PYROTECHNIC ROBOT – COSTRUCTIVE DESIGN AND COMMAND

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Abstract:

Pyrotechnic robots are service robots used to reduce the time for intervention of pyrotechnic troops and to diminish the danger for the operators. Pyrotechnic robots are used to inspect dangerous areas or/and to remove and to distroy explosive or suspicious devices/objects. These robots can be used to make corridors through mined battle fields, for manipulation and neutralization of unexploded ammunition, for inspection of vehicles, trains, airplanes and buildings. For these robots, a good functional activity is determined with regard to work space dimensions, robotic arm kinematics and gripper characteristics. The paper shows the structural, kinematic, static synthesis and analysis as well as the design and functional simulation of the robotic arm and the grippers attached on the pyrotechnic robot designed by the authors.

Key words: *analysis, kinematics, constructive design, CAD simulation.*

Introduction

Pyrotechnic robots are service robots used to reduce the time for intervention of pyrotechnic operators and to diminish the danger for them (www.salvex.com).

Pyrotechnic robots are used to inspect dangerous areas or/and to remove and to distroy explosive devices. These robots can be used to make corridors through mined battle fields, for manipulation and neutralization of unexploded ammunition, for inspection of vehicles, trains, airplanes and buildings. For these robots, a good functional activity is determined with regard to work space dimensions and robotic arm kinematics.

In the paper, the kinematic synthesis and analysis, one command scheme and a functional simulation are shown regarding the robotic arm from the pyrotechnic robot designed by the authors.

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Pyrotechnic robots – general aspects

A pyrotechnic robot has three main mechanical components: a mobile platform, a robotic arm (the manipulator) and a gripper (Paun, Constantin, 2002), (Staretu, Daj, 2004, pp.55-58).

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, see Fig. 1. and Table 1 (www.salvex.com).

After the comparative structural analysis for more types of pyrotechnic robots (Fig. 2,a,b), for the designed robot we adopted the structural scheme of Fig. 2,c. This structure is formed of a platform with crawlers, a robotic arm and a linkage gripping mechanism with two jaws.

The platform has the degree of freedom M = 2 and each crawler is powered by an electric motor.

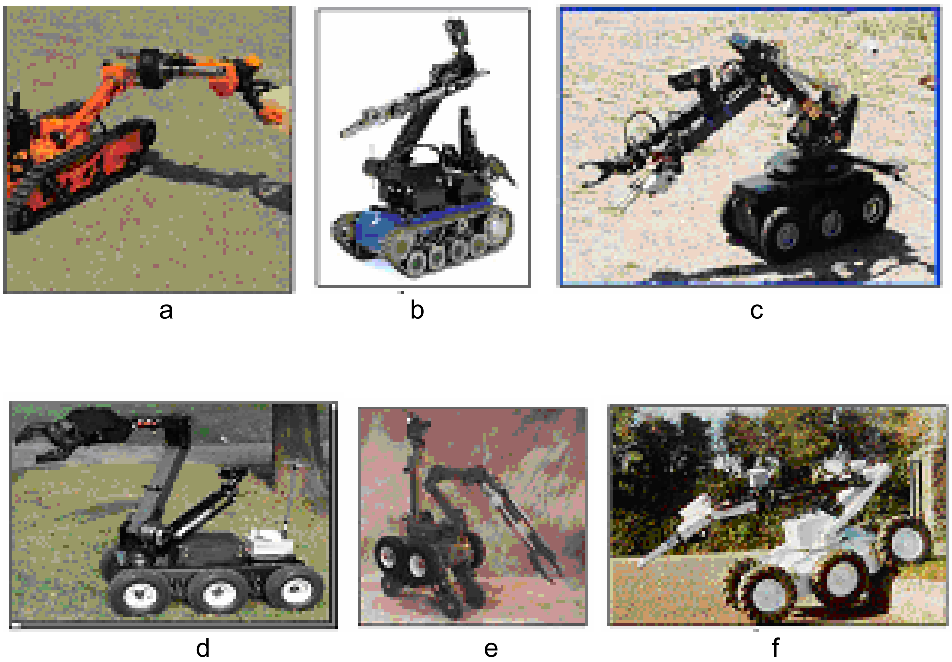


Figure 1 – Main types of pyrotechnic robots
Slika 1 – Glavni tipovi pirotehničkih robota

