12th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2008, Istanbul, Turkey, 26-30 August, 2008

DESIGN AND FUNCTIONAL SIMULATION FOR A PYROTECHNIC ROBOT

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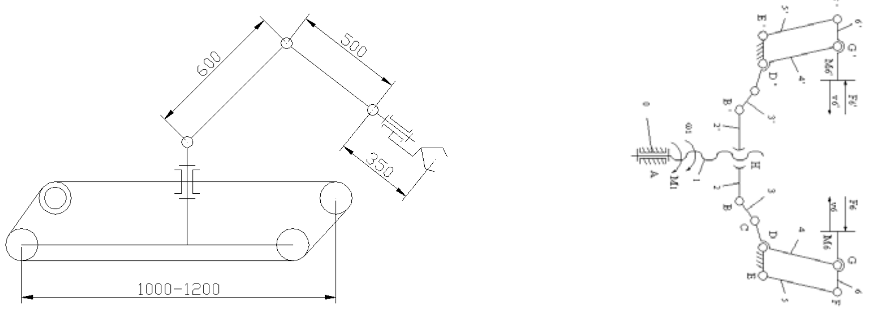
ABSTRACT
Pyrotechnic robots are service robots which are used to reduce the intervention time of pyrotechnic troops and the danger for the operators. Pyrotechnic robots are used to inspect hazardous areas or/and to remove and to destroy explosive or suspect devices/objects. These robots can be used to make some corridors through mined battle fields, to manipulate and neutralize the intact ammunition, to inspect vehicles, trains, airplanes and buildings. For these robots an effective functional activity is to determine the dimension of the work space, the kinematics of the robotic arm and the characteristics of the gripper. In the paper, structural, kinematic, static synthesis and analysis, design and functional simulation are shown on a robotic arm and the grippers attached from a pyrotechnic robot designed by the authors.
Keywords: pyrotechnic robot, design, functional simulation

1. INTRODUCTION
Pyrotechnic robots are service robots which are used to reduce the intervention time of pyrotechnic troops and to reduce the danger for the operators.
In general, pyrotechnic robots are used to inspect hazardous areas or/and to remove and to destroy explosive devices. These robots can be used to make some corridors through mined battle fields; they can be used as well for manipulation and neutralization of the intact ammunition, for inspection of the vehicles, trains, airplanes and buildings. For these robots an effective functional activity is to determine the dimensions of the work space, the kinematics of the robotic arm and the characteristics of the gripper.
In the paper, structural, kinematic, static synthesis and analysis, design and functional simulation are shown on a robotic arm and the gripper attached from a pyrotechnic robot designed by the authors.

2. STRUCTURAL SYNTHESIS AND ANALYSIS

2.1. Structural Synthesis
A pyrotechnic robot has three main mechanical components: a mobile platform, a robotic arm (the manipulator) and a gripper [2, 3, 8].
The mobile platform can be equipped with wheels or crawlers, the robotic arm is a manipulator with 5 or 6 axles and the gripper is usually a gripping mechanism with jaws or, rarely, an anthropomorphic mechanical gripper.

After the comparative structural analysis for more types of pyrotechnic robots [3,8], for the robot which was designed we adopted the structural scheme in fig.1,a.This structure is made of a platform with crawlers, a robotic arm and a linkage gripping mechanism with two jaws. The mobility degree of the platform is M = 2, each crawler is powered by an electric motor. For the gripper, using structural synthesis, the following problems were solved: a correct stroke (relative big – for objects with middle gauge); a gripping force of ≈12 daN; two support- jaws elements; a sound amplification of the motor force and a plane – parallel movement. This scheme (fig. 1, b) has the particularity that it is powered through a screw and it has a parallelogram mechanism like the support-jaws one.



a b

Figure 1. Structural schemes

2.2. Structural Analysis

After structural analysis of the robotic arm the following conclusions can be drawn: there are 6 outer connections (L = 6) and the degree of mobility is 5 (M = 5). The gripper's one is M = 1[1,5,6].

