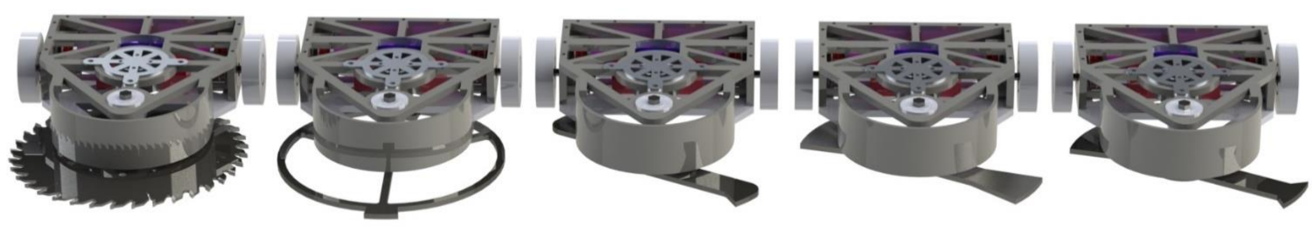
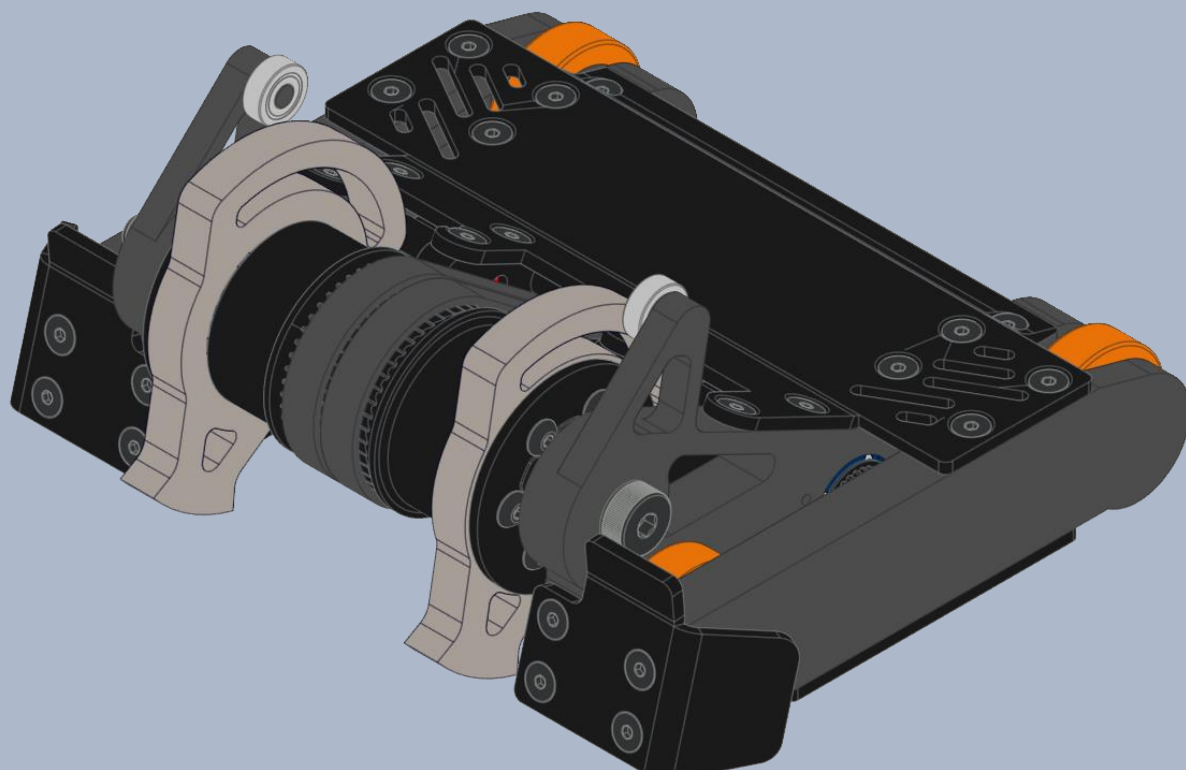


Beetleweight Combat Robot Design Handbook

Created for the Rose-Hulman Combat Robotics Team

Garnache, Peter

Repeat Robotics | 2020



Contents

Introduction

The combat robot handbook was written to act as a guide for new builders looking to start designing and building mainly beetleweight combat robots. I have included information ranging from general combat information, specific mechanical component descriptions, and advice to designing and building combat robots. A lot of the information that I have included in this guide has come from my experience fighting robots in college, years of following robot combat extensively, and my education in mechanical engineering from Rose-Hulman. The contents of this document are by no means hard rules, rather most recommendations and opinions are formed from my experience in the past few years.

This document will also link to a lot of resources that I have used for some topics, as the creators of these resources have much more experience than me. I will try to give credit to these creators when it applies as well.

Thanks for reading this document and good luck!

Robot Weight Classes

The combat robotics community spreads across the entire world, with major competitions happening on almost every continent. There have been many weight classes seen in combat robotics, from 25g to 350lbs, but not all of them have active competitions. The following is a guide to combat robot weight classes. Robots weighting less than 6lb are considered "Insect" weight classes, due to the class names (mantis, beetle, ant, fairy, flea).

Fleaweight – 75g weight limit

This weight class limits competitors' weights at 75 grams. Most flea weight robots struggle to have damaging weapons due to tight weight budgeting, but an experienced builder can fit a devastating weapon within the weight limit. These robots generally run 3D printed frames. These robots have a low power to weight ratio, so armor is not as important. The key factor in this weight class is ground clearance, as a bot that can reliably get underneath other robots is bound to be successful. Competitions for fleaweight robots are practically nonexistent in the US but prosper in Europe and Australia.

Fleabite - Flea

Fairyweight (UK Antweight)– 150g weight limit

This weight class limits robot weight to 150 grams. This extra weight make it much easier to add a destructive weapon to robots, so there are a lot of hard hitters. Most of the destructive robots are limited to direct drive horizontal spinners, which shows the importance of a good wedge at this weight class. This weight class is popular due to the inexpensive nature of the robot parts and low danger due to smaller weapons, but weight management is still the most important part of designing one of these robots. Competitions for Fairyweight robots can be found throughout the US, Europe, and Australia.

Don't Hug me I'm Scared - Fairy

US Antweight – 1lb weight limit

This weight class limits weight to 1lb. Robots in this weight class range from homebuilt wedges made from cutting boards to extremely overdesigned robots such as ORBY Buzz. This is a great weight class to start in, as robot building methods such as direct driving weapons and wheels can be employed without major modifications and post processing. This weight class is less competitive than the beetleweight combat robot class which makes it ideal for a first robot. There are also several successful kit robots that can be purchased for the Antweight class. Competitions for Antweight robots can be found throughout the US, Europe, and Asia.

ORBY Buzz - Ant

There is also a "plastic ant" subdivision of Antweight robot combat where robots must be entirely fabricated from plastic parts (aside from electronics, motors, and fasteners). This class is rapidly growing in popularity as an entry level class due to the ease in fabrication and low damage rate which make the robots extremely affordable compared to other weight classes.

US Beetleweight – 3lb | UK – 1.5kg

Lynx - Beetle

Beetleweight robots are limited to 3lb in the US, and 1.5kb in Europe. This is by far the most competitive insect weight class. Brushless motors at for this scale robot provide insane power to weight ratios, due to the push for light motors in the giant drone market, which makes beetleweight robots incredibly dangerous. The most successful beetleweight robots feature tons of custom parts and have been through many design iterations to perfect the robot design. Because beetleweight robots are so powerful, an important aspect of designs is modularity. The most successful beetleweight robots are able to modify their weapons and/or armor in order to provide the maximum advantage against a specific robot. There are successful kit bots in the beetleweight class including D2, Kinetic, and Weta kitbots. Beetleweight robots are fought around the world and are one of the most common weight classes for competitions. There is also a televised competition (on YouTube) run with beetleweight robots in the UK called Bugglebots.