Table 1

Main characteristics

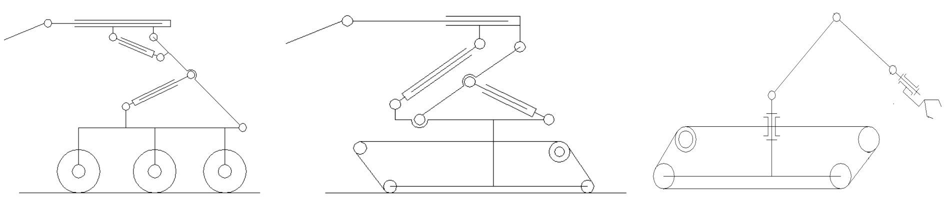
Tabela 1

Glavne karakteristike

Nr.	Robot	Platform						
		length	width	height	turret	speed	movement	Slope
1.	Vanguard MK1	915 mm	435 mm	405 mm (packed)	+/- 120°	12,33 m/min	crawlers	40°
2.	Teodor	1300 mm	680 mm	405 mm	420°	0-50 m/min	crawlers	35°
3.	MR1	1170 mm	700 mm	950 mm	-	-	Wheels	40° (with crawlers)
4.	Andros	1245 mm	445,5 mm	1118 mm	-	-	crawlers	45°
5.	Hobo	1468 mm	701 mm	881,4 mm	-	50 m/min	wheels	42°

Nr.	Robotic arm		Gripping system	
	vertical	Horizontal	useful weight	stroke
1.	1320 mm	965 mm	8 Kg (extended arm) 16 Kg (contracted arm)	0 - 20 cm
2.	2400 mm	2800 mm	20 Kg (extended arm) 30 Kg (contracted arm)	0 - 30 cm
3.	2650 mm	1850 mm (5150 mm)	15 Kg (at 3,5 m) 122 Kg (at 1 m)	-
4.	-	-	-	-
5.	-	-	-	-

After the structural analysis of the robotic arm, the following conclusion can be formulated: there are 6 outside connections (L = 6) and the degree of freedom is 5 (M = 5). The gripper has M = 1.



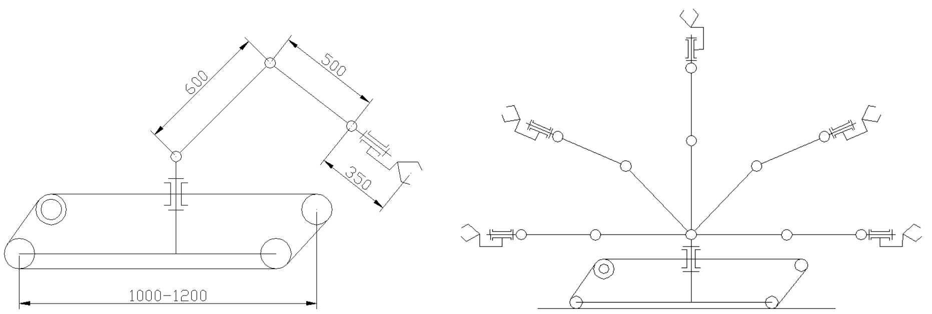
a b c

Figure 2 – Structural schemes
Slika 2 – Strukturalne šeme

Designed robot – main characteristics

Structural synthesis of the robotic arm

For the first time, the kinematic synthesis is used to obtain the main dimensions (Fig. 3) for optimum workspace.



a b

Figure 3 – Kinematic scheme: the main dimensions (a) and extrem positions of the robotic arm (b)
Slika 3 – Kinematička šema: glavne dimenzije (a) i krajnji položaji robotičke ruke (b)

Kinematic analysis of the robotic arm

The direct kinematics is used to determine the position of the K characteristic point. In this situation, the movements of the joints are known. The kinematic scheme is shown in Fig. 4

