Detail study of bullet being fired from gun

DETAIL STUDY OF BULLET BEING FIRED FROM GUN

Recoil of a Gun

When a bullet is fired from a gun, the gases produced in the barrel exert a tremendous force on the bullet (action force). As a result, the bullet moves forward with a great velocity called the muzzle velocity. The bullet at the same time exerts an equal force on the gun in the opposite direction (reaction force). Due to this the gun moves backwards. This backward motion of the gun is called the recoil of the gun. The velocity with which the gun moves backwards is called the recoil velocity.

Recoil of Gun Let 'M' be the mass of the gun and m that of the bullet. Before firing both are at rest. After firing let 'V' be the velocity of the gun and 'v' that of the bullet. By law of conservation of linear momentum,

Initial momentum of gun and bullet = final momentum of gun and bullet.

The initial momentum of the gun and the bullet is equal to zero since they are initially at rest.

Final momentum after firing = $M*V + m*v = 0$

[The negative sign indicates that the gun is recoiling]

Long recoil operation

Key for recoil operation diagrams.

Block diagram of long recoil operation cycle.

Long recoil operation is found primarily in shotguns, particularly ones based on John Browning Auto-5 action. In a long recoil action, the barrel and bolt remain locked together during recoil, compressing the recoil spring or springs. Following this rearward movement, the bolt locks to the rear and the barrel is forced forward by the spring. The bolt is held in position until the barrel returns completely forward during which time the spent cartridge has been extracted and ejected, and a new shell has been positioned from the magazine. The bolt is released and forced closed by its recoil spring, chambering a fresh round.

The long recoil system is over a century old and dominated the automatic shotgun market for more than half that century before it was supplanted by new gas-operated designs. While Browning halted production of the Auto-5 design in 1999, Franchi still makes a long recoil operated shotgun line, the AL-48, which shares both the original Browning action design, and the "humpbacked" appearance of the original Auto-5. Other weapons based on the Browning system were the Remington Model 8 semi-automatic rifle (1906), the Frommer Stop line of pistols (1907) and the Chauchat machine rifle (1915).

Cycle diagram explanation

1. Ready to fire position. Bolt is locked to barrel, both are fully forward.
2. Recoil of firing forces bolt and barrel fully to the rear, compressing the return springs for both.
3. Bolt is held to rear, while barrel unlocks and returns to battery under spring force. Fired round is ejected.
4. Bolt returns under spring force, loads new round. Barrel locks in place as it returns to battery.

Short recoil operation

The barrel from a Para Ordnance P12.45, a M1911-derived design which uses short recoil operation. Under recoil, the barrel moves back in the frame, rotating the link (shown in the unlocked position), which causes the rear of the barrel to tip down and disengage from the slide.

The short recoil action dominates the world of centerfire automatic pistols, being found in nearly all such weapons chambered for 9x19mm Parabellum or greater caliber (smaller calibers, .380ACP and below, generally use the blow-back method of operation). Short recoil operation differs from long recoil operation in that the barrel and slide recoil only a short distance before they unlock and separate. The barrel stops quickly, and the slide continues rearward, compressing the recoil spring and performing the automated extraction and feeding process. During the last portion of its forward travel, the slide locks into the barrel and pushes the barrel back into battery.

The exact method of locking and unlocking the barrel is the primary differentiating factor in the wide array of short recoil designs. Most common are the John Browning tilting barrel designs, based either on the swinging link and locking lugs as used in the M1911 pistol, or the linkless cam design used in the Hi Power. Other common designs are the locking block design found in the Beretta 92, rollers in the MG42, or a rotating barrel used in the Steyr TMP among others. Perhaps the most unusual is the 1890 toggle bolt design of Hugo Borchardt, most used in the German Luger pistol.

While the short recoil design is most common in pistols, the very first short recoil operated firearm was also the first machine gun, the Maxim gun. It used a toggle bolt similar to the one Borchardt later adapted to pistols. Browning also used the short recoil action in larger guns, including the M2 machine gun, which has seen service for over 80 years as a heavy machine gun with all branches of the United States military.