Hobbyweight – 12lbs

Upchuck - Hobby

Hobbyweight robots weigh up to 12 lbs. This class of robots is relatively common in the US with many competitions hosted every year. Unlike some of the lower weight classes, these robots can be designed with a variety of interesting and unique using pneumatic and hydraulic systems, as off the shelf parts start to become viable in weight budgeting. This weight class allows for more creativity in robots as they are much larger than insect weight robots and can fit more complex mechanisms. The weapons on these robots store incredible amounts of energy, which means that robots must be designed more robustly than those in smaller classes. Robots need strong frames and heavy armor to be effective. These robot competitions are generally held in arenas that are larger and stronger than ones used to hold beetleweight robots, as walls that can contain a beetleweight are not strong enough to withhold the weapons on a hobbyweight.

Dogeweight – 15 lbs

RGBeater - Doge

Dogeweight robots weight just a small amount more than Hobbyweight robots, at 15lbs per robot. This means that designing a dogeweight robot is very similar to designing a hobbyweight. The biggest difference between these two classes is the competitions. Hobbyweight robots compete at independent hobbyist competitions where dogeweight competitions are generally hosted by educational institutions. Both NRL (National Robot League) and Xtreme BOTS host competitions that only fight dogeweight robots. Similar to robots in the hobbyweight class, robots in the dogeweight class can have very powerful and destructive weapons. Because of the large weapons in this weight class, their frames must be very robust and well-engineered. Design methods that work at smaller weight classes don’t always scale up to these larger robots, as the forces involved with their weapons are enough to deform structure that seem very rigid at first glance.

Featherweight – 30 lbs

Featherweight combat robots weigh up to 30 lbs. This weight class is very popular for experienced builders, as a single builder with experience can design and fabricate a Featherweight. There are several competitions for these robots annually in the US and worldwide. Featherweight robots are generally less weapon oriented than smaller robots and focus more on reliability and defensive armor. Good engineering becomes more important when fighting at the featherweight scale because parts need to be relatively lighter than smaller scale robots while providing the same performance.

Crippling Depression - Feather

Another popular class is the featherweight sportsman class. Robots with spinning weapons are limited to very low tip speeds resulting in low kinetic energy. This removes dangerous spinners from the competition and allows robots to be less heavily armored and to try innovative new designs. Robots under this ruleset are also required to have an active weapon to prevent wedge robots from dominating the competition. Common robot designs for this class are overhead saw robot, lifters, flippers, and grapplers.

Other Larger Weight Classes

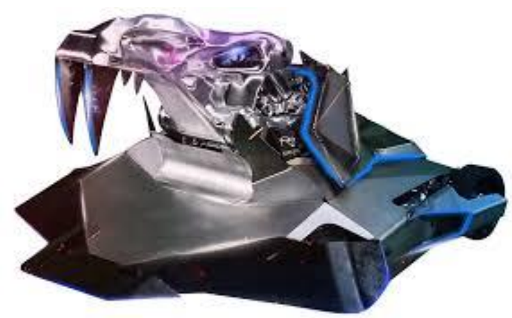
Competitions for robots above the featherweight class are few and far between. The cost of building these robots grows exponentially between weight classes, so it takes a well sponsored team with experience to compete at this scale. Televised competitions have recently been restricted to heavyweight robots, with Battlebots filming in the US and several heavyweight competitions filming in China including FMB (Fight my Bots), Clash Bots, and KOB (King of Bots).

Competition	Weight
Lightweight	60 lbs
Middleweight	120 lbs
US Heavyweight	220 lbs
International Heavyweight	110 kg
Battlebots Heavyweight	250 lbs

Apollo - Robot Wars

ORBY Blade - KOB

Bite Force - Battlebots



Spectre - KOB

Robot Weapon Types

Vertical Spinners

Vertical spinner robots have a weapon that spins at a high speed in the vertical plane and damages with an impact from their robot. For this guide, we will differentiate vertical spinners and drums with the criteria that vertical spinners must have a weapon thickness of less than the weapon radius. These spinners spin so that the impact point of the weapon is moving up at the front of the robot (effectively an "uppercut"). These robots are generally more stable than horizontal spinners because when they hit their opponent, the force of impact pushes them into the ground and throws the opponent into the air.

Vertical spinners have several factors that determine the competitiveness of the design. The most important aspect of a vertical spinner is the ground game and weapon impact angle. These will determine how effective hits from the spinner are. Unlike horizontal spinners, most vertical spinners do not have weapons that protrude past the frame boundaries. Their weapons are generally recessed into the body of the spinner and sit behind something that feeds robots up into the weapon. When facing a robot with a wedge or wedgelet on the front, it is imperative that your vertical spinner gets underneath so your weapon can hit them.

Tempus - Vertical Spinner

Another important factor in a vertical spinner design is the drivetrain. Vertical spinners can run both two wheel and four wheel drive effectively. Four wheel drive gives vertical spinners more traction for pushing and helps to counter the gyroscopic effects from turning resulting in a robot that is easier to control. Two wheel drive vertical spinners are simpler but suffer from reduced pushing power and lack of grip. For more information on drive types see the "Combat Robot Drivetrain Types" section.

The last important factor in a vertical spinner design is the weapon type. Vertical spinners generally spin either a bar or a disk weapon, depending on the opponent facing. Disks are more popular for vertical spinners because they store more energy for a given mass but are vulnerable to horizontal spinners. Because of this it is common to see vertical spinners with both a disk and bar configuration. Vertical spinners spin their weapons at high speeds in order to maximize stored energy, so it is also common to see them compete with single tooth asymmetric weapons. This increases the energy that they store in their weapons.

Drizzle – Vertical Disk

One factor that vertical spinners can suffer from is gyroscopic forces on the robot due to the high momentum of the weapon. The weapons on vertical spinners act as a gyroscope and resist the robot's turning motion. When vertical spinners turn too fast, one end of the robot lifts off the ground. This effect can be used to self-right some robots but can also flip a robot upside down. Because of this effect vertical spinners need to limit the turning speed for their robots when turning in place.

Vertical spinners also suffer when inverted. Due to complications with brushless ESCs in insect weight robots, most vertical spinners are only able to spin their weapons in one direction. This means that when inverted they spin down at the front of the robot which renders them much less effective. Competitive vertical spinners are able to drive while inverted and self-right by impacting their weapon against the wall or their opponent, with a dedicated self righting mechanism, or using the gyroscopic forces caused by spinning their robot.

Drum Spinners

Icky Mouse - Drum

Drum spinners are a subsection of vertical spinners that have longer weapons with smaller diameters that spin at a much higher speed. These robots have weapons that are much thicker than vertical spinners and have a radius that is smaller than the thickness (width) of the weapon. Drum spinners are mostly driven with two wheel drive and have smaller and more compact frames than any other weapon type. They also tend to have more weight in their weapons than other robot types.

Because the weapon on a drum spinner protrudes past the frame of the robot, their ground clearance is not as important as other vertical spinners. Most robots get away with a small piece of metal pointed towards the ground to stop other robot's wedges from getting under their robot but those are not necessary to have a successful bot.

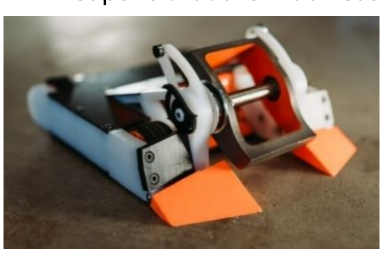
Bequinox - Drum

There are several popular ways to make a drum spinner's weapon. The first is to fabricate a single piece drum out of a hardened steel. This is hard to do without highly specialized tools. An easier way to make a drum is to mount hardened steel teeth to a drum using bolts, but these weapons have to be manually balanced which takes a considerable amount of time. The easiest way to make a drum weapon is by layering hardened steel disks with softer aluminum spacers. This simulates the large impact face of a unibody drum while also storing a large amount of energy in the rotating mass of the weapon.