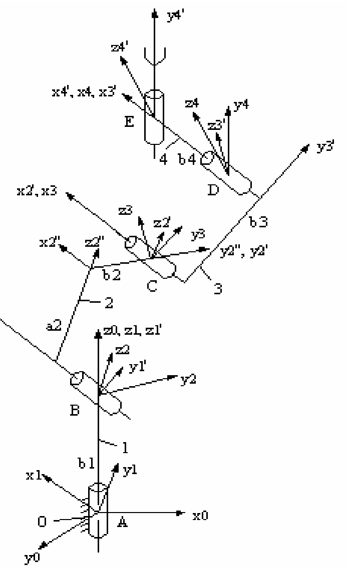


Figure 4 – Kinematic scheme
Slika 4 – Kinematička šema

Regarding this kinematic scheme, the homogeneous rotative and translational matrices have the following form (Dudita, 1989):

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

(1)

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

With the rotative matrices from the joints and the translational matrices between the joints, the direct model of the finite movements can be obtained as a compound homogeneous operator E06. We used the MAPLE soft for this. For example:

E05:=simplify(multiply(E01,E12,E23,E34,E45)) and

E35:=multiply(E34,E45);

$$E35 := \begin{bmatrix} 1 & 0 & 0 & 0 \\ b4 & \cos(fi54) & 0 & \sin(fi54) \\ 0 & \sin(fi43)\sin(fi54) & \cos(fi43) & -\sin(fi43)\cos(fi54) \\ 0 & -\cos(fi43)\sin(fi54) & \sin(fi43) & \cos(fi43)\cos(fi54) \end{bmatrix}$$

E25:=simplify(multiply(E23,E34,E45));

E15:=simplify(multiply(E12,E23,E34,E45));

This is verified with numerical values in the following form:

L1:=[fi10=Pi/3,fi21=Pi/6,fi32=Pi/3,fi43=Pi/4,fi54=Pi/12];

$$L1 := \left[fi10 = \frac{1}{3}\pi, fi21 = \frac{1}{6}\pi, fi32 = \frac{1}{3}\pi, fi43 = \frac{1}{4}\pi, fi54 = \frac{1}{12}\pi \right],$$

L2:=[b1=100,a2=600,b2=200,b3=500,b4=90];

$$L2 := [b1 = 100, a2 = 600, b2 = 200, b3 = 500, b4 = 90],$$

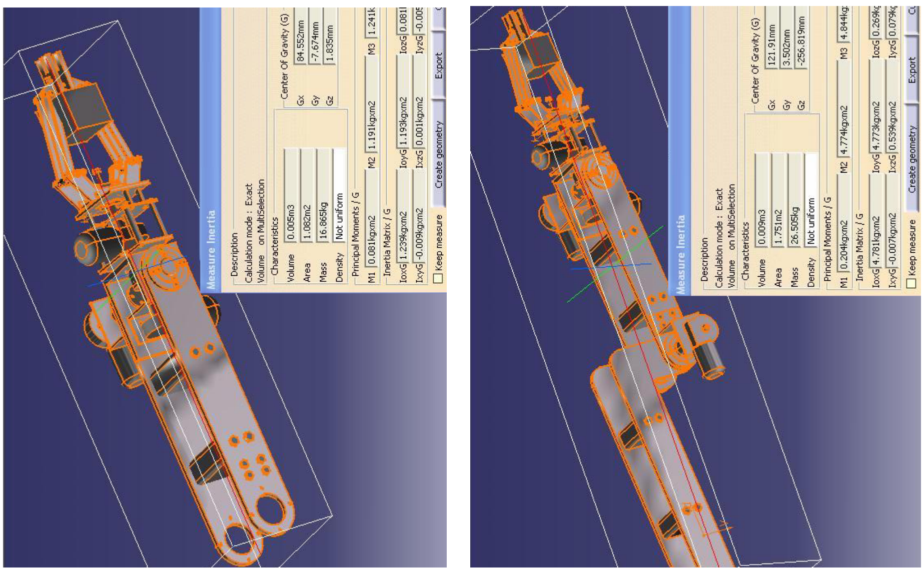
E05s:=evalm(Msubs(L1,L2,E05));

$$E05s := \begin{bmatrix} 1 & 0 & 0 & 0 \\ 154.8076212 & .3244692642 & .6123724358 & .7209158735 \\ 14.54482663 & .9280226547 & -.3535533909 & -.1173624830 \\ 1219.615242 & .1830127019 & .7071067812 & -.6830127020 \end{bmatrix}.$$

The position of the K characteristic point will be: x = 154.8 mm; y = 14.544 mm; z = 1219.61 mm.

