UDK: 623.45: 623.5
COSATI: 19-01

Use of pyrotechnic charge for cutting rope

Danilo Serdarević, MSc (Eng)[1)]
Milorad Savković, PhD (Eng)[1)]

Pyrocutter cartridge is an autonomous device that uses pyrotechnical charge for cutting rope while saving catapulted pilots. This work presents construction design and results of inner ballistic tests of pyrotechnical charge and pyrocutter cartridge as a functional device. The chosen pyrotechnical charge secures the necessary delay time. The scope of this thesis includes statistical analysis of the delay time, block diagram of used measuring instruments and block diagram of system functions as well as an estimate of reliability.

Key words: **pyrotechnic, pyrocutter, pyrotechnical charge, internal ballistic testing, catapult seat.**

Introduction

WHEN eliminating human intervention in various applications is demanded, executive elements have to be added to process equipment. One solution for the device for cutting rope in the system for saving pilot's life after ejecting, without human intervention would be pyrocutter R-4 (Fig.1).

Figure 1. Pyrocutter R-4

In a relatively small space (not bigger than an average pencil), a device that enables successful cutting of rope, after approximately 4s from taking out the pin, that is attached to the flap of the casing of rescue and survival kit used after successful ejecting from the damaged plane was placed. [1].

This paper shows the technical solution, block diagram of functions, reliability of system, results of static tests of pyrotechnical charge and function of the device as a whole. Statistics analysis of delay had also been done, based on the measurement results.

Concept of pyrocutter and function

Pyrocutter has three parts:

- Blade
- Pyrotechnical charge
- Activation needle with a safety.

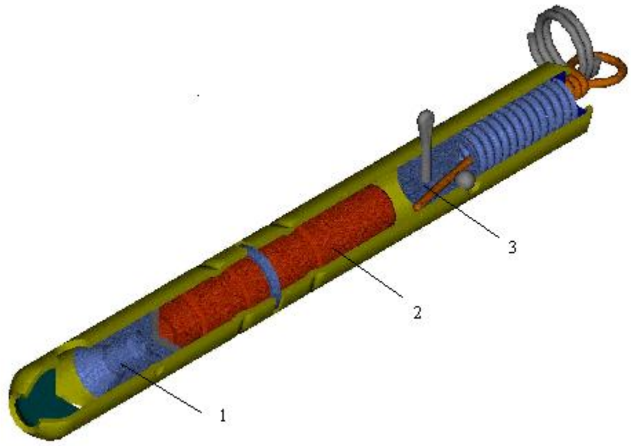

Figure 2. Main elements of pyrocutter (1-Blade, 2-Pyrotechnical charge, 3-Actvation needle)

Blade (Fig.2) consists of an anvil and a knife. Considering the fact that the analysed pyrocutter is used for cutting a rope made of a relatively soft and ductile material, the anvil is made of soft material, led (Pb), and the knife from ring shaped steel with sharp edges. Under the pressure of combustion gasses from the pyrotechnical charge, the knife moves and blade cuts off the rope, by successfully inserting itself in the anvil and successfully breaking every thread of the rope.

Pyrotechnical charge of pyrocutter (Fig.3) is a system that generates gas for moving the knife with the specified delay time from the moment of removing the safety. Pyrotechnical charge consists of a cap (E96), priming (SC-1), relay, delay and ignition (PIR R-06) composition. All these elements are pressed in the body of the pyrotechnical charge. After its activation, the needle cap activates the priming composition, which activates the delay composition. Speed of combustion and thickness of delay composi-

1) Military Technical Institute (VTI), Ratka Resanovića 1, 11132 Belgrade

tion guarantees the delay time. After activating the flame mixture, products of combustion generate pressure that presses the knife and enables the function of the pyrocutter. The deviation of combustion speed and thickness of delay composition as well as conditions of combusting, determine the deviation of delay time. Design of the pyrotechnical charge include small side openings designed for depressurising products of combustion of delay composition, and spring with piston in the combustion chamber secures regulated free volume, necessary elements for combustion of delay and ignition composition.