Drum spinners are some of the most competitive robots competing in the beetleweight class today for several reasons. First, their weapon design has the highest energy storage to radius ratio as most of their mass is close to the impacting radius. These robots also have weapons that cover most of the width of the robot, so it is hard to hit the front of a drum robot without being hit by the weapon.

Beater Bar Spinners

K2 - Beater Bar



Lynx - Beater Bar

Beater Bar spinners are a variant of drum spinners with weapons that are much easier to fabricate. These weapons are cut out of a flat piece of stock in an outline of a square, with a hollow interior. These can be cut with only a few operations and are close to as effective as a drum at a fraction of the price. These weapons are either cut from aluminum and use bolts as the teeth on the weapon (K2) or are cut from a solid piece of hardened steel (Lynx).

Kinetic Kit

Because these weapons are very successful and relatively easy to fabricate, there are several kits for sale with beater bar weapons. These include the Weta robot kit (with a hubmotor inside the weapon), the Kinetic Robot Kit, and the Fingertech Beater Bar Assembly (featuring a belt driven weapon).

Beater bar robots have always been some of the most competitive robot designs, as they are a mix between the energy storage of a drum weapon and the ease of fabrication that makes them accessible to novice builders.

Horizontal Spinners

Horizontal spinners have a weapon that spins in the horizontal plane and usually have a much larger diameter than vertical or drum spinners but spin at a much slower speed. These robots are generally split into one of three categories of horizontal spinner:

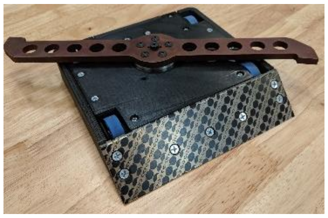
- Undercutters
- Horizontal Bar spinners
- Overhead Spinners

Silent Spring - Undercutter

Undercutter robots have their weapon mounted under the chassis, as close to the ground as possible. These robots are very successful when created right, with both the #1 and #5 ranked beetleweight robots being undercutters. Undercutters gain an advantage over other robots due to their low blades that hit robots underneath the frame. This allows undercutters to directly hit wheels, which are the most critical parts of combat robots. Due to the weapon spinning close to the ground, other robots find trouble getting under the weapon without taking much damage. Undercutters can use both disks or bars for weapons, but disks are more widely used as they store energy more efficiently and are not as vulnerable to hits from vertical spinners.

Psychotic Break V2 - Horizontal Bar

Horizontal bar spinners have their weapon mounted higher than undercutters, as their blade spins between the bottom and top of their chassis. Horizontal bar spinners generally have bar weapons, as their weapons are vulnerable to vertical spinners. Robots with this configuration can either drive their weapon by belt (more common) or use a hubmotor sandwiched between two frame rails to drive the weapon (less common). These spinners are vulnerable to wedges as their weapons struggle to get good bite and are deflected upward. These robots are also very prone to self-inflicted damage, as their weapon can be forced into the floor or wall of the arena after being deflected off a wedge, causing their robot to fly around the arena. They are the easiest horizontal spinner to design and build, as the weapon assembly is supported on both sides, but have not found as widespread success as undercutters.



Anxiety Attack - Overhead

Overhead bar spinners have their weapon mounted above the chassis. These robots are able to spin weapons with much larger diameters than any other beetleweight robots as their chassis and drivetrain does not inhibit the weapon at all. These robots are very fun to design and build and can be unbelievably destructive due to their high energy storage but are hard to build successfully due to several inherent flaws. These robots lack the ability to drive while inverted, as the weapon lies between the wheels and the ground. There are several ways to add a self-righting capability to these robots, but they all rely on the weapon motor working. Because these robots store more energy in their weapon compared to other spinners, they have the greatest strain on the chassis and weapon system whenever they land a hit. These robots also are vulnerable to vertical spinners due to the high mounting point of their weapon. When designed and driven correctly, overhead spinners can be the most dangerous robots in an arena, but due to several inherent issues, they will never be the most competitive robot design.

Full Body Spinners

Full body spinners have a spinning weapon that protrudes outside the robot's drive chassis and surrounds the entire robot. There robots have weapons that usually weigh more than any other robot weapon type and function as both weapon and armor. Full body spinners are split up into three categories:

- Ring Spinners
- Shell spinners
- Meltybrain Spinners

Orbit - Ring Spinner

Ring Spinners spin a ring around the robot's frame. These rings are supported at the outside of the robot and do not cover the top of the robot. Because the robot's top is not covered by any spinning parts, these robots can use wheels that are larger than the height of their frame and stick out the top, which renders them invertible. While being invertible is a huge advantage for these robots, one of the things that they lack is weapon durability. Because the weapon spins around the body of the robot (with several contact points to the frame) the robot will fail to operate correctly with any amount of deformation in the weapon ring. Due to the complexity in the design and the lack of durability in the weapon, ring spinners are not very competitive at the 3lb scale.

Wajoo - Shell Spinner

Shell spinners have a weapon that covers the top of the robot as well as the sides and protects the entire robot. These robots are not able to drive when inverted, as the robot's wheels cannot protrude above the top of the frame due to the spinning shell. These robots can self-right with raised parts of the weapon shell that can de-stabilize the robot when spinning upside down. These weapons are much more robust to damage, as they generally spin about a shaft in the center of the robot and deformation of the outer shell does not necessarily mean that the weapon will be disabled. These weapons are generally driven through either a belt drive or with a hub-motor inside the weapon. Shell spinners are generally better than ring spinners, although they are very complex and require very good engineering design to be competitive. They also require good driving, as it is easy to lose control of the robot and have it bounce uncontrollably from wall to wall.

One of the problems that plagues both ring and shell spinners is the problem of traction during the weapon spinup. Because they have weapons with large moments of inertia (due to the large radius) both of these robot types are prone to losing traction in the drive when the weapon first starts spinning. These robots are also plagued with long spinup times (again due to the high MOI) which allows robots with a fast drivetrain to immediately rush into them and stop them from reaching a dangerous speed.

Halo - Meltybrain

Meltybrain Spinners are a special type of robot that uses its body as a weapon and the drivetrain to power it. They power their drive motors in opposite directions to spin the robot at speeds similar to the operating rpm of weapons and attack their opponent by ramming into them. These robots are the most software-heavy weapon type, and are very hard to control, but they can deliver powerful blows due to the entire mass of the robot storing kinetic energy for impacts. These robots are an engineering marvel but are overall impractical for the average builder.

Non-Spinner Robots

All of the robots that I have designed and built have used spinning weapons, and spinner robots tend to do the most damage and create the most interesting fights. This doesn't mean that non-spinner robots are not worth building, as any well designed and driven robot can take home a tournament, but the rulesets and arenas have encouraged spinning weapons on robots. I will try to provide some insight into the non-spinner robot classes, but this information is from observations from the robots and competitions I have followed rather than from my own competition experience.

Lifter Robots

Lifter robots have a weapon that preforms a controlled motion meant to raise some part of the opposing robot. These weapons move slower than flipper robots and have positional control throughout the entire range of movement. At the insect scale, these weapons can be driven by either a motor or a high power servo, but at higher weight classes they are generally driven by a motor. Lifter weapons are the simplest and safest active weapon as they do not store energy and are generally driven by simple mechanisms including levers and four-bar linkages. Some lifter robots also have integrated grabbing mechanisms that allow their robot to hold their opponent as they lift them off the ground. Well-designed lifter robots can self-right their robots using their lifting arm. Lifter robots can be very effective and competitive in arenas that feature some sort of arena out feature. This could come in the form of a small out of bounds area in one side of the arena, or a pit out feature. Lifters also do well in arenas with significant arena hazards but in simple arenas they struggle to do enough damage to consistently knock out robots. They do excel against all robots that are not invertible, as they are designed to flip robots over.