Static analysis

Static calculations aim at determining external forces acting on the inner mechanism and forces acting on the kinematic elements. Forces, masses, and centers of gravity of the elements necessary to calculate the time necessary to driving the couplings were determined using the CATIA software (Doc. 1, 2005). Fig. 5 shows two schemes for computing the static momentum for couplings C and B of the robotic arm.



a b

Figure 5 – Computation model for momentum in couplings C(a) and B(b)
Slika 5 – Računarski model za moment sile u spojevima C(a) i B(b)

Constructive design

Based on the results of the kinetic-static analysis, dimension calculations were made (strength calculations) of the component parts (elements) and then we realized the technological project of the robot mechanical parts. The technical drawing of the assembly in some specific positions is shown in Fig. 6.

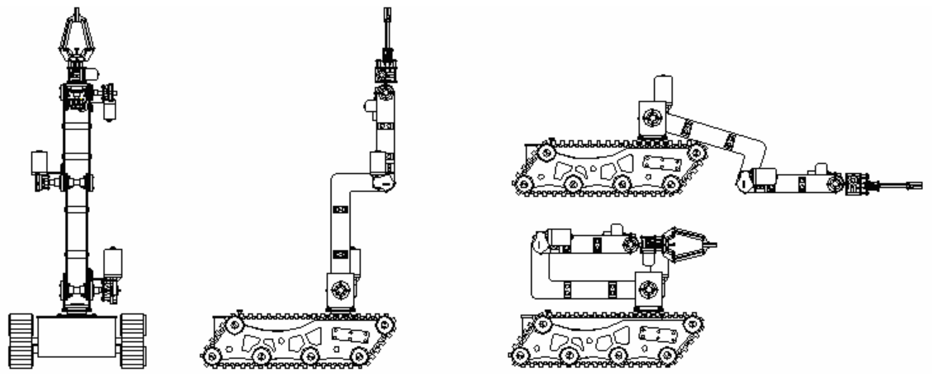
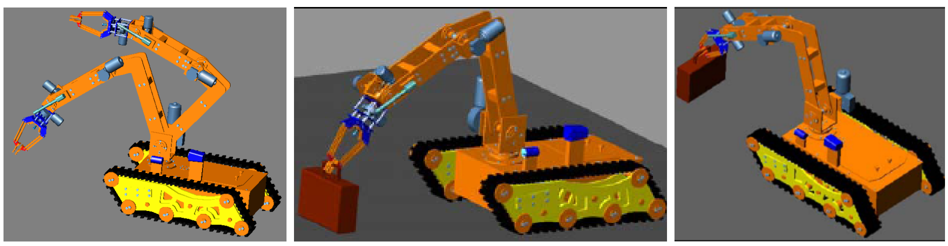


Figure 6 – Technical project of the pyrotechnic robot
Slika 6 – Tehnički projekat pirotehničkog robota

Functional simulation

The kinematic dimensions and the forces between the constructive elements were used for the calculation of strength and then a 3D model was obtained with the CATIA software (Doc.1, 2005). This model was used at a functional simulation for the robotic arm (Fig.7).



a b1 b2

Figure 7 – Functional simulation: without object(a) and with an object(b1,b2)
Slika 7 – Simulacija funkcije: bez objekta (a) i s objektom (b1, b2)

The functional simulation is used to obtain an optimum version of the robotic arm and of the pyrotechnic robot as well.

Command scheme

The general scheme for the command and control subsystem is shown in Fig. 8. The control scheme enables the remote control of the pyrotechnic robot via a cable or wireless. The command is carried out through a laptop on whose screen images from robot-mounted cameras are projected. In Fig. 8 we can identify the main electronic components of the control scheme.

