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# The static balancing of the industrial robot arms Part II: Continuous balancing

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**Abstract**

The paper presents some new constructional solutions for the balancing of the weight forces of the robot arms, using the elastic forces of the helical springs. The balancing is exactly realised in all points of work field by using the elastic system which contains the high pair mechanisms. For the performance study of the static balancing mechanisms, a new notion, namely *efficaciousness coefficient*, is defined. This coefficient is equal to the ratio of the mechanical work consumed for acting the unbalanced arm and the mechanical work consumed for moving the balanced arm. The static balancing mechanism is useful if the efficaciousness coefficient is greater than one. Finally, the results of solving a numerical example are presented. © 2000 Elsevier Science Ltd. All rights reserved.

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

## 1. Introduction

The exact balancing of the weight force of an industrial robot arm, for any value of its position angle contained in the work field, continuous balancing in other words, may be made with the elastic system that contains a cam mechanism.

The drawback of having a higher pair between cam and follower roll is set off by the

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accuracy of balancing. The cam may be fixed on frame or on arm, and may have a rotational or a translational motion.

In order to study the performances of the static balancing mechanisms, a new notion, namely *efficaciousness coefficient*, is defined. This coefficient is equal to the ratio of the mechanical work consumed for acting the unbalanced arm and the mechanical work consumed for moving the balanced arm. The static balancing mechanism is useful if the efficaciousness coefficient is greater than one.

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

In the same manner as the discrete balancing [4], in order to realise a continuous balancing of the weight force of a industrial robot arm by the elastic force of a helical spring [2–3,5], it is necessary that the spring be joined with one of its ends to a link which moves with respect to the frame or with respect to the arm (Figs. 1 and 2).

In the kinematics scheme depicted in Fig. 1, the balancing spring **4** is joined with the $B$ end to the follower **2** of a cam mechanism. The cam is fixed to the arm **1**.

If the work field is defined by the limits $\varphi_{\min} = \pi/4$, $\varphi_{\max} = 3\pi/4$, then the follower **2** should slide along the $OY$ co-ordinate axis for reasons of symmetry.

The parametrical equations of the directrix curves of the cam active surfaces are:

$$x_1 = Y_C \sin\varphi \mp \frac{R(\mathrm{d}Y_C/\mathrm{d}\varphi \cos\varphi - Y_C \sin\varphi)}{P};$$

$$y_1 = Y_C \cos\varphi \pm \frac{R(\mathrm{d}Y_C/\mathrm{d}\varphi \sin\varphi + Y_C \cos\varphi)}{P},$$

where $R$ is the radius of the follower roll **3**,

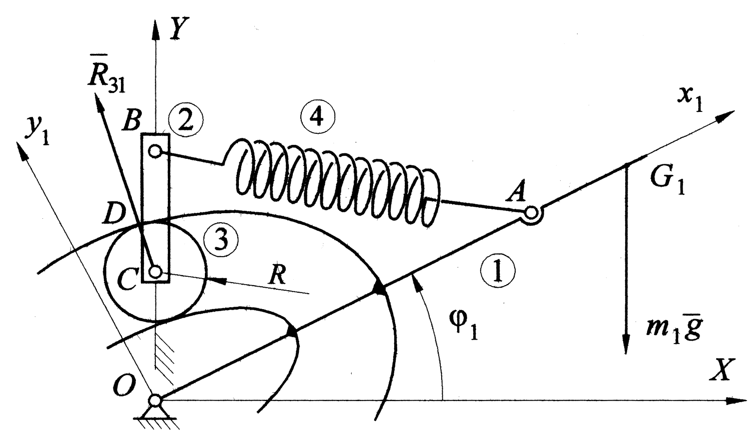


Fig. 1. Balancing elastic system with movable cam and translational follower.

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