3. KINEMATIC SYSNTHESIS AND ANALYSIS OF A ROBOTIC ARM AND GRIPPER

3.1. Kinematic Synthesis

The kinematic synthesis is used to obtain an optimum work space for the robotic arm and a correct closing of the gripping mechanism. This is possible with a good correlation between linear and angular dimensions. (see fig. 1).

3.2. Kinematic Analysis

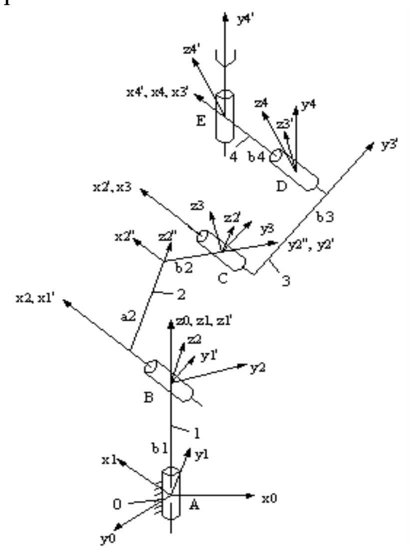
The direct kinematics for the robotic arm is used to determine the position of the K characteristic points, attached to the gripper. In this situation the movements of the joints are known. The kinematic scheme of the robotic arm is shown in fig.2, a. As far as this kinematic scheme is concerned, the homogeneous rotary and translational matrices have the following structure [1]:

$$Rx := \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \cos(x) & -\sin(x) \\ 0 & 0 & \sin(x) & \cos(x) \end{bmatrix} \quad Ry := \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos(y) & 0 & \sin(y) \\ 0 & 0 & 1 & 0 \\ 0 & -\sin(y) & 0 & \cos(y) \end{bmatrix}$$

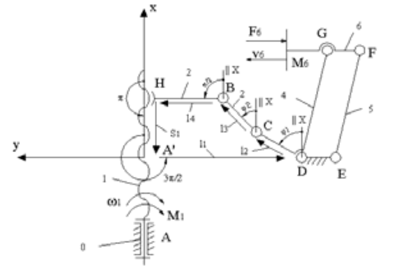
$$Rz := \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos(z) & -\sin(z) & 0 \\ 0 & \sin(z) & \cos(z) & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad T := \begin{bmatrix} 1 & 0 & 0 & 0 \\ x & 1 & 0 & 0 \\ y & 0 & 1 & 0 \\ z & 0 & 0 & 1 \end{bmatrix}. \tag{1}$$

With the rotary matrices in the joints and the translational matrices between the joints, the direct model of the finite movements can be obtained as a compound homogeneous operator $E_{06} = A_{01}A_{12}A_{23}A_{34}A_{45}A_{56}$ (where the matrix Aij are transfer matrices between the referential system j and

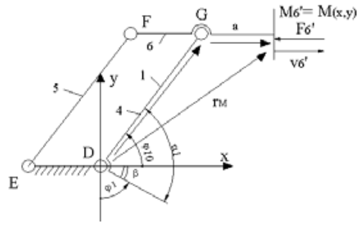
the referential system i). We used the MAPLE soft on this purpose. For the dimensions adopted for the robotic arm the position of the K characteristic point will be: x = 154.8 mm; y = 14.544 mm; z = 1219.61 mm.
For the cinematic analysis of the gripper, the vector closed chain method is used successively for each mono-contour mechanism (A'DCBH contour, fig. 2, b1, and DGG' contour, fig. 2, b2). The vector equations are: $\overrightarrow{A'D} + \overrightarrow{DC} + \overrightarrow{CB} + \overrightarrow{BH} + \overrightarrow{HA'} = \vec{0}$ and $\overrightarrow{DG} + \overrightarrow{GG'} + \overrightarrow{G'D} = \vec{0}$.