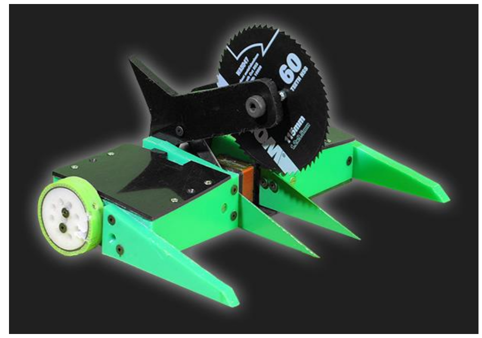
Flipper Robots

Kelpie - Pneumatic Flipper

Unlike lifter robots, flipper robots have a weapon that stores energy and releases that energy in a flipping mechanism that does not have controlled movement. Insect weight flippers are not very common, as it is hard to fit the hardware required for a flipper robot within the small weight allowances. Flippers can operate using either springs, pneumatics, kinetic energy, or hydraulics. Kinetic energy flippers feature very complex mechanical systems that make reliability a challenge, and hydraulic components are not available at weights to make them practical for any small weight class. The most common flippers in insect weight robots are spring and pneumatic robots, although there are no off the shelf solutions for beetleweight pneumatics so builders must design their own systems. Additionally some rulesets at events ban pneumatic powered weapons due to safety concerns. Flipper robots work best in an arena with an arena out feature but can be powerful enough to damage robots and achieve knockout victories in a standard arena.

Pad Thai Doodle Ninja - Four-bar Spring Flipper

Overhead Saw Robots



Maximum Ogerdrive - Overhead Saw

Articulated saw robots have a weapon that has a spinner at the end of an arm that can be independently articulated. Most of these robots have a sawblade at the end of the arm that they use to cut through other robots, taking advantage of robots that lack top armor. The other type of weapon is referred to as a “hammer saw” and is no different from a regular spinning weapon as it imparts kinetic energy to the other robot through an impact. These robots usually have a very open front end with prongs protruding from the robot, as they need to control other robots and hold them still for the sawblade to be effective. These robots can be effective, but they require a robust design and a talented driver, as there are four output devices on the robot that must be controlled. These robots do not need a pit out but can benefit from one as their chassis is usually designed to control the robot.

Axe Robots

Hello There - Axe

Axe robots have a weapon that swings a mass over the top of the robot in a limited arc to impart kinetic energy into their opponent. These robots can be powered with either a high-speed servo or a motor. Like overhead saws, these robots try to take advantage of the light armor on the top of insect robots. These robots are generally less competitive than vertical spinners for a few key reasons. First, their weapon must be triggered before the opponent is in front of the robot, as the hammer takes time to complete its swing, which makes them very hard to drive effectively. Insect weight robots move at a much faster relative speed than larger robots, which makes it hard to time axe swings precisely enough to do meaningful damage. Second, they struggle to store comparable energy to spinners as their weapon only has up to 180 degrees of motion to accelerate before impacting the target. Hammer robots also have problems with the front end of their robot lifting off the ground as they swing due to the large torques applied to their weapon. Because of these fatal flaws, hammer bots are not generally competitive at insect scales, but can be much more competitive at heavier weight classes.

Crusher Robots

Unconscious 514 - Crusher

Crusher robots have an overhead arm with a sharp point that is meant to pierce through the top of robots and cause damage to the internals. There robots are generally designed with a large mechanical advantage from the motor to the piercing tip. The fatal flaw of these robots is that they must hold their opponent in place for the crusher to pierce into the robot, and most crushers actuate their weapon fairly slowly due to the large gear reduction required to pierce other robots. Crusher robots are mechanically complex and hard to drive effectively, which results in poor performance in competitions. Crusher robots are some of the best looking combat robots, but they are generally not competitive at the insect scale.

Wedge Robots

Wedge robots do not have an active weapon but are very durable and rely on pushing their opponent around until they break. These robots are simple and very competitive.

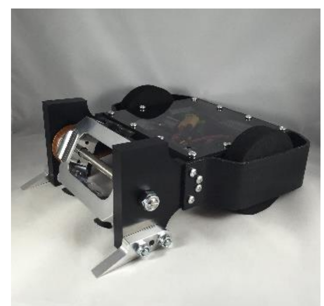
Beetleweight Kitbots

I felt like it was important to mention some of the ready-to buy beetleweight kits available today for robots as well as my opinions on them.

The first robot kit that we find is the D2 Wedge kit. These kits are some of the most durable wedge bots available on the market. They are sold at botkits.com and cost between $300-$400 depending on the options selected and can easily win competitions out of the box. These robots are four wheel drive robots with independent drive (1 motor per wheel) and a hinged wedge on the front. They are made from CNC machined 6061 bulkheads and include a titanium wedge. These robots are also seen in a wedgelet configuration that allows for even tighter ground clearance. These robots are durable enough that 5 of them have competed together as a multi-bot in the 15lb dogeweight class. These robots are only as good as their driver, as their exposed wheels can be ripped off by a spinner. While undercutter robots hold both the first and fifth place rankings on botrank, D2 kits hold second through fourth place, with many more in the top 25. These robots are durable, reliable, and overall a very formidable opponent.

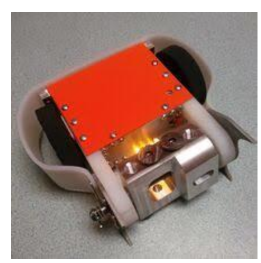
D2 Robot Kit

The second robot kit worth mentioning is the KINETIC kit from botsdepot.com. This robot costs almost $700 but includes everything you could need for a robot (minus the transmitter). It also features a very competitive beater bar spinner, and adjustable ground scraping wedgelets on both sides. This robot uses two wheel drive with wheel guards and sports a CNC machined UHMW frame. These robots are not as widespread as the D2 robots but are still dangerous competitors due to their deadly weapon. Bots Depot also sells the weapon from their kit as a standalone kit for builders to use in their own robot designs. Fingertech robotics also sells a similar beater bar kit for a very reasonable price which has been used on the two time Bugglebots champion, K2.



KINETIC Robot Kit

The next robot kit worth mentioning is the WETA 2.6 Drum Beetle Kit. This robot is produced by kitbots.com and costs between $400 and $850, with options ranging from just the frame and weapon to a turnkey robot immediately ready to fight. This robot includes a 1lb hubmotor powered drum, two wheel drive, wheel guards and UHMW and 60601 Al Frame parts. The robot that this kit was based on “Weta, god of ugly things” is the second beetleweight to earn an “honorable mention” title in the robot combat hall of fame. This kit robot is deadly and has won many tournaments under different names. Kitbots also sells the weapon for this robot allowing teams to integrate it into their robot without having to design their own weapon system.



WETA Robot Kit

The final robot kit is the horizontal spinner robot Vector from Endbots.com. This robot is a horizontal spinner that costs $500 fully assembled. The Vector kits are the most recent kit to come to market, so they lack the strong track record of the other kit robots, but the robot includes Onyx 3D printed parts and a 7075 Al frame with an AR500 weapon.

Vector Robot Kit

Power Transmission

Power transmission is an important topic not only for combat robotics, but also for mechanical design. Power transmission refers to using a mechanical connection to transfer power from one location to another.

Gear Ratios

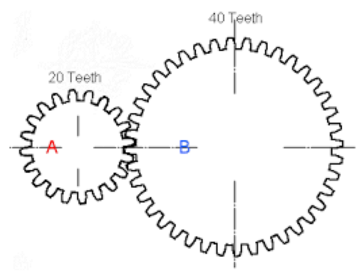
The most important concept relating to power transmission is gear ratios. A gear ratio is a number that effectively approximates the relationship between the input and output of a single stage of a power transmission system. A gear ratio is usually expressed as

$$t_{in}:t_{out} = r_{out}:r_{in} = n_{out}:n_{in}\ ,$$

where t represents a number of turns about the shaft, r represents the radius of the object where contact occurs, and n represents the number of teeth on a profiled surface. This equation can be used to explain the relation between gears, pulleys, sprockets, and a whole variety of other mechanical devices. Gear ratios for multiple stage systems are the product of the individual gear ratios of each stage. Gear ratios change both the torque and the speed of the output relative to the input following the following equations

$$\tau_{out} = {}^{n_{out}}/_{n_{in}} * \tau_{in}$$

$$\omega_{out} = {}^{n_{in}}/_{n_{out}} * \omega_{in}$$



The ratio from A to B would be 2:1

where τ is the torque transmitted around the rotational axis of the shaft and ω is the rotational speed of the shaft. A gear reduction is a gear ratio where the input shaft spins faster than the output ($t_{in} > t_{out}$).