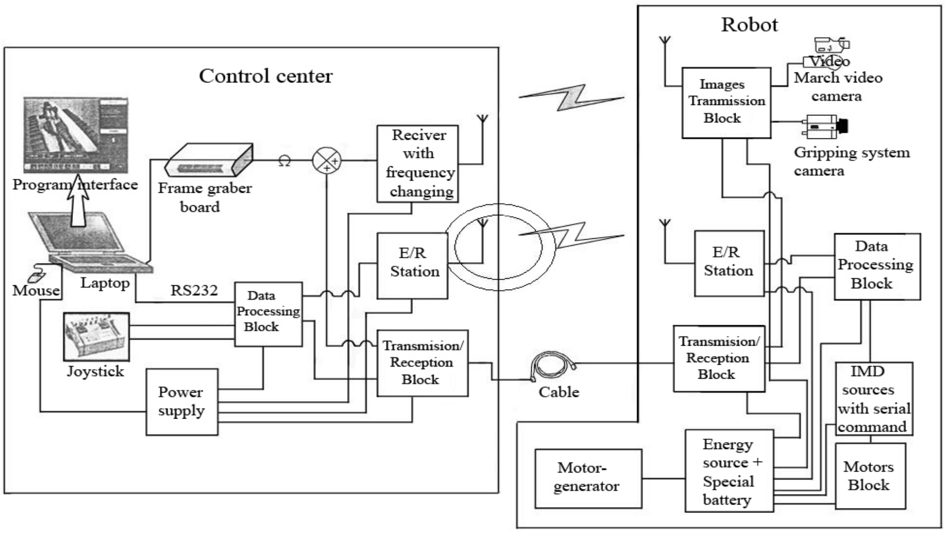
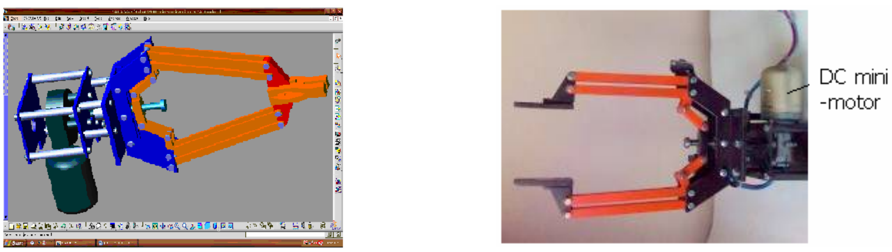


Figure 8 – Command scheme
Slika 8 – Šema upravljanja

Prototype of the gripper

Based on the technical project in CATIA (Fig. 9a) the gripper prototype was made, Fig. 9b. The useful weight is 6 kg and the stroke is 0-26 cm.



a b

Figure 9 – CATIA project of the gripper (a) and prototype of the gripper (b)
Slika 9 – Projekat hvataljke pomoću softvera CATIA (a) i prototip hvataljke (b)

Conclusions

The following conclusions can be formulated in accordance with the considerations presented:

1. The main kinematic mechanical component of the pyrotechnic robot is the robotic arm.
2. The dimensions of the robotic arm are essential for local work space of the pyrotechnic robot.
3. The kinematic models (direct and reverse too) are very important for finding the position of the characteristic point of the robotic arm.
4. A functional simulation using a 3D model is very important for obtaining an optimum version of the robotic arm and for the pyrotechnic robot.

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ANALIZA, PROJEKTOVANJE KONSTRUKCIJE I UPRAVLJANJE PIROTEHNIČKIM ROBOTOM

OBLAST: mašinstvo
VRSTA ČLANKA: originalni naučni članak

Sažetak:

Pirotehnički robot je uslužni robot koji se koristi za brže intervenisanje pirotehničkih jedinica kojim se smanjuje izlaganje opasnosti rukovaoca. Pirotehnički roboti koriste se za ispitivanje opasnih zona i/ili za uklanjanje i uništavanje eksplozivnih ili sumnjivih uređaja/predmeta. Mogu da se koriste za izradu prolaza kroz minska polja, za rukovanje neeksplodiranom municijom i njeno uništavanje, za pregledanje vozila, vozova, aviona i građevina. Dobra funkcionalna aktivnost ovih robota određena je dimenzijama njihovog radnog prostora, kinematikom robotske ruke i karakteristikama hvataljke. U ovom radu prikazane su strukturalna, kinematička i statička sinteza i analiza, kao i projekat i simulacija funkcije robotičke ruke i hvataljki na pirotehničkom robotu koji je projektovao autor ovog rada.

Ključne reči: *analiza, kinematika, projekat konstrukcije, CAD simulacija*

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