a



b_1



b_2

Figure 2. Kinematic schemes

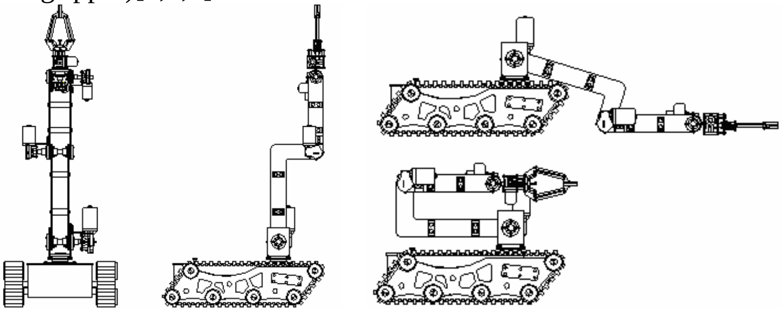
4. STATIC SYNTHESIS AND ANALYSIS

4.1. Static Synthesis
The static synthesis solves the problems of getting the necessary capacity for the robotic arm to transfer 12-14 daN and the necessary gripping force (~ 12 daN).

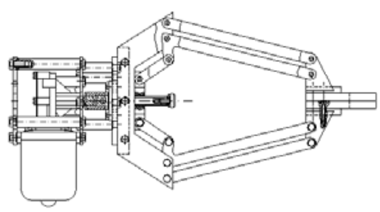
4.2. Static Analysis
The static analysis solves the problem of obtaining the necessary motor forces and the internal forces (forces between elements). The functions of the external forces are obtained with the balance theorem applied to the entrance and emergence powers of the mechanism[1,6].

5. DESIGN AND FUNCTIONAL SIMULATION

5.1. Design
The calculation of strength was performed according to the internal forces which act between elements. Then the technical project has made (fig.3, a, for platform and robotic arm and fig.3, b for the gripper)[4,5,6].



a



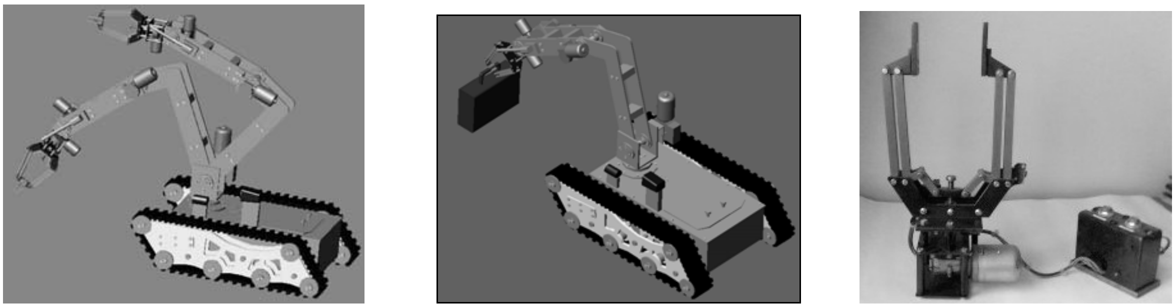
b

Figure 3. Constructive solutions

Afterwards the project has all the conditions for practical achievement.

5.2. Functional Simulation

The CAD functional simulation (fig.4, a, b), in CATIA [6], is used to identify an optimum version for the constructive solution and for testing an attachment version of the gripping of a pyrotechnic robot. A prototype of the gripping mechanism is shown in fig.4, c.



a b c

Figure 4. Functional simulation (a,b) and prototype of the gripper

In the future, our intention is to export the CAD model for pyrotechnic robot in virtual reality soft-VRML, for to simulate different activities, possible to be made with this robot. The virtual functional simulation is useful to train the operators too.

6. CONCLUSIONS

The following conclusions can be drawn according to the considerations made in this paper:

a. The main kinematic mechanical components of the pyrotechnic robot are: the platform, the robotic arm and the gripper.

b. The dimensions of the robotic arm are essential for the local work space of the pyrotechnic robot and the characteristics of the gripper are very important for to grasp in safety the different dangerous objects.

c. The kinematic models (direct and reverse too) are very important for finding the position of the characteristic point of the robotic arm and the kinematic analysis of the gripper is important for to identify its main kinematic characteristics.

d. A functional simulation using a 3D model is very important to get an optimum version of a robotic arm and for a pyrotechnic robot as well.

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