Common Power Transmission in Robotics

This section will focus on translating rotational motion between a motor and a driven load. There are five good ways to do this, and this section will break down how each of these ways works, and then compare them in different loading scenarios. Each of these methods is suited for different applications, and a table summarizing the differences is shown below:

Drive Type	Input/Output Relation	Configurable Ratios	Protects Motor	Allows Slip	Backlash	Point of Failure
Direct	Colinear	No	No	No	None	Motor or Shaft
Gearbox	Colinear or small offset	Yes	Somewhat	No	Medium	Gears or Output Shaft
Gear	Offset parallel	Yes	Yes	No	Small	Smaller Gear or Motor Shaft
Belt	Offset parallel	Yes	Yes	Sometimes	Large	Belt or Pulley
Chain	Offset parallel	Yes	Yes	No	Medium	Chain or Motor Shaft

Features for Power Transmission Methods

Direct Drive

Direct drive is used in applications where the load does not experience any impact forces. In applications where direct impacts are expected, motors used for direct drive can be reinforced with larger drive shafts. Direct drive systems are generally smaller than other power transmission methods (the motor can be partially inside the driven load), but they lack the strength and robustness of other solutions and do not allow for any gear reductions between the motor and load.

Gearboxes

N20 Motor with Gearbox

Gearboxes are attached to the end of a motor and provide a reduction in speed or torque between the input and the output. Gearboxes are mostly used to reduce speed and increase the torque applied to the output but can be designed for any ratio to be achieved. Because the output on most gearboxes applies more torque than the input, the output shaft is generally larger and stronger than the input shaft. Most small, hobby sized motors have output speeds in the 10,000 rpm range. A lot of applications that motors are used for require more torque than these motors can provide and need the motor to spin at a fraction of its maximum speed. Gearboxes are added to these motors to reduce the maximum output speed and increase the torque at the output. Motors are commonly sold with gearboxes attached and are called gearmotors. These motors are sold with either a standard gearbox or a planetary gearbox. Planetary gearmotors can achieve higher reductions in a smaller, more durable package. Gearmotors can also be used in series with other power transmission methods but are the most space-efficient ways to implement high reductions. In combat, drive motors are generally gearmotors or brushless motors coupled to planetary gearboxes. These motors are also used in weapons of non-spinner weapons including saw arm actuation and lifter arms.

Planetary Gearbox

Gear Drive

Gear Drive

Gear drive is different from using a gearbox because the output shaft is offset from the input shaft. A gear drive stage connects the input and output shaft with two gears. Gear drives are used for reductions over a small distance, as the distance between the two shafts is the sum of the two gears’ pitch radii. A pitch radius is a the most important parameter when designing gear drives as the shafts must be positioned so the two gears’ pitch circles are tangent at the point of contact. Gears are designed to perform optimally at this condition, which makes it hard to change out gear ratios once shaft locations are fixed.

In combat robotics, gears are generally used to drive non-spinner weapons that want a small reduction and little to no slip between the motor and the driven load. Gear drives can increase the torque that a motor can provide for weapon arms on lifter, saw, or hammer robots. Gear drive is not a common drive method for spinning robots because there is slip integrated into the system. When a spinner weapon goes from spinning at a high speed to stopping spinning quickly it can cause a lot of stress on the motor. Without some sort of slip in the driving system (to stop the motor from stopping so fast) parts of the motor can break or the motor can induce a large current in the electronics driving it, potentially breaking the driving ESC.

Belt Drive

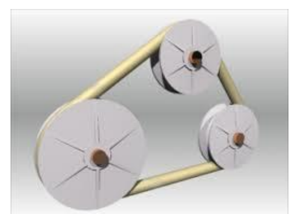
Belt drive is used to connect two shafts with a gear ratio that are spaced far enough away that gear drive is not effective. Belt drives utilizes a belt (lmao) to transfer torque between two pulleys. Belts are by far the most common method of power transmission in insect weight robots, especially in spinning weapons. Belts are durable, simple, and can allow for slip between the pulleys which can protect the drive motors from damaging accelerations. There are several types of belts that are common in combat robotics including V-belts, round belts, and timing belts.

V-Belt

V-Belt Drive

V-Belts are commonly used in weapon drive systems. Because they have no teeth on them, they rely entirely on friction to transfer power between the drive and driven pulleys. The largest advantage of using v-belts is their tendency to slip under high torque situations. When a weapon impacts a target and slows down quickly, a v-belt will isolate that acceleration from the motor and protect it. This gives robot increased reliability but has a few downsides. First, a v-belt will sometimes slip when starting up, due to improper tensioning or a very powerful motor. This increases the spinup time for the driven load. Another problem with V-belts is that they heat up and stretch when they slip often. Powering a V-belt pulley when the loaded pulley is not able to spin will likely heat up the belt and stretch it to a point of failure. V-belts also need to be properly tensioned between the input and output in order to work effectively. The best v-belt systems incorporate some sort of spring driven active tensioner which keeps the belt stretched tight against the pulleys. If the belt is replaced often enough and the pulley separation is calculated correctly in the design, it is possible to use v-belts without a tensioner as long as they are often replaced.

Round Belt



Round Belt Drive

Round belts are similar to v-belts in the way they transfer loads. They have similar pros and cons but have one major difference. Round belts are purchased in bulk tubing lengths, then cut to length and fused to create a single belt. V-belts are purchased at the length that they will be used at, and as such are stronger than round belts in tension. This means that V-belts will be better suited for any large torque applications. Round belts are commonly used because they are cheaper than other belt styles (belting is bought in bulk material and is not specific to the application) and it is simpler to apply in a pre-made design as there are no external tensioners or complex math needed. Round belts are commonly used in robot drive applications, connecting two wheels to a motor for four wheel two motor drive.

Timing Belt

Timing Belt Drive

Timing belts are flat belts that have teeth protruding off the surface of the belt. These teeth allow the belt to transfer large torques between the two pulleys but do not allow for any kind of slip. Timing belts can be used to power both weapons and drive on insect scale robots, although they are not used to power weapons at larger weight classes. Timing belts are easier to implement as they often work without tensioning systems, and they can provide a faster spinup in a weapon system or more accurate movement in a drive, but they do not protect the drive motors which can lead to failure.

An Introduction to Bearings

Anyone who has designed a robot from scratch has used bearings of some sort. Low power rotating shafts can spin in place through a hole without too much of a problem but increasing the speed of the shaft can create drastic problems with efficiency loss. The solution for this problem is the use of some sort of bearing. Bearings support a shaft and decrease friction. While most traditional bearings support rotating shafts, linear bearings allow for support in linear motion. The three main types of bearings used in combat robotics are ball bearings, needle roller bearings, and bushings.

Ball Bearings

Ball bearings are the most commonly used bearings. They use steel balls top reduce the friction between the outer and inner races. These bearings are commonly used as they are very cheap and are usually around 99% efficient. Ball bearings are also able to withstand both axial and radial loads. Ball bearings will have both a maximum speed rating as well as radial and axial load ratings on the spec sheet when bought from a manufacturer. For use in combat robotics, these bearings are often found in both the drivetrain and the weapon. When used in the weapon, these bearings can fail if one of the races cracks or one of the balls shatter upon a big impact. If this happens, the bearing will lock up and be noticeably harder to turn, and usually makes a scratching or crunching noise when turned. One important consideration when implementing these bearings is to keep the spinning and stationary hardware from touching the opposite races. If a shaft is spinning in the inner race, and the outer race is fixed, then whatever is connected to the shaft should not be able to touch the outer race of the bearing, and any fixed hardware should be located away from the inner race. This decreases friction and can stop the bearings from binding up or overheating.

