Operating Mechanisms & Function Cycle of MK 19 MOD 3 40 mm Grenade Launcher

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Abstract- The Mk 19 is a belt-fed, blowback-operated, air-cooled, crew-served, fully automatic weapon. The weapon operates on the blowback principle, which uses the chamber pressure from each fired round to load and re-cock the weapon.

This paper presents a study of the operating mechanisms and function cycle of 40 mm Grenade Launcher, which is very important weapon, used by the Egyptian army and has been manufactured recently in Egypt. Studying of this weapon helps in understanding its construction and design, finding out the causes of its malfunctions, improving the efficiency of its maintenance and repair, and making weapon development easier. All operating mechanisms have been simulated by using AUTODESK INVENTOR 2016 and the function cycle of the weapon is calculated based on real calculations and measurements of the needed parameters such as: impulse of powder gases, return spring stiffness, buffer stiffness and weights of moving parts. Finally the function cycle of 40 mm Grenade Launcher has been calculated according to the standard rate of fire as almost 400 round per minute.

I. Introduction

Although the MK 19 is a recent entry into the Army's inventory, development began in 1963. The first version was a hand-cranked, multiple grenade launcher called the MK 18. In 1966, the need for more firepower inspired the development of a self-powered 40-mm machine gun called the MK 19, MOD 0. This model was neither reliable nor safe enough for use as a military weapon system. Product improvements begun in 1971 resulted in the 1972 MOD 1, of which only six were produced. The MOD 1 performed effectively in Navy riverine patrol craft and broader applications for the MK 19 were found. In 1973, the Navy developed the MOD 2, which featured improved reliability, safety, and maintainability. In 1976 a complete redesign resulted in the MK 19, MOD 3, which the Army adopted in 1983. The Army now uses the MK 19 within the tactical environment for defense, retrograde, patrolling, rear area security, urban operations, and special operations.

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I. Operating mechanisms

For the calculation of the weapon's function cycle, it was necessary to understand and study the different mechanisms that makes the complete function cycle and enables the weapon to perform its task reliably.

During the cycle of operation of this weapon, it has six major Mechanisms, which are:

1- Charging mechanism.
2- Extracting mechanism.
3- Cocking mechanism.
4- Firing mechanism.
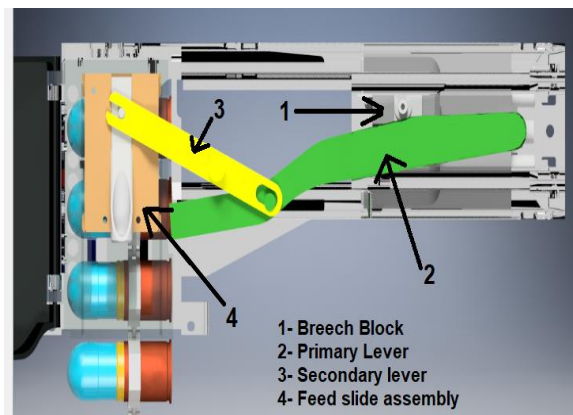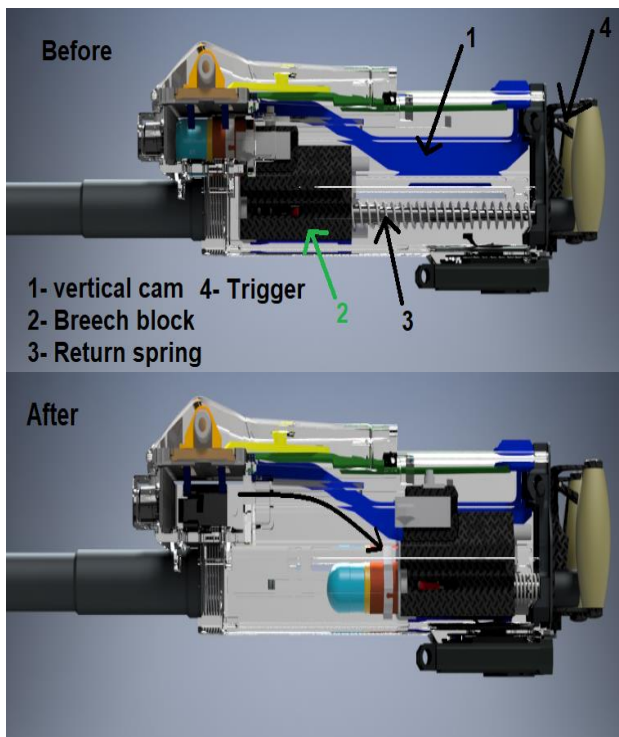5- Recoil and automatic feeding mechanism.