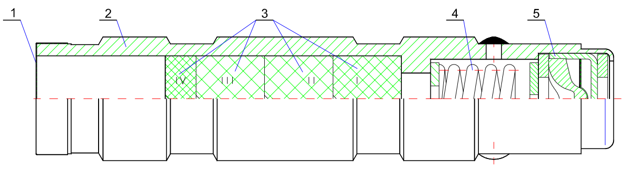

Figure 3. Pyrotechnical charge of pyrocutter R-4 (1-Membrane, 2-Body, 3-Pyrotechnical charge, 4-Spring, 5-Cap)

Activation needle (Fig.2) with safety is a small mechanism for single use. Needle is in a secured position, pressed with a spring, which has enough force to give the needle the initial impulse for activating the cap. Safety is double, meaning that there is a transport safety and safety for activation by wire; after pulling the wire the ball moves and releases the needle, initiating the pyrocutter.

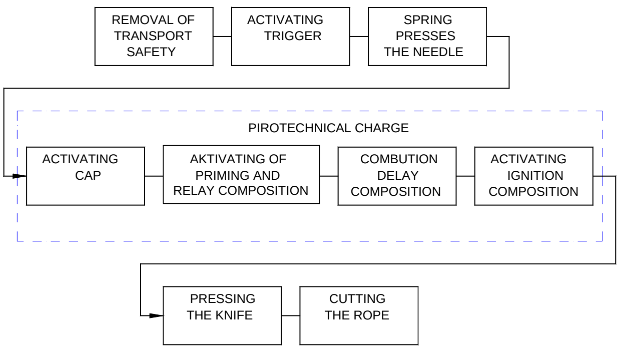

Figure 4. Block diagram of pyrocutter function

Block diagram of pyrocutter functions is presented in Fig.4. The designed construction of pyrocutter, which consists of three above-mentioned subsystems, is incorporated in a single housing. By size and shape the housing resembles an average pencil.

Reliability of pyrocutter

Block diagram of pyrocutter function (Fig.4) indicates that this device has elements that are in single line, so overall reliability of the system is defined by the formula:

$$R = R_I \cdot R_K \cdot R_P \cdot R_S \qquad (1)$$

R_i - reliability of needle with spring and safety

R_K - reliability of cap

R_p - reliability of pyrotechnical charge (priming, delay and ignition composition)

R_S - reliability of cutting (knife and anvil).

Presuming that the denoted subsystems and positions have been manufactured well with quality checks between phases, their single reliabilities are almost the same and with the value of 0,999, so the overall reliability of the pyrocutter is:

$$R = 0{,}999^4 = 0{,}996 \qquad (2)$$

Results of pyrotechnical charge tests

For testing series of pyrotechnical charges we have used 20 pieces [2]**.** Samples are subjected to following tests:

- Visual and dimensional control
- Gas tightness control
- Transport safety check
- Endurance on accidental vibrations test
- Thermal cycling
- The effect of high humidity.

Static test was done on samples that were previously exposed to the tests mentioned above. During the static test the internal ballistic values were measured by a tool (Fig.5), which enables measuring the delay time. Delay time was set by registering the time for the rise of pressure in the chamber and the moment of contact between the needle and cap. The same time base was used for both channels. Block diagram of measuring equipment is given schematically on Fig.6.

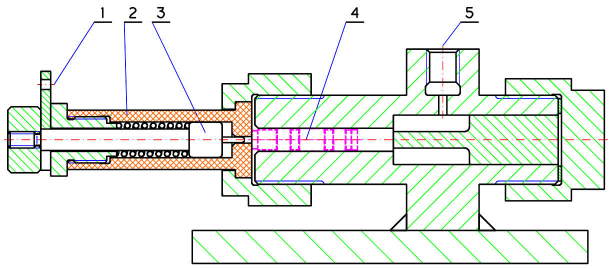

Figure 5. Tool for static test of pyrotechnical charge of pyrocutter (1-Trigger, 2-Isolator, 3-Needle, 4-Pyrotechnical charge, 5-Connection for pressure measurement

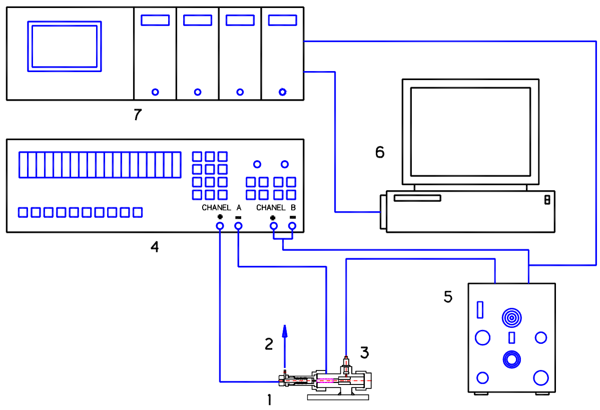

Figure 6. Block diagram of measuring equipment for measuring pressure and delay time (1-Test motor, 2-Trigger, 3-pressure transmitter Kistler 6001H, 4-Universal counter HP5334A, 5-Charge amplitude Kistler 50011, 6-PC, 7-Oscilloscope Nicolet 440)

