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# The static balancing of the industrial robot arms Part I: Discrete balancing

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## Abstract

The paper presents some new constructional solutions for the balancing of the weight forces of the industrial robot arms, using the elastic forces of the helical springs. For the balancing of the weight forces of the vertical and horizontal arms, many alternatives are shown. Finally, the results of solving a numerical example are presented. © 2000 Elsevier Science Ltd. All rights reserved.

*Keywords:* Industrial robot; Static balancing; Discrete balancing

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## 1. Introduction

The mechanisms of manipulators and industrial robots constitute a special category of mechanical systems, characterised by big mass elements that move in a vertical plane, with relatively slow speeds. For this reason the weight forces have a high share in the category of resistance that the driving system must overcome. The problem of balancing the weight forces is extremely important for the play-back programmable robots, where the human operator must drive easily the mechanical system during the training period.

Generally, the balancing of the weight forces of the industrial robot arms results in the decrease of the driving power. The frictional forces that occur in the bearings are not taken

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into consideration because the frictional moment senses depend on the relative movement senses.

In this work, some possibilities of balancing of the weight forces by the elastic forces of the cylindrical helical springs with straight characteristics are analysed.

This balancing can be made discretely, for a finite number of work field positions, or in continuous mode for all positions throughout the work field. Consequently, the discrete systems realised only an approximatively balancing of the arm.

The use of counterweights is not considered since they involve the increase of moving masses, overall size, inertia and the stresses of the components.

## 2. The balancing of the weight force of a rotating link around a horizontal fixed axis

There are several possibilities of balancing the weight forces of the manipulator and robot arms by means of the helical spring elastic forces.

The simple solutions are not always applicable. Sometimes an approximate solution is preferred, leading to a convenient alternative from constructional point of view.

The simplest balancing possibility of the weight force of a link **1** (the horizontal robot arm, for example) which rotates around a horizontal fixed axis is schematically shown in Fig. 1. A helical spring **2**, joined between a point *A* of the link and a fixed *B* one, is used. The equation that expresses the equilibrium of the forces moments [1], which act to the link **1**, is

$$(m_1 OG_1 \cos \varphi_i + m_{2A} X_A)g + F_s a = 0, \quad i = 1, \dots, 6, \quad (1)$$

where the elastic force of the helical spring is:

$$F_s = F_0 + k(AB - l_0),$$

and

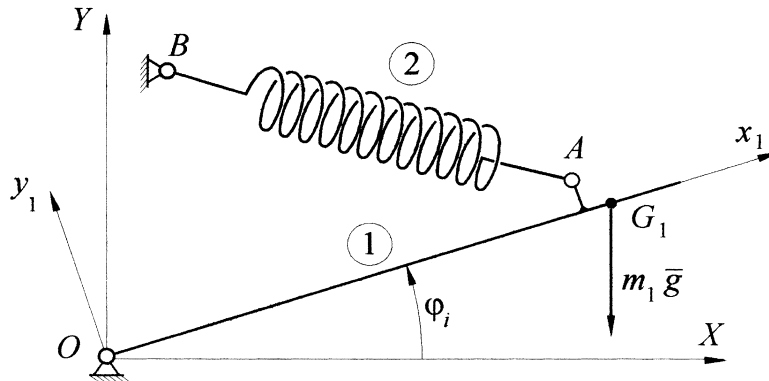


Fig. 1

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