A. Charging mechanism

Figure 1 Charging Mechanism

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This mechanism enables the motion of the leading round to the loading space under the action of the feeding slide, and it is considered as the first step carried out by the operator as the following:

1- Pulling the bolt (breech block) to the rear by using the two charging handles.
2- This rearward motion causes the primary drive lever to move to the left. So, the secondary drive lever connected to the primary one rotates around the point of fixation with the top cover assembly.
3- The feed slide assembly moves to the right by the forked end of the secondary lever which rests on the inner feed slide pin.
4- The linked rounds of the belt move to the loading space by the feeding pawls. Now, the leading round is aligned with the bolt face.

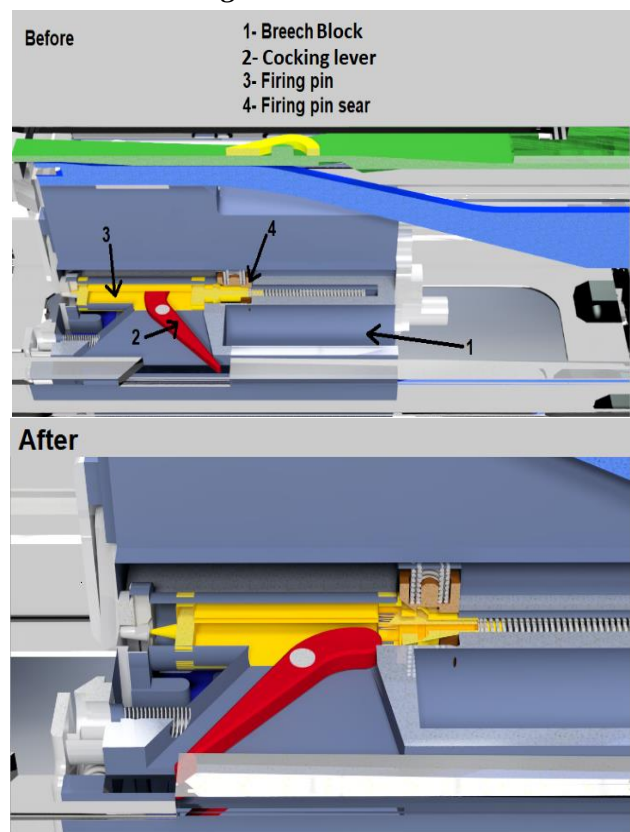## B. Extracting mechanism

Figure 2 Extracting Mechanism

This mechanism moves the round from the feeding space to the bolt fingers in the following steps:

1- After charging the gun, the operator presses the trigger so the bolt moves forward under return spring action.

2- The bolt's extractor snap over the cartridge of the round, As the operator charges the gun again, this forces the male and female links between the rounds apart.
3- The round is now pulled backwards by the extractor and slides over the curve of the vertical cam assembly so it is forced down to the face of the bolt, out of the extractors, and into the bolt fingers. Simultaneously, the rounds in the feeding space have been moved over one place similar as in the charging method.
4- Now the primer of the round is aligned with the firing pin, ready for firing.
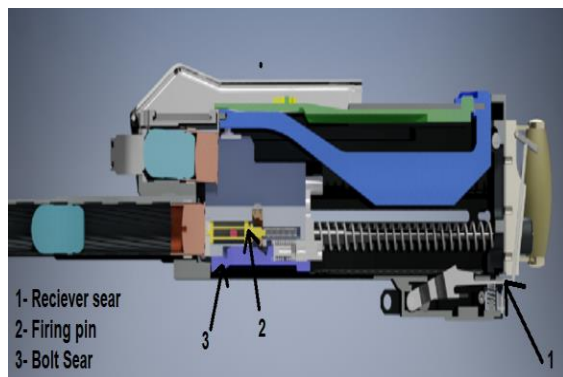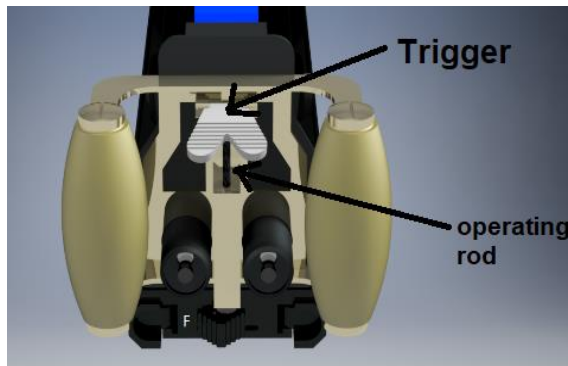
C. Cocking mechanism

Figure 3 Cocking Mechanism

During the backward motion, the cocking lever is forced to rotate around its point of fixation and retracts the firing pin. So, The firing pin is held rearward by the firing pin sear.

