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SERVO MAGAZINE

FOR THE ROBOT INNOVATOR

www.servomagazine.com

May 2010

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Rolling Thunder has a solid rep in the community for service and quality, and Pete did fight Weta, God of Ugly Things at Moto (see companion article, "Reversing The Trend"), so I feel pretty comfortable endorsing these mounts without the usual body of combat data to back them up. I welcome feedback from folks who use these. SV


B-16 mounts.


Beetle motor 1.

RioBotz Combot Tutorial Summarized — LaunchBots

● Original Text by Professor Marco Antonio Meggiolaro, Summarized by Kevin Berry

Professor Marco Antonio Meggiolaro, of the Pontifical Catholic University of Rio de Janeiro, Brazil, has translated his popular book — the *RioBotz Combot Tutorial* — into English. Last fall, *SERVO* summarized Chapter 3, "Materials," focusing on commonly used materials for combat bot building. This month, we attempt to do justice to a portion of his exhaustive chapter on weapon design. Chapter 6 — "Weapon Design" — is a college level textbook on the design and operational theory of today's combat weapon systems. In this article, we present a much simplified version of the "LaunchBots" section of this chapter. Marco's book is available free for download at **www.riobotz.com.br/en/tutorial.html**. For hard copy purchase (at no profit to Marco) go to Amazon, published by CreateSpace. All information here is provided courtesy of Professor Meggiolaro and RioBotz.

Launcher Design

Launchers need to deliver a huge amount of energy during a very brief time. Because of that, they're almost invariably powered by high pressure pneumatic systems. A 4" bore cylinder with 8" stroke pressurized at 1,000 psi would accelerate a 220 lb mass with an average power of about 566 HP!

Of course, this power is only delivered during a very short time. However, a lightweight electric motor or internal combustion engine cannot supply this unless, of course, the motor is used to store kinetic energy in a flywheel during a few seconds with an ingenious and very strong mechanism that suddenly transfers this energy to the launcher arm — as done by Team Whyachi's Warrior SKF robot (**Figure 1**). Such a sturdy mechanism is not simple to build.

FIGURE 1

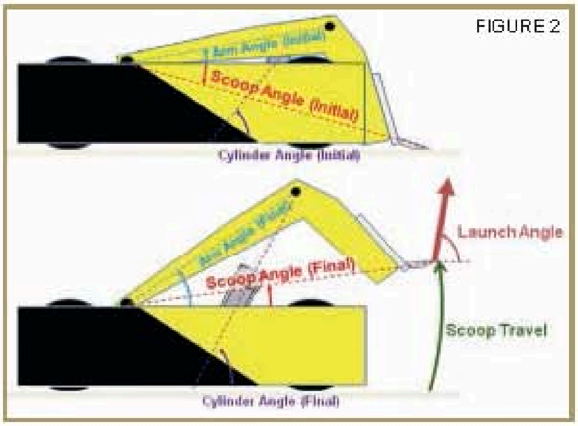
Hydraulic systems are not good options either for launchers. They can deliver huge forces and accelerations, but their top speed is relatively low.

Most launchers try to either maximize the height or the range of the throw. "Height launchers" try to launch the opponent as high as possible and try to flip it while causing damage when it hits the ground. "Range launchers" try to launch the opponent as far as possible — not necessarily high — trying to throw it out of bounds to the arena dead zone.

Three-Bar Mechanisms

A very popular launcher design uses a three-bar mechanism. The "three bars" are the pneumatic cylinder, the main structure of the

FIGURE 2



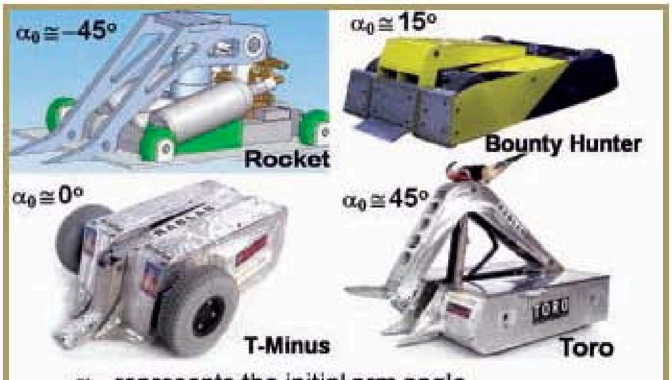


FIGURE 3


FIGURE 4

launcher arm, and the part of the robot chassis that connects the arm and cylinder pivots. The launcher arm tip features a wedge-like scoop. The initial and final angles of the arm and scoop tip are shown in **Figure 2**.

During the launch, the arm follows a circular path, with an arc length that is usually between one and two times the height of the launcher chassis. The launch angle is approximately perpendicular to the average between the initial and final scoop angles.

Figure 3 shows four different launcher configurations. The lightweight Rocket has both initial arm and scoop angles that are around minus 45°, making it a good "range launcher" due to the average 45° force it delivers. The only problem with this design is that it requires a high chassis to get a sufficiently long arm with that minus 45° angle, decreasing its stability and making it more vulnerable to spinners.

Height launchers Bounty Hunter and T-Minus were able to lower their height when the arms are retracted, due to their low initial arm angle of about 15° and 0°, respectively. Their average scoop angle during the launch is close to zero (horizontal), leading to an almost vertical launch angle and force that allows them to throw the opponents very high in the air. Their low initial cylinder angle (below 45°) puts a lot of stress on the back pivot joint of the arm, initially trying to push the arm forward with almost the same force used to launch the opponent. This forward force — which tries to rip off the back pivot — is not necessarily wasted because it doesn't produce extra work. However, this added force increases the friction losses in the joints. This is the price to pay for a low profile launcher.

Toro, on the other hand, has an initial cylinder angle close to 90°, which doesn't stress the arm pivot too much. It is also a height launcher because its average cylinder angle is close to zero