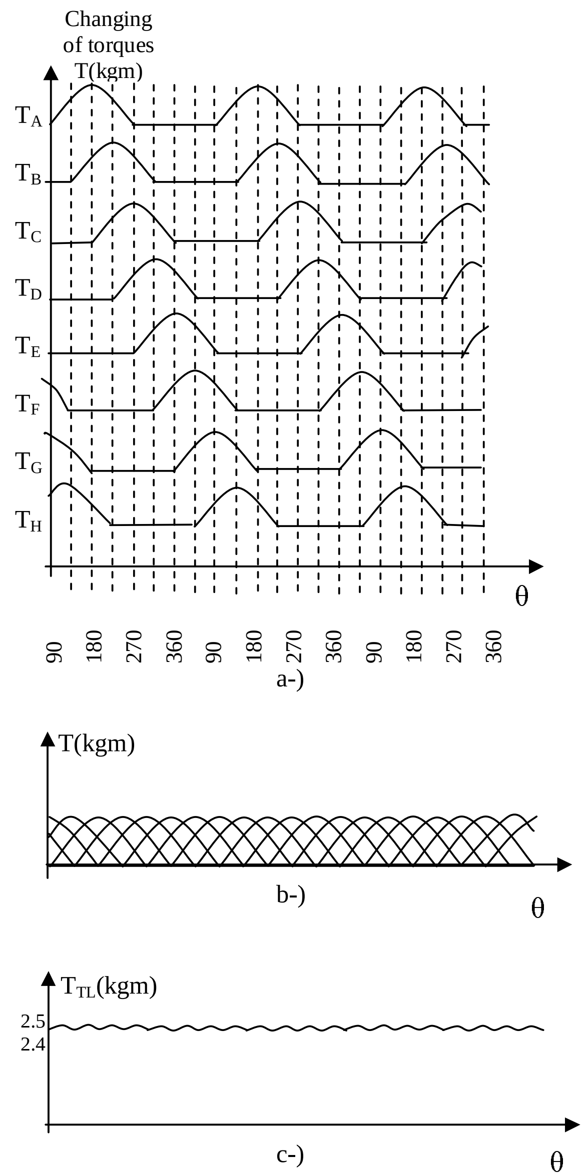


Figure 4

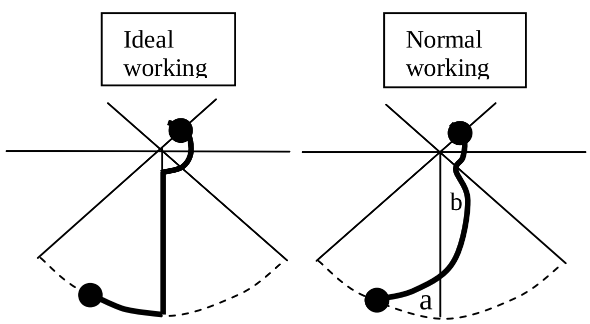
Figure 4b shows mass torques together and figure 4c shows totol torque of all masses. The fluctiations, which are seen in figure 4c, can be decreased by increasing the number of arms. But this changing results in control difficulties and some mechanical problems.

The following is assumed to exist under ideal conditions

- Firiction force is 0.
- All masses' force is 0 at the center of the DBS. So, the total force of right side masses is 0, too.
- Masses movement (from the center to the end or from the end to the center) occurs on the Y axis instantly. In other words, at the 90^0 point masses move to the end from the center and at the 270^0 point they move to the center from the end.

Under normal conditions these items are olso factors which decrease the productivity of the system. The biggest loss occurs when masses move. By setting the starting point of the masses' movement the production loss can be decreased. Another big loss occurs due to the mechanical structure. Even if the masses are located at the nearest points to the center, their distance to the centre is not 0

Figure 5 shows the losses at the a and b areas while masses are moving



Fugure 5

When the system speed is high, masses will not be able to reach the arm's end. At the proper speed of the system, to get the maximum torque masses must complete their movements in nodded areas (Figure 6a). Otherwise, there will be 4 active motors used (normally 2 active motors are enough for rotating) and energy consumption of the system will be bigger (Figure 6b).
At the starting period, the first masses' movements occur at those arms which are near to the X axis. At the normal working the arms near to the Y axis are used.