Radial Ball Bearing

Needle Roller Bearings

Needle roller bearings are similar to ball bearings but use cylindrical rollers instead of balls to decrease friction. These bearings have the downside of being hard to implement and more expensive than ball bearings, but they offer several performance advantages. They also do not usually have an inner race, as the rollers directly touch the shaft, which decreases their size drastically. This makes them easier to use in tight spaces and can decrease the size of the object that they are spinning. The only problem with needle bearings is that they are not capable of resisting axial loads. This means that they need to be used in conjunction with some sort of thrust bearing or bushing that is able to mitigate the axial loads. Needle bearings are more complex and more expensive to properly implement, but they can provide the reliability that is essential for winning combat robots.

Needle Roller Bearing

Bushings

Bushings allow for rotational motion without any internal moving parts. Bushings are generally made from oil impregnated copper, and they release the oil as lubricant as they are used. Bushings are not commonly used in combat robotics, as they are less efficient that ball and needle bearings, and cannot withstand high speeds, but they are worth looking into for applications that need to withstand high loads in small spaces at low speeds.

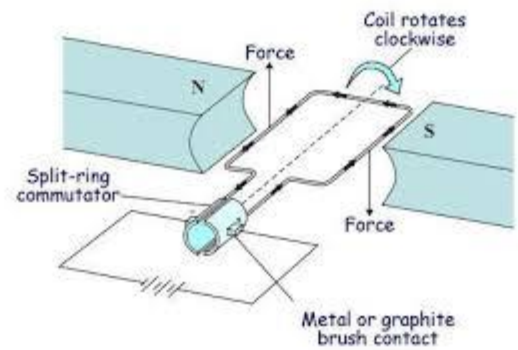
Bushing | Flanged Bushing

DC motors

DC motors are motors that draw their power from a constant DC voltage power supply. Most small, non-industrial motors are DC motors. There are two distinct types of DC motor: brushed and brushless. DC motors run current through loops of wire to induce magnetic fields, then repel against permanent magnets in order to create motion. Motors usually have very small diameter wires and can fit thousands of loops of wire inside the motor to improve the power in the motor.

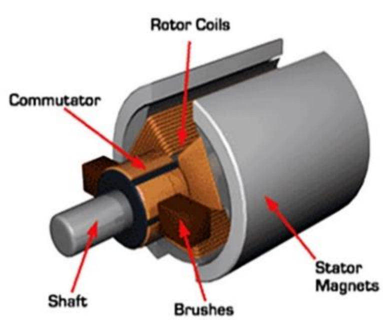
Brushed DC Motors

Brushed DC Motors are the cheaper of the two types of motor. They also are much easier to control, as they will spin continuously with a constant voltage input. Brushed motors are named after the brush contacts that change the voltage inputs to each motor wire coil.



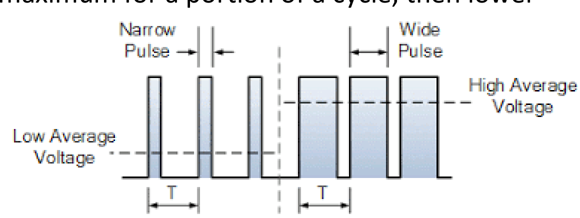
Brushed DC Motor Diagram

A voltage is applied across two (or more) brushes in the motor. These brushes touch the commutator, which is connected to the ends of the loops of wire. As current flows through the wire, it generates a magnetic field that repels against the permanent magnet mounted on the edge of the motor. As the motor starts to move, due to the force from the permanent magnet, the brushes lose contact with the commutator sides, and the momentum of the motor carries it forward until it contacts the other side of the coil. This then inverts the magnetic field produced in the coil, which continues the motion of the motor.



1Brushed DC Motor Internals

Electronic Speed Controllers are unable to directly dictate the speed of a brushed motor. Lowering the voltage applied to the terminals limits the amount of torque that the magnetic field generates, which limits the maximum speed of the motor. Speed controllers are able to keep full torque and control the speed of the motor with PWM signals. PWM signals keep the voltage at the maximum for a portion of a cycle, then lower the voltage to 0 for the rest of the cycle. The duty cycle of a PWM signal is the percentage of the cycle where the signal is high. Using PWM signals, the motor can use maximum torque while changing the maximum speed of the motor. In order to keep the speed of a motor relatively constant, most speed controllers operate at a frequency of more than 1kHz, which means that a single cycle takes less than 0.001 seconds. This allows for smooth speed control of motors.

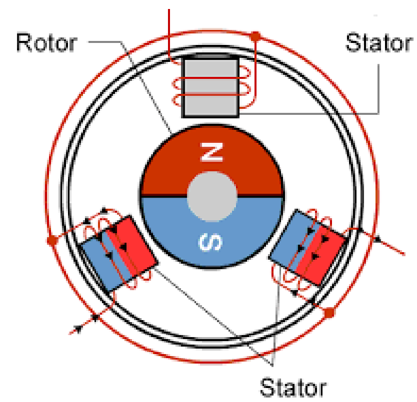


PWM Signal

Brushed motors are a cheap and easy to implement. Most brushed motors are wound to spin at thousands of rotations per minute and are attached to planetary gearboxes to reduce the speed and increase the torque output. Coupled with the right gearbox, brushed motors are available for almost any speed range needed. Brushed motors are often used in combat robots as drive motors or to power non-spinning weapons.

Brushless DC Motors

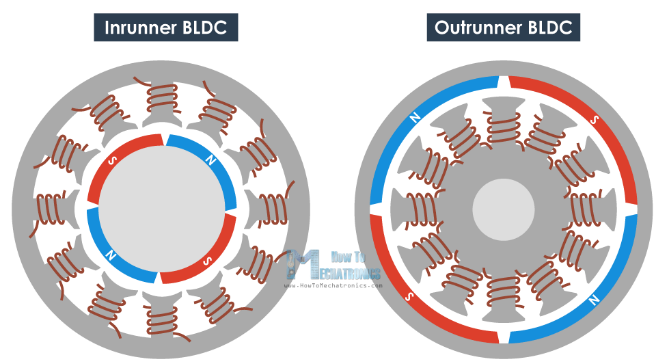
Brushless DC motors are more complex to control than brushed motors, but they have a much greater power density. These motors have three windings and keep the windings stationary to spin the permanent magnets. These robots require complex speed controllers that apply voltages to the coils in the stator to keep it spinning. One advantage that these motors have over traditional brushed motors is that they will always be able to use 100% of their available power, no matter what speed they are spinning at.



Brushless DC Motor Diagram

Brushless motor electric speed controllers (ESCs) change the input voltages to each of the three wires to rotate the motor. In order to efficiently drive these motors, they need some sort of feedback to tell the current position and speed of the rotor. There are three types of feedback that ESCs can use. Many hobbyist motors that are used for drones don't have any type of sensor onboard. These motors are controlled by speed controllers that measure the back EMF generated by the dormant coil and use that measurement to estimate rotor speed and position. This control method is very cheap, as it does not require any sensors, but does not work well at low speeds. Motors controlled through this method lack low speed torque and can sometimes have cogging issues when trying to spin up to speed. More expensive motors use either hall sensors to provide feedback about the position of the magnetic field, or rotary encoders to provide precise position feedback. Not only do these motors cost more, but their controllers are more expensive too. The tradeoff for the complexity and cost is that they have full power at even 0 speed. These motors are generally used in slow applications, such as a robot's drivetrain.

There are two major types of brushless DC motors. Inrunners have the magnetic ring on the inside of the motor, and stator is located around the shell of the motor. These motors are commonly sensored and used in hobbyist boats and cars. Outrunners have the magnet ring mounted to the exterior frame of the motor, and the coils of the stator are mounted inside. Outrunners are generally air cooled and are commonly used in drones and planes. Both of these motors come in a variety of sizes and power ratings. Outrunners are also usually lighter and smaller than inrunners.



Inrunner and Outrunner Motors

Hobbyist brushless outrunner motor sizes are formatted as **## where the ** is the stator width and ## is the stator length. These numbers are not the external sizing of the motor but they do effect the torque and power that the motor is able to produce. These motors also have a KV rating that conveys the maximum speed as a ratio of the input voltage. KV ≈ rpm/volts at no load.