The gun is prevented from firing by the firing pin sear and the cocking lever until the bolt is released forward.

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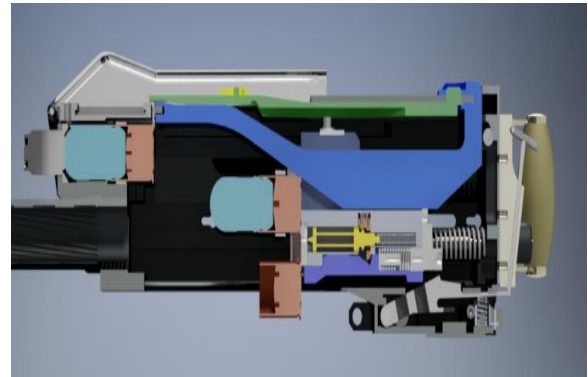### D. *Firing mechanism*

Figure 4 Firing Mechanism

When pressing the trigger, the firing process is carried out as the following:

1- The trigger presses on the operating rod which presses on the receiver sear so it disengages the bolt sear.
2- The bolt moves forward under action of the return spring with the round in its fingers.
3- The cocking lever hits the forward end of the left-hand receiver rail slot and forced rearward to enable motion of the firing pin when released.
4- The bolt sear hits a plate in the bottom of the receiver so it pushes the firing pin sear up to release the firing pin which moves forward under action of firing pin spring.

E. *Recoil and automatic feeding*

During recoil, several functions happen almost at the same time:

1- Powder gases produced from the propellant moves the bolt backwards with a new round in the extractor.

Figure 5 Automatic Feeding Mechanism

2- This new round is extracted and is come down by the vertical cam over the spent case.
3- The spent case is ejected out from the bottom of the gun.
4- The feed slide assembly pulls a new round to the loading space to be ready to be delinked and extracted.
5- The cocking lever is pushed forward to cock the firing pin.
6- The bolt reaches its extreme rear position after the energy is stored in the return springs while any excess energy is absorbed by the buffer.
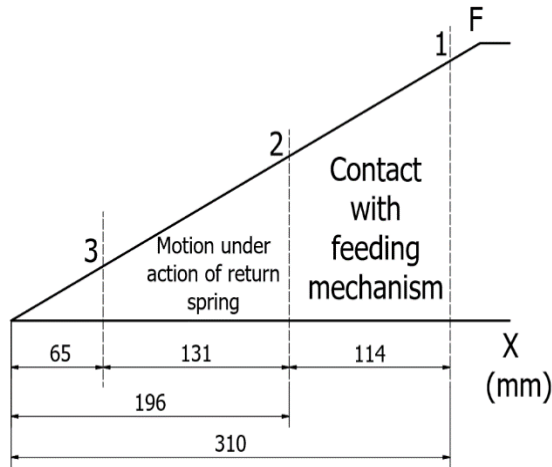7-

II.   Function cycle

At first, Due to the complication of the weapon design and its large size, there was a difficulty in disassembly of the weapon in order to measure the parameters needed for the function cycle such as weight of moving parts, stiffness of return springs and buffers, lengths of tracks during recoil and counter recoil. But this task became easy after using the service manual and technical manuals of the weapon.

A. *Forward motion of the breech block*

It is divided into two tracks:

1- Contact of breechblock with feeding mechanism.
2- Motion under action of return spring.

It is noted that, the used buffer is a dissipative type, which affects only the backward motion by resisting the motion of the BB, and then the stored energy is dissipated.

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Figure 6 Characteristic curve of return spring during forward motion

Total Stiffness of the return springs:

It was measured experimentally by hanging known weight then measuring the change in the length of the return spring.