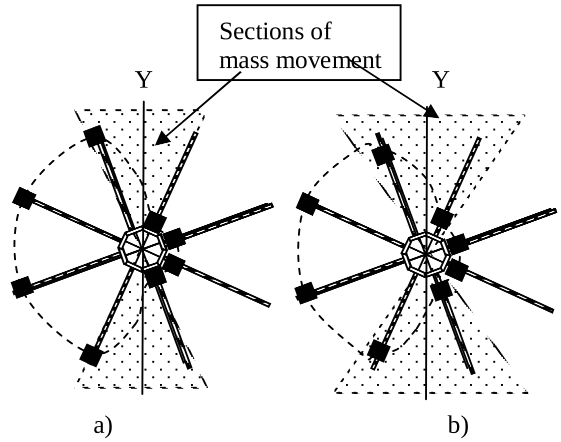


Figure 6

IV GETTING TOTAL TORQUE EQUATION AS A MODEL

Total torque effects the power, speed, acceleration and direction of the system. So, DBS's model can be explained with the total torque equation.

Figure 7 shows movement-time relation of masses. t_1-t_2 section and t_3-t_4 section are forward and backward movements of the masses, respectively.

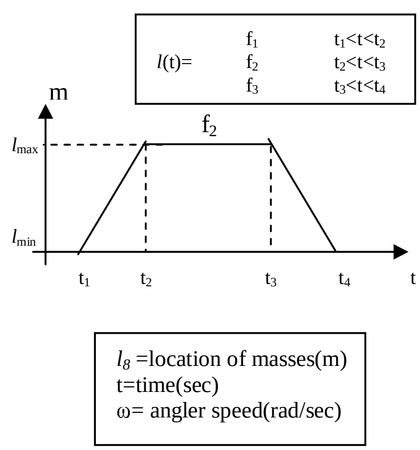


Figure 7

t_2-t_1=$(l_{max}-l_{min})/V_{step}$ t_4-t_3=$(l_{max}-l_{min})/V_{step}$

$f_1=((l_{max}-l_{min})/(t_2-t_1)).(t- t_1) + l_{min}$

$f_2= l_{max}$

$f_3 == ((l_{min}-l_{max})/(t_4-t_3)).(t- t_3) + l_{max}$

While the system is rotating the time difference between the two arms can be expressed as

$t_f = \pi/4/\omega(t)$

The locations(r_{1-} r_8) of all masses on the arms

for m_1 mass $l_1=l_1(t)$

for m_2 mass $l_2=l_1(t-(1.t_f))$

: :

for m_8 mass $l_8=l_7(t-(7.t_f))$

$$\mathbf{[\ [m_1 g l_1(t)\cos(t)]+[m_2 g l_2(t-(t_f))\cos(t-(t_f))]+ [m_3 g l_3(t-(2t_f))\cos(t-2t_f))]+......+[m_8.g.l_8(t-(7.t_f)). \cos(t-(7.t_f)\ )]\ ]=m_T.l_{max}.(d\omega/dt)>m_{load}.g.l_{load}}$$

for ω=x', the state-space equation is

$$\dot{x} = A(t)x + b(t)u$$

Dinamic Balancing System shows a lineer varying structure.

V CONTROL OF THE SYSTEM

The fuzzy control inputs are demanded speed, measured speed and direction. The control outputs are the Limiting circle(to limit motion of masses) and starting points for the forward and backward motion.

There is a coefficient taken between the radius of Limiting circle and the difference of the demanded speed and measured speed in the control. There are other two coefficients between starting points and measured speed. Figure 8 shows general control diagram.

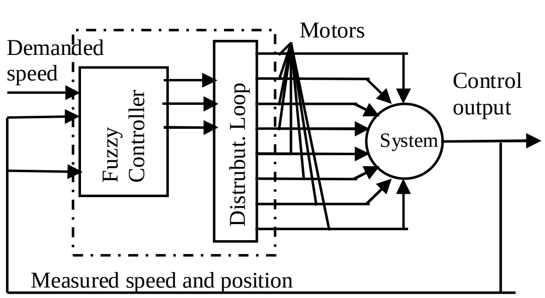


Figure 8

V1 APPLICATION OF MATHEMATICAL MODELLING AND CONTROL USING A GRAPHIC ANIMATION

The dimensions of the system can be fixed by the program and the working of the system can be seen for different load combinations. There is a part from the program at figure 9. The Changing of the torque and the speed of the system can be observed on the graphic form of the program.