A more detailed explanation of how brushless DC motors and speed controllers can be found here: https://howtomechatronics.com/how-it-works/how-brushless-motor-and-esc-work/

Design for Manufacturing Tips and Tricks

The ability to design a part for a specific manufacturing process is an important skill for an engineer to develop. The following section describes some of the following manufacturing methods and gives some tips and tricks I have learned when designing parts for those fabrication methods.

Waterjet Cutting

Waterjet cutting is a 2D fabrication process that uses high pressure water combined with some sort of abrasive element to cut through materials. Waterjets are used to cut anything from plastics to hardened steel. A waterjet usually accepts a DXF file which an operator converts to a toolpath.

- Waterjets are unable to do partial cuts into materials. This means that any cuts for a waterjet need to be through the whole part and not partial “pockets” in the part. Additionally, any countersinking or counterboring for screws will need to be done after fabrication.
- Waterjets take several seconds to pierce through the material for each cut, reducing the number of cuts by connecting holes will decrease fabrication cost.
- Waterjets have a cutting diameter is around .040 inches, which prohibits smaller details.
- Waterjets will leave draft on the parts, so tight tolerance area will need to be finished afterwards. Undersizing holes will allow for a post-fab operation to reach the correct size.

Laser Cutting

Laser cutting is another 2D fabrication process that uses a high power laser to cut through material. Hobby-grade laser cutters are able to cut some plastics and wood, but high powered industrial lasers can cut anything from aluminum to hardened steel. A laser cutter also uses a DXF file.

- Laser cut parts are unable to do partial cuts as well. Any cuts must be through the entire part.
- Laser cutting does not leave draft on parts, so there is not as much of a need for post-fab operations. Bearing and press fits should still be machined post-fabrication for precise fits.
- Laser cutters have cutting diameters of less than 0.001”, which allows for detailed cuts.

Plasma Cutting

Plasma cutting is yet another 2D fabrication process that uses an electrical arc to cut material. Plasma cutting is much cheaper than laser or waterjet but has some large restrictions. Plasma cutters can only cut through electrically conductive materials and are much less accurate than laser and waterjet cutters. Plasma cutters also leave rough edges that must be ground post process.

- Plasma cutting is good for rough shapes that do not need to be very precise, as all cut surfaces will need to be ground down to shape.
- Plasma cutting is good for welded assemblies, as connections will be ground before welding
- Plasma cutting is not good for thick material, or for hardened materials, as plasma cutting is a heat generating process, and will destroy the heat treatment on the material.

CNC Machining

CNC Machining is a 3D milling process where a spinning cutting tool removes material while following a computer controlled path. CNC machining is complex and takes a long time to learn but can create accurate parts with complex shapes. CNC Machines are capable of cutting, pocketing, facing, and more operations. CNC machines require a camming software to program their movements to cut a shape from a stock material as well as compatible 3D model.

- Because all internal cuts are being made by an endmill, it is very complicated to make internal edges without fillets. Adding fillets can decrease the complexity and time by magnitudes.
- When designing a part for a CNC machine, try to think about how many tooling changes the part will need. If internal pockets have relatively small radii, it will take multiple tools to efficiently create the pocket. Instead, try using a larger internal radius.
- When designing a part, try to limit the setups that are required. Every hole or pocket will need to be cut from a setup perpendicular to the hole, so limit geometry from new directions.
- When designing a part, consider how it will be held during cutting operations. Complex parts may need extra holes added to mount the piece to a fixture, which will also need to be made.
- When designing a part, consider how the machine will zero itself between setups. Add edges perpendicular to the machine axes to allow for easy zeroing.

CNC Routing

CNC Routing is a 2.5D machining operation. It uses a spindle and endmills to remove material from the stock like a CNC machine, but it generally uses only a single setup for its work. CNC routers generally are used to cut soft materials including wood, plastics, and sometimes aluminum. CNC routers require a camming software to generate toolpaths from a part model similar to CNC machines.

- Because all internal cuts are being made by an endmill, it is very complicated to make internal edges without fillets. Adding fillets can decrease the complexity and time by magnitudes.
- Design your part to minimize the amount of post processing needed by limiting features perpendicular to the cutting plane of the machine.
- Cut weight from parts without sacrificing much strength by cutting pockets inside the parts while leaving ribs along major loading paths to retain strength and rigidity.

3D printing (FDM) (Filament Based)

3D printing is a 2.5D additive manufacturing process. Printers deposit material layer by layer which stack up to create a finished part. These printers are great for rapid prototyping and fast fabrication and print parts from a variety of plastics. They will never be as strong as a part milled from solid stock, but when printed under perfect conditions, they can come close. 3D printers use a slicing software to generate a toolpath from a STL model of the part.

- 3D Printed parts are weakest in shear loading perpendicular to the extruding head's direction. They also cannot print overhangs greater than 45 degrees without support material. Design your part with the printing orientation in mind in order to minimize overhangs and keep the part strong in its loading directions.
- Often it is not worth pocketing a 3D printed part, as using a smaller infill amount can sometimes increase the strength of the part while also decreasing the weight.
- Holes that are being printed perpendicular to the extruder will often need some sort of post-processing to remove the support material from inside the hole.
- 3D printed parts tend to expand slightly, so make sure to undersize external features or oversize internal features for tight tolerance fits.
- Utilize tapered heat-set insets or embedded nuts for load-bearing threads.
- Sometimes it is worth printing a part as two separate parts that press together to minimize support material. Adding a 45 degree chamfer to overhanging edges also improves prints.

Combat Robot Materials

One of the hardest decisions for inexperienced builders to make is what materials to use for each part. This section of the handbook will try to help with that choice by providing some insight into common materials for combat robots.

3D Printed Plastics

PLA +

PLA is one of the easiest to use 3D printing materials. It is effective without humidity and temperature control and can be printed without a heated bed. PLA is very brittle when compared to the other filaments and is not recommended for combat applications.

ABS

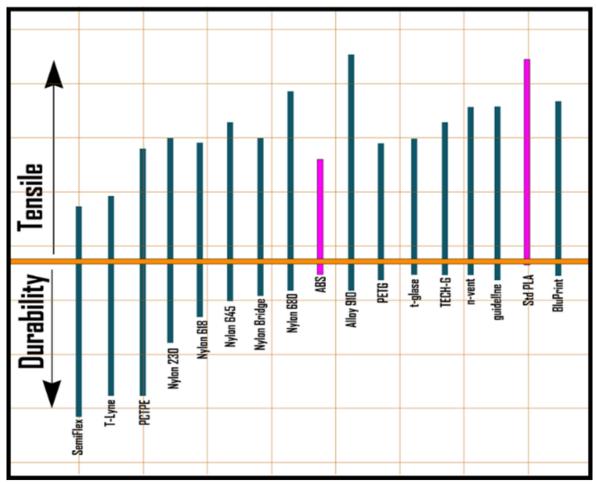
ABS is a strong and ductile filament that is much harder to print. ABS shrinks as it cools which can leave parts deformed after printing which makes a heated bed and enclosure a necessity. While ABS is a better filament for combat than PLA, there are even better filaments that are much easier to work with.

PETG

PETG is described as a material that combines the performance of ABS with the ease of printing of PLA. It is strong and ductile and has very little warpage or other printing issues. PETG is a good filament for combat robotics but is not used at the highest levels.

Nylon and Derivatives (Alloy 910, Nylon X, Nylon G)

There are many types of filament that use nylon as the base. Nylon filaments are more complex than the other materials, and are often found with fibers embedded in the material for added strength. Some of the most used nylon derivatives for combat robotics are listed below:



3D Printer Filament Comparison

Alloy 910 is an engineered plastic to be as close to be good all around for engineering uses.
NylonG has glass fibers embedded in the material to improve the durability of the part.
NylonX has carbon fiber strands embedded in the filament to improve the strength.
Onyx has carbon fiber strands and has remarkable flexural strength.