$K_{Total} = 2020$ (N/m)

Resistance against motion:

R = 85 (N)

Forces of Return spring:

Assuming that the efficiency of the return springs during forward motion is 90%

Position	X (m)	F= 0.9 *K_{Total}* X (N)
1	0.31	563.58
2	0.196	356.32
3	0.065	118.17

Reduced Mass of Breech block , its components and return springs:

$M_{reduced} = M_{Breech\ Block} + \frac{1}{3} M_{spring} + M_{spring\ casing}$

$+ M_{buffer}$

$M_{reduced} = 9.5\ (kg)$

Weight of feeding slide:

$W_{slide} = 10\ (N)$

Distance moved by feeding slide :

$X_{slide} = 0.08\ (m)$

Track 1 ——2▶

No impact occurs between the BB and the feeding mechanism as both starts motion from rest together with a transmission curve between them that transfers motion from BB to the slide through primary and secondary levers.

$V_1 = 0\ (m/s)$ (BB starts motion from rest)

$\frac{1}{2} M_r (V_2{}^2 - V_1{}^2) = (\frac{F_1 + F_2}{2}) * X_{1-2} - R * X_{1-2}$
$- W_{slide} * X_{slide}$

$\alpha_{1-2} = 0.64 + 0.14 \left(\frac{F_2}{F_1}\right)$

$t = \frac{\lambda_{1-2}}{v_1 + \alpha_{1-2}(v_2 - v_1)}$

Track 2 ——3▶

$V_3 = \sqrt{V_2{}^2 - \left(\frac{F_2 + F_3 - 2R}{M_r}\right) * \lambda_{2-3}}$

$\alpha_{2-3} = 0.64 + 0.14 \left(\frac{F_3}{F_2}\right)$

$t = \frac{\lambda_{2-3}}{v_2 + \alpha_{2-3}(v_3 - v_2)}$

Results

Track	V (m/s)	X (m)	t (s)
1-2	2.994	0.114	0.05226
2-3	3.628	0.131	0.0382

Total time during forward motion:

$t_{forward} = t_{1-2} + t_{2-3} = 0.05266 + 0.0382$

$= 0.09046\ (s)$

B. Backward Motion of breech block

It is divided into four tracks:

1- Action of powder gases.
2- Motion against return spring.
3- Contact with feeding mechanism.
4- Motion against buffer.

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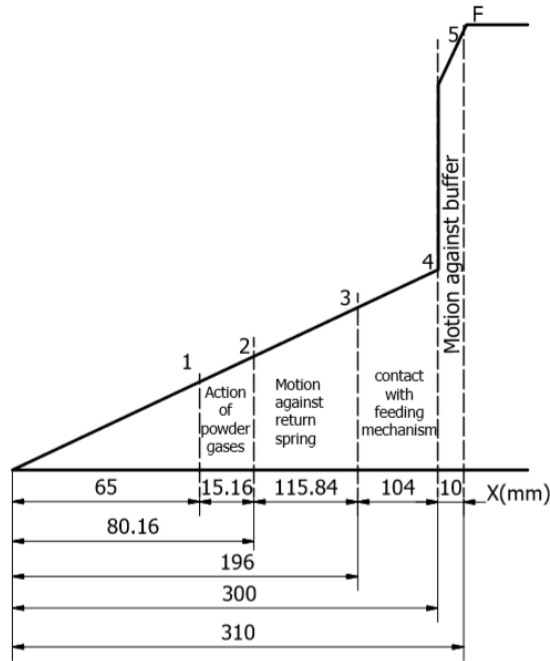
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Figure 7 Characteristic curve of return spring during backward motion

Stiffness of Buffer:

$K_{Buffer} = 22500$ (N/m) (Measured)

Precompression of buffer = 50 (mm)

Impulse of powder gases:

$I_{gases} = 59.5$ (N/s)   (calculated from internal ballistics)

Weight of slide and belt:

$W_{slide+belt} = 27$ (N)

Forces of Return spring:

Position	X (m)	F= $K_{Total} * X$ (N)
1	0.065	118.17
2	0.08016	161.92
3	0.196	118.17
4	0.3	1731 (buffer action)
5	0.31	2144.95 (buffer action)

Track 1 ———2▶

$V_2 = 0.4 * 3.628 = 1.451$ (m/s)