Cycle diagram explanation

Block diagram of short recoil operation cycle.

1. Ready to fire position. Bolt is locked to barrel, both are fully forward.
2. Upon firing, bolt and barrel recoil backwards a short distance while locked together, until the barrel is stopped.
3. The bolt unlocks from the barrel and continues to move to the rear, ejecting the fired round and compressing the recoil spring.
4. The bolt returns forward under spring force, loading a new round into the barrel.
5. Bolt locks into barrel, and forces barrel to return to battery.

Muzzle booster

Main article: Muzzle booster

Some short-recoil operated firearms, such as the German MG42 machine gun, use a mechanism at the muzzle to extract some energy from the escaping powder gases to push the barrel backwards, in addition to the recoil energy. This boost provides higher rates of fire and/or more reliable operation. This type of mechanism is also found in some suppressors used on short recoil firearms, under the name gas assist or Nielsen device, where it is used to compensate for the extra mass the suppressor adds to the recoiling parts both by providing a boost and decoupling some of the suppressor's mass from the firearm's recoiling parts.

Inertia operation

The newest design in recoil operated firearms is the inertia operated system. In a reversal of the other designs, the inertia system uses nearly the entire firearm as the recoiling component, with only the bolt remaining stationary during firing. Because of this, the inertia system is only applied to heavily recoiling firearms, particularly shotguns. Currently the only inertia operated firearms are either made by Benelli, or use a design licensed from Benelli, such as Franchi. In the Benelli implementation, a two part, rotating locking bolt, similar to that in many gas-operated firearms, is used as basis of the action.

Before firing, the bolt body is separated from the locked bolt head by a stiff spring. As the shotgun recoils after firing, inertia causes the bolt body to remain stationary while the recoiling gun and locked bolt head move rearward. This movement compresses the spring between the bolt head and bolt body, storing the energy required to cycle the action. Since the spring can only be compressed a certain amount, this limits the amount of force the spring can absorb, and provides an inherent level of self-regulation to the action, allowing a wide range of shotshells to be used, from standard to magnum loads, as long as they provide the minimum recoil level to compress the spring. Note that the shotgun must be free to recoil for this to work--the compressibility of the shooter's body is sufficient to allow this movement, but firing the shotgun from a secure position in a rest or with the stock against the ground will not allow it to recoil sufficiently to operate the mechanism.

Block diagram of inertia operation cycle.

As the recoil spring returns to its uncompressed state, it pushes the bolt body backward with sufficient force to cycle the action. The bolt body unlocks and retracts the bolt head, extracts and ejects the cartridge, cocks the hammer, and compresses the return spring. Once the bolt reaches the end of its travel, the return spring provides the force to chamber the next round from the magazine, and lock the bolt closed.

Cycle diagram explanation

1. Ready to fire position. Bolt is locked to barrel, both are fully forward.
2. Upon firing, the firearm recoils backwards into the shooter's body. The inertial mass remains stationary, compressing a spring. The bolt remains locked to the barrel, which in turn is rigidly attached to the frame.
3. The compressed spring forces the inertial mass rearwards until it transfers its momentum to the bolt.
4. The bolt unlocks and moves to the rear, ejecting the fired round and compressing the return spring.
5. The bolt returns to battery under spring force, loading a new round and locking into place.
6. The shooter recovers from the shot, moving the firearm forward into position for the next shot.

RECOIL: -

Recoil is the 'kick' given by a gun when it is fired. In technical terms, this kick is caused by the gun's backward momentum, which exactly balances the forward momentum of the projectile. In most small arms, the momentum is transferred to the ground through the body of the shooter; while in heavier guns such as mounted machine guns or cannons, the momentum is transferred to the ground through a mounting system.