Test for determining internal ballistic characteristics was conducted on 10 samples at the temperature of +20°C, with 5 samples at the temperature of +50°C and 5 samples at the temperature of -30°C. Test results of are given in the Table 1.

Table 1 Results of internal ballistic tests of pyrotechnical charge

Number	Temperature °C	Maximum pressure bar	Delay time s	
	20	54,90	5,28	4,84 $\sigma = 0,5$
		52,32	4,47	
		55,57	4,25	
		56,14	5,47	
		50,69	5,11	
		64,04	5,37	
		58,26	4,01	
		49,54	4,96	
		41,38	5,03	
		49,38	4,43	
	50	42,78	4,56	4,71 $\sigma = 0,7$ σ
		50,09	5,60	
		50,78	3,48	
		57,45	5,11	
		52,31	4,79	
	-30	59,21	5,08	5,04 $\sigma = 0,2$ σ
		58,77	4,76	
		40,23	5,02	
		59,96	5,31	

The measured internal ballistic values are within the boundaries for pyrotechnical charge [4]. Based on test results of the measured delay time of pyrotechnical charge during static tests on all three temperatures, the normal distribution of the delay time was defined, with an average value of m=4,8 s and standard deviation $\sigma = 0,5$ s (Fig.7).

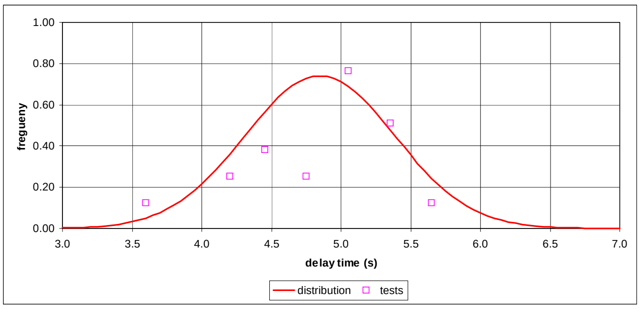

Figure 7. Distribution of measured delay time values approximated by normal distribution (m=4,8 and σ=0,5 s)

Results of pyrocutter tests

For testing the function of pyrocutter 30 samples were used [3]. Function test was performed on samples previously subjected to the tests mentioned. Function test was performed in a tool (Fig.8) at the temperature of +20°C, +50°C and -30°C. The rope was successfully cut in all tests.

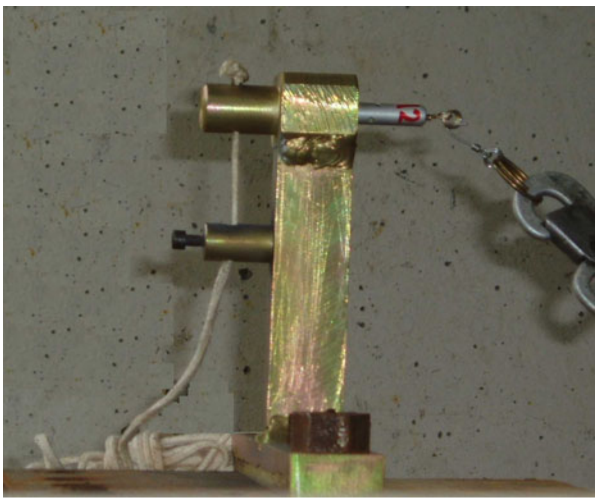

Figure 8. Pyrocutter in function testing tool

Delay time was measured with a stopwatch. Test results of are given in Table 2.