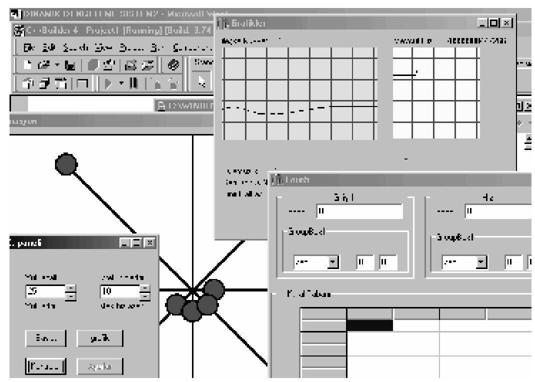


Figure 9

VII SOME PROTOTYPE APPLICATION RESULTS

When system works without load, it is difficult to control it because the acceleration change is fast(Figure 10). The success of the fuzzy control unit was assesed in this non - loaded working. Normally, control unit doesn't let the rotating speed of the system exceed 10 deg/sec limit. In case it does exceed that limit, control unit waits in passive position.

There is no need for 4 motors to be active at the period of starting. Only one mass movement can start rotation, then normal working can go on with two active motors.

As can be seen from graphes, the energy consumption of the DBS is the same every time. Because motors suffer only from masses which move on arms, not load connected to system's shaft. The more the load's gravity is, the slower the system's speed. In this case the energy consumption of motors does not change.

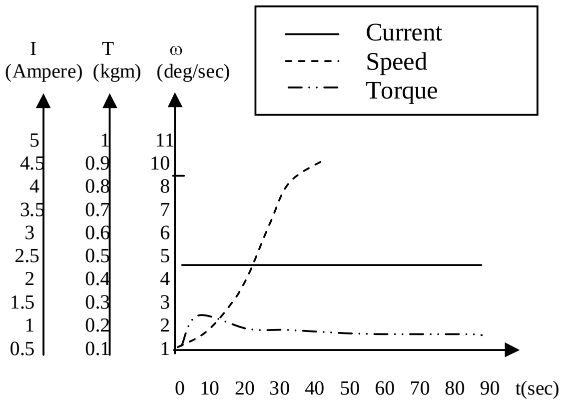


Figure 10

In loaded working starting time can be made shorter by making 4 motors active, having set demanded speed high at control panel (Figure 11). System works slowly and its control is easy because of the load effect.

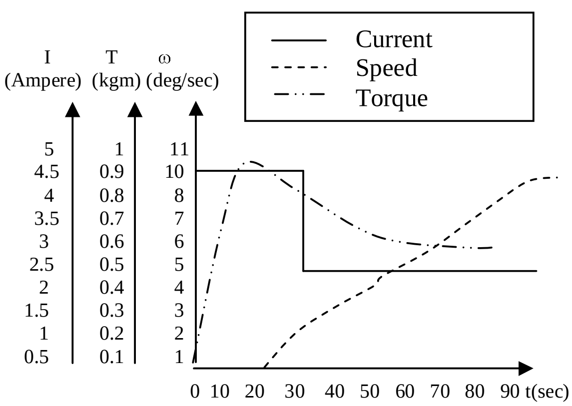


Figure 11

VIII CONCLUSION

The introduced prototype can not be used to compare DBS's performance with other vertical load transport systems because its dimensions are very small compared to its normal ones. But prototype results show that counter masses logic can be used commonly and affectively not only in the lift systems but also in other vertical transport systems.

The results also show that although controller has got 3 inputs, 8 outputs and all masses must be directed to suitable places continuously, the system can be controlled by using an adaptive control such as fuzzy control.

In the next study, the information on DBS control will be introduced, and then, the system performance, energy consumption and soft starting charesteristics will be discussed in full length.

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