The change in momentum results in a force which, according to Newton's second law is equal to the time_derivative of the backward momentum of the gun. The backward momentum is equal to the mass of the gun multiplied by its reverse velocity. This backward momentum is equal, by the law of conservation of momentum, to the forward momentum of the ejecta of the gun (the projectile(s), wad, sabot, propellant gases, and so on). Provided that the mass and velocity of the ejecta are known, it is possible to calculate its momentum and thus the recoil. In practice, however, it is often easier simply to measure the recoil force directly, as with a ballistic pendulum.

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Recoil momentum and recoil energy

There are two conservation laws at work when a gun is fired: conservation of momentum and conservation of energy. Recoil is explained by the law of conservation of momentum, and so it is easier to discuss it separately from energy.

The recoil of a firearm, whether large or small, is a result of the law of conservation of momentum. Assuming that the firearm and projectile are both at rest before firing, then their total momentum is zero. Immediately after firing, conservation of momentum requires that the total momentum of the firearm and projectile is the same as before, namely zero. Stating this mathematically:

$p_f + p_p = 0$

Where p_f is the momentum of the firearm and p_p is the momentum of the projectile. In other words, immediately after firing, the momentum of the firearm is equal and opposite to the momentum of the projectile.

Since momentum of a body is defined as its mass multiplied by its velocity, we can rewrite the above equation as:

Where:

m_f is the mass of the firearm

v_f is the velocity of the firearm immediately after firing

m_p is the mass of the projectile

v_p is the velocity of the projectile immediately after firing

A consideration of energy leads to a different equation. From Newton's second law, the energy of a moving body due to its motion can be stated mathematically as:

Where:

m is the mass of the firearm system, or ejecta and projectile after leaving the barrel

v is its velocity

This equation is known as the "classic statement" and yields a measurement of energy in joules (or foot-pound force in non-SI units). Et is the amount of work that can be done by the recoiling firearm, firearm system, or projectile because of its motion, and is also called the translational kinetic energy. In the firearms lexicon, the energy of a recoiling firearm is called felt recoil, free recoil, and recoil energy. This same energy from a projectile in motion is called: muzzle energy, bullet energy, remaining energy, down range energy, and impact energy.

There is a difference between these two equations and events. The momentum equations describe conditions immediately after firing, before the projectile has left the barrel, while the energy equation describes conditions after the projectile has left the barrel.

The recoil impulse Ir of a small arm can be roughly described as:

Where:

V0 is the muzzle velocity

mp is the mass of the projectile

c is the mass of the propellant charge

This equation is an approximation. The constant of 1.75 varies for differing propellants.

See physics of firearms for a more detailed discussion.

Perception of recoil

Recoil while firing is shown above:-

For small arms, the way in which the shooter perceives the recoil, or kick, can have a significant impact on the shooter's experience and performance. For example, a gun that "kicks like a mule" is going to be approached with trepidation, and the shooter will anticipate the recoil and flinch in anticipation as the shot is released. This leads to the shooter jerking the trigger, rather than pulling it smoothly, and the jerking motion is almost certain to disturb the alignment of the gun and result in a miss.

This perception of recoil is related to the acceleration associated with a particular gun. The actual recoil is associated with the momentum of a gun, the momentum being the product of the mass of the gun times the reverse velocity of the gun. A heavier gun, that is a gun with more mass, will manifest the momentum by exhibiting a lessened acceleration, and, generally, result in a lessened perception of recoil.

One of the common ways of describing the felt recoil of a particular gun/cartridge combination is as "soft" or "sharp" recoiling; soft recoil is recoil spread over a longer period of time, that is at a lower acceleration, and sharp recoil is spread over a shorter period of time, that is with a higher acceleration. With the same gun and two loads with different bullet masses but the same recoil force, the load firing the heavier bullet will have the softer recoil, because the product of mass times acceleration must remain constant, and if mass goes up then acceleration must go down, to keep the product constant.