Table 2. Results of function testing of pyrocutter

Number	Temp. °C	Delay time s	
1	20	5,83	5,63 $\sigma = 0,3$
2		5,84	
3		5,43	
4		5,82	
5		5,85	
6		5,60	
7		5,81	
8		5,00	
9		5,50	
10	50	5,35	5,68 $\sigma = 0,3$
11		5,76	
12		6,01	
13		5,90	
14		5,94	
15		5,83	
16		5,86	
17		5,25	
18		5,83	
19		5,03	
20	-30	5,46	5,32 $\sigma = 0,5$
21		5,83	
22		5,61	
23		5,05	
24		4,05	
25		5,45	
26		5,35	
27		6,06	
28		5,32	
29		5,00	

Analysis of pyrotechnical charge and pyrocutter tests

Analysis of the results has determined that the middle value of the delay time of the pyrotechnical charge is m=4,8 s (table 1), with a standard deviation of σ=0,5 s. Mass, shape and dimensions, as well as physical, mechanical, energy and kinetic characteristics of pyrotechnical charge provide the demanded ballistic characteristics for installation into a unit.

Average delay time of a pyrocutter from the moment of pin activation until the cutting of rope is m_u=5,6 s (table 2). Longer delay time of pyrocutter then of the pyrotechnical charge is the result of the measuring method choice (hand measuring with a stopwatch for pyrocutter test), as well as time objectively needed for separate parts to perform their function, e.g. pulling the safety, moving the needle, cutting the rope and etc.

Conclusion

The shape, the achieved internal ballistic characteristics and the function of the developed solution of the pyrocutter, suits the purpose set.

The design offers the possibility of using pyrotechnical elements for various purposes. One of the aspects could be using it for non-military purposes, in car or process industry.

References

[1] MARK HEWISH: *Bringing safety down to earth*, Janes international, defence review, 1999, No.5, pp.48-53.

[2] SERDAREVIĆ,D., NEGOICIĆ,D.: *Ispitivanje prototipske partije pirotehničkog* Savković M:*punjenja pirorezača R-4*, Elaborat VTI-02-01-0838, Beograd, mart 2004.

[3] Radni tim TOC-a: *Elaborat o završnom ispitivanju prototipske partije Pirorezača R-4*, TOC-11-11026, Beograd, juni 2004.

[4] NEGOICIĆ,D., SERDAREVIĆ,D.: *Standard narodne odbrane za pirotehničko punjenje pirorezača R-4*, SNO 8823/04, Beograd, mart 2004.

Received: 10.02.2005.

Primena pirotehničkog punjenja za sečenje užeta

Pirorezač je autonoman uređaj koji koristi pirotehničko punjenje za sečenje užeta prilikom spašavanja pilota tokom katapultiranja. U ovom radu su dati konstrukciono rešenje i rezultati unutrašnje balističkog ispitivanja pirotehničkog punjenja i pirorezača kao funkcionalne celine. Izabrano pirotehničko punjenje obezbeđuje potrebno vreme kašnjenja. U okviru ovoga rada data je statistička analiza vremena kašnjenja, šema mernog lanca i blok dijagram funkcionisanja sistema, kao i procena pouzdanosti.

Ključne reči: **pirotehnika, pirorezač, pirotehničko punjenje, unutrašnje balističko ispitivanje, sedište za katapultiranje**

Application de la charge pyrotechnique pour couper un cable

Le pyrocisailleur est un dispositif autonome qui utilise la charge pyrotechnique pour couper le cable lors du sauvetage du pilote pendant le catapultage. Ce papier présente la solution de construction et les résultats des essais balistiques intérieurs concenant la charge pyrotechni-que et le pyrocisailleur. Comme l'ensemble fonctionnel on a choisi une charge pyrotechni-que capable d'assurer le temps nécessaire de retard. Dans ce travail on présente aussi une analyse du temps de retard, un schéma de chaine de mesure et le bloc-diagramme du foncti-onnement de système ainsi que l'estimation de la fiabilité.

Mots clés: **pyrotechnie, pyrocisailleur, charge pyrotechnique, essai balistique intérieure, siège catapultable**

Применение пиротехнического заряда для резки троса

Пирорезак независимый прибор, который пользуется пиротехническим зарядом для резки троса при спасении лётчика в процессе катапультирования. В этой работе приведены конструктивное решение и результаты внутренего баллистического испытания пиротехнического заряда и пирорезка в роли функционального целого.

Выбранный пиротехнический заряд обеспечивает необходимое время выдержки. В рамках этой работы приведены : статистический анализ времени выдержки, схема мерной цепи и блок-диаграмма функционирования системы, а в том числе и оценка надёжности.

Ключевые слова: пиротехника, пирорезак, пиротехнический заряд, внутренее баллистическое испытание, катапультируемое сидение лётчика