$I_{gases} - I_{\substack{Return \\ spring}} = \varphi_b . M_{reduced}(V_2 - V_1)$

where $\varphi_b = 1.157$

Track 2 ———3▶

$$V_3 = \sqrt{V_2{}^2 - \left(\frac{F_2 + F_3 + 2R}{M_r}\right) * \lambda_{2-3}}$$

$$\alpha_{2-3} = 0.64 + 0.14\left(\frac{F_2}{F_3}\right)$$

$$t = \frac{\lambda_{2-3}}{v_2 + \alpha_{2-3}(v_3 - v_2)}$$

After impact with feeding mechanism:

$$V_3{}' = V_3 - \frac{V_3(1 + b)}{1 + \dfrac{M_r}{M_{prim.lever} . k^2}}$$

b=0.4, $M_{prim.lever}$=0.1(kg),k=0.7017 (measured from transmition curve of feeding mechanism)

$V_3{}' = 5.8$ (m/s)

Track 3 ———4▶

$$\frac{1}{2} M_r(V_3{}'^2 - V_4{}^2) = \left(\frac{F_3 + F_4}{2}\right) * X_{3-4} + R * X_{3-4} + W_{slide+belt} * X_{slide}$$

$$\alpha_{3-4} = 0.64 + 0.14\left(\frac{F_3}{F_4}\right)$$

$$t = \frac{\lambda_{3-4}}{v_3 + \alpha_{3-4}(v_4 - v_3)}$$

Track 4 ———5:▶

$$V_5 = \sqrt{V_4{}^2 - \left(\frac{F_4 + F_5 + 2R}{M_r}\right) * \lambda_{4-5}}$$

$$\alpha_{4-5} = 0.64 + 0.14\left(\frac{F_4}{F_5}\right)$$

$$t = \frac{\lambda_{4-5}}{v_4 + \alpha_{4-5}(v_5 - v_4)}$$

Results

Track	V (m/s)	X (m)	T(s)
1-2	6.558	0.0156	0.01
2-3	5.84	0.11584	0.0191
3-4	2.835	0.104	0.0272
4-5	0.765	0.0175	0.0078

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Total time during backward motion:

$$t_{backward} = t_{1-2} + t_{2-3} + t_{3-4} + t_{4-5}$$

$$= 0.01 + 0.0191 + 0.0272 + 0.0078 = 0.0641 \text{ (s)}$$

III. Results

Total time:

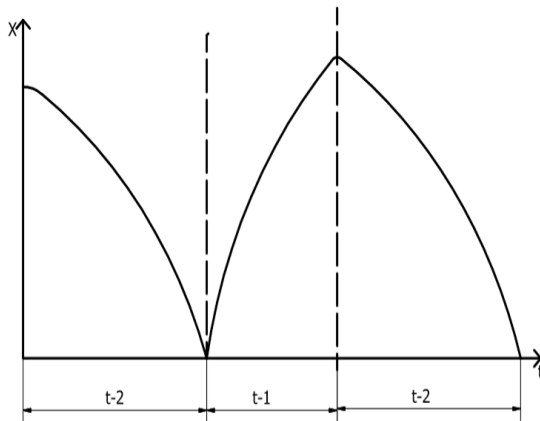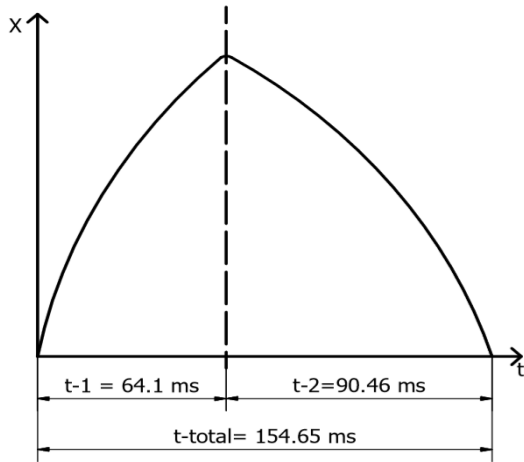$$t_{total} = t_{forward} + t_{backward}$$

$$= 0.09046 + 0.0641 = 0.15465 \text{ (s)}$$

Rate of Fire:

$$k = \frac{60}{t_{total}} = \frac{60}{0.15465} \approx 388 \, RPM$$

Function Cycle of weapon:

Figure 8 Function cycle

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2-Service manual, MK 19, 40-mm grenade machine gun, mod (fm 3-22.27(fm 23.27)) 27 December 1988

3- Lecture Notes - Construction of Weapons and Ammunition II

4-Lecture Notes- Design of Automatic Small Arms I

5-Lecture Notes-Des   ign of Small Arms II