Keeping the above in mind, you can generally base the relative recoil of firearms by factoring in a number of figures such as bullet weight, powder charge, the weight of the actual firearm etc. The following are base examples calculated through the Handloads.com free online calculator, and bullet and firearm data from respective reloading manuals (of medium/common loads) and manufacturer specs:

- In a Glock 22 frame, using the empty weight of 1.43lb (0.65kg), the following was obtained:
- 9 mm Luger: Recoil Impulse of .78 ms; Recoil Velocity of 17.55ft/s (5.3m/s); Recoil Energy of 6.84ft·lbf (9.3J)
- .357 SIG: Recoil Impulse of 1.06 ms; Recoil Velocity of 23.78ft/s (7.2m/s); Recoil Energy of 12.56ft·lbf (17.0J)
- .40 S&W: Recoil Impulse of .88 ms; Recoil Velocity of 19.73ft/s (6.0m/s); Recoil Energy of 8.64ft·lbf (11.7J)
- In a Smith and Wesson .44 Magnum with 7.5-inch barrel, with an empty weight of 3.125lb (1.417kg), the following was obtained:
- .44 Remington Magnum: Recoil Impulse of 1.91 ms; Recoil Velocity of 19.69ft/s (6.0m/s); Recoil Energy of 18.81ft·lbf (25.5J)
- In a Smith and Wesson 460 7.5-inch barrel, with an empty weight of 3.5lb (1.6kg), the following was obtained:
- .460 S&W Magnum: Recoil Impulse of 3.14 ms; Recoil Velocity of 28.91ft/s (8.8m/s); Recoil Energy of 45.43ft·lbf (61.6J)
- In a Smith and Wesson 500 4.5-inch barrel, with an empty weight of 3.5lb (1.6kg), the following was obtained:
- .500 S&W Magnum: Recoil Impulse of 3.76 ms; Recoil Velocity of 34.63ft/s (10.6m/s); Recoil Energy of 65.17ft·lbf (88.4J)

In addition to the overall mass of the gun, reciprocating parts of the gun will effect how the shooter perceives recoil. While these parts are not part of the ejecta, and do not alter the overall momentum of the system, they do involve moving masses during the operation of firing. For example, gas operated shotguns are widely held to have a "softer" recoil than fixed breech or recoil operated guns. In a gas operated gun, the bolt is accelerated rearwards by propellant gases during firing, which results in a forward force on the body of the gun. This is countered by a rearward force as the bolt reaches the limit of travel and moves forwards, resulting in a zero sum, but to the shooter, the recoil has been spread out over a longer period of time, resulting in the "softer" feel.

DETAIL STUDY OF THROWING A STONE

PROJECTILE MOTION -an important 2-dimensional movement.

This is very common movement - every time a ball is hit or thrown through the air. It occurs in a vertically aligned plane (an up-down plane) instead of on the flat plane.

Whenever a stone is thrown, it moves forward and up and down. It does not move sideways (if we ignore affects due to the air) so it remains in a vertical plane.

The arrows represent the velocity at three instances; the beginning, the centre and the finish.

Let's look at the velocity at the beginning of its motion - the initial motion.

From sideways on, it is moving at an angle to the flat ground. We can think of this true initial velocity as being made of two velocities just as the ant had two velocities when on the conveyor belt.

We can split the true initial velocity into the two parts either algebraically or geometrically because we have selected a very simple angle between the parts - 900 ! Whenever we split a vector back into right angled parts we say we are finding the components of the vector.

We use the simple trig functions of sine, cosine and tangent together with Pythagoras' Theorem to find the components of the initial velocity.

Let vo be the true initial velocity

sin θ = upwards initial velocity, voy (sin θ = opp/hyp)

vo

So voy = vo sin θ

cos θ = forwards initial velocity, vx (cos θ = adj/hyp)

vo

So vx = vo cos θ

The value of this is that we can now work out what is happening when something is thrown.

Remember that the acceleration of gravity only acts downwards locally towards the centre of the Earth. That means that the acceleration only affects the verticalcomponent of the motion! The forward part, vx does not change throughout the flight (provided we ignore the air).

References:

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Bhavicatti

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