Engineering Plastics

HDPE (High Density Polyethylene)

HDPE is a wear resistant high strength plastic that can be bought in sheets. This material has a great strength to weight ratio and is surprisingly cheap. It has excellent impact resistance and is uses in combat robotics as a frame material or as ablative armor.

UHMW (Ultra High Molecular Weight Polyethylene)

UHMW is slightly stronger than HDPE but is much less rigid. While this improves the material’s impact resistance it makes it harder to use effectively. UHMW used for frames needs to be thicker than HDPE to prevent any unwanted flexing of the frame. Many successful robots have UHMW frames with internal pockets to reduce the weight while keeping the frame rigid and increasing the strength.

Aluminum

6061 Aluminum

6061 Aluminum is the most commonly used aluminum alloy. It is easy to machine but is softer than many other metals. It is also cheaper than many other types of aluminum. 6061 can be used for any part of the robot except for the impactors on a weapon. Many teams design frames or wheel hubs or weapon hubs from aluminum, but using aluminum as an impactor on a weapon will lead to very quick wear.

7075 Alumiunum

7075 Aluminum is both harder and stronger than 6061 aluminum. It is also more expensive and harder to machine than other Aluminum alloys. It is commonly used in the same applications at 6061 but specifically is used in parts that see high loads, such as weapon supports.

Steel

4140 Steel

4140 steel is a chromoly steel that exhibits excellent hardenability and a good balance of ductility and strength. This material is commonly used in wedges in lower weight classes and can be heat treated with a blowtorch. Welding 4140 is not recommended as it is very susceptible to cracking during the welding process.

S7 Tool Steel

S7 tool steel is a very shock resistant hardened steel. It is generally regarded as one of the best materials for robot weapons and is used for weapons where more than a profile is needed. S7 tool steel is shipped out in its annealed form, which makes machining easier. After machining, the steel must be heat treated to restore its hardness and impact resistance. This makes this material more expensive for most builders, as heat treating steel requires particular equipment that most builders do not have. S7 offers the most benefits for machined asymmetrical drums but can be used in any weapon application.

AR 400 and 500 (Hardox)

AR steels are abrasion resistant steels that are generally used for shooting targets and armored vehicles. The number designation after the AR stands for the hardness of the material, harder materials are more abrasion resistant and stronger. AR steel is sold in a pre-hardened condition and is very tough to machine. The most common ways to shape AR steels is using a waterjet or a fiber laser. While these manufacturing methods are expensive, they are much cheaper than having a S7 weapon machined and heat treated and do not sacrifice much in the result. These materials are commonly used for spinning weapons but can also be used as wedges and, at higher weight classes, frames.

Titanium

The most common titanium for combat applications is grade 5 (6AL4V). Titanium offers high strength at a lower weight than many steels found above. It is very hard to machine compared to other materials on this list. Titanium is generally found on combat robotics in weapon shafts, wedges, frame materials, and can be used as a weapon for the smallest scale robots (usually antweights and lighter).

Carbon Fiber Sheet

Carbon fiber sheet is made up of layers of carbon fibers, laminated together. It has a strength to weight ratio of almost 10 times more than alloy steel. The only problem with carbon fiber is that it is very brittle. Some combat teams use carbon fiber for top and bottom plates, but it is to brittle to repeatedly withstand direct contact with weapons.

Common Beetleweight Drive Motors and Applications

Brushed Motors

16mm Gearmotor

16mm gearmotors are primarily used in antweight combat robots. These motors are DC brushed motors coupled to a 16mm diameter spur gear set. These motors can be purchased in a variety of gear reductions, with the 500 and 1000 rpm variants being the most common. With sufficient shaft support these motors can be used in beetleweight robots, although they have less power than larger motors. These motors are good for a four wheel drive robot that is focused on a large spinning weapon. Spinners do not need as much drive and pushing power as non-spinning robots.

22mm Planetary Gearmotor

22mm planetary gearmotors make use of a planetary gearbox to transfer power from the motor to an output shaft. These gearmotors are heavily used in beetleweight combat robots, as they have similar power output to a 25mm gearmotor in a smaller and lighter package. The output shafts on these motors are not designed for the forces seen in combat robots and are a common failure mode of beetleweight drive systems. These motors are powerful enough for a two motor four wheel drive setup but can also be used to power a single wheel. These motors generally support face mounts with four mounting screws, rather than the two screws seen on the 16 and 25mm spur gearmotors. The gearbox can also have some material removed from it in order to further decrease the weight.

25mm Gearmotor

25mm gearmotors are the simplest and cheapest dc motors suitable for beetleweight drive. While these motors can be used directly out of the box, applying Loctite to the gearbox mount screws and covering the outside in epoxy can extend their lifetime in a combat environment. The output shaft of these motors is also not always seen as good enough for combat, and the shafts should optimally have a second support if being used to directly drive a wheel.

Brushless Drive Motors

18XX brushless outrunner to 22mm gearmotor

Many different teams have designed brushless gearbox conversions that couple an 1806 brushless motor to a 22mm planetary gearbox. These brushless drive prototypes are available to purchase from several robotics teams. There are also several tutorials explaining how to assemble a custom brushless solution. Brushless motors give magnitudes more power at a lower weight with a smaller footprint than a traditional brushed drive motor. These motors do need more complex speed controllers and are more design intensive than implementing brushed drive, as the brushless motors must be shielded from the rest of the internals inside the robot.

Some Beetleweight robots have also found success using a brushless motor to drive wheels through a belt or gear reduction, but the lack of low speed torque makes this drive system challenging.

Further Resources

Combat Robotics Stores

Antweight kits, drive motors, hardware, beater bar kits - https://www.fingertechrobotics.com/

Motors, wedges, wedgebot kits - https://www.botkits.com/

Motors, ESCs, nutstrip - https://www.kitbots.com/

DESC, Electronics, Motors, Horizontal spinner kit - https://www.endbots.com/

Brushless drive, electronics, wheels - https://rectifiedrobotics.com/

Brushless drive - https://www.owobotics.com/

Billet Brushless Drive - https://shop.teambtr.com/

Antweight parts, Beetleweight motors - https://bristolbotbuilders.com/

Brushless Drive Motors, ESCs, SMEEEE kit - https://robotmatter.com/

Undercutter kits, drive motors - https://absolutechaosrobotics.bigcartel.com/

Digital robot designs - https://justcuzrobotics.e-junkie.com/

Helpful Calculators

Spinning Weapon Calculator - http://runamok.tech/RunAmok/spincalc.html

Belt Length Calculator - https://www.bbman.com/belt-length-calculator/

Robot Part Suppliers

Small Bearings - https://www.avidrc.com/

General Hardware - https://www.mcmaster.com/

Hard to find belts - https://www.biedlers-belts.com/

RC Components, brushless motors, ESCs, Batteries - https://hobbyking.com/

RC Components, brushless motors, ESCs, Batteries - https://www.getfpv.com/

High quality small bushless motors - https://emax-usa.com/

Hardware, MC29 brushed controller - https://www.vexrobotics.com/

Helpful Fabricators

Custom Laser cut parts - https://sendcutsend.com/

Waterjet cutting - https://www.bigbluesaw.com/

Carbon Fiber CNC machined parts - https://cncmadness.com/

Custom machined parts - https://www.xometry.com/

Custom engineered/machined parts - https://wedgeindustries.net/

Design Resources

Ask Aaron – Many years of answering combat robot questions - http://runamok.tech/AskAaron.html

Robert Cowan – Beetleweight Robot design, CNC manufacturing - https://www.youtube.com/channel/UCPOTPYuDsKnXP9I-ph4yMgg

Team Just 'Cuz Robotics – Beetleweight robot design, weapon design, - https://www.youtube.com/channel/UCsoZN2VwWJbJ30y2e2sfmnw

Team Panic - Antweight and Fleaweight robot designs - https://www.youtube.com/channel/UCKVSXljMloS4gWibRwCFzRA

Equals Zero blog – Combat robots, vans, cool projects - https://www.etotheipiplusone.net/

C+ : The variable constant – Silent Spring Beetleweight - https://thevariableconstant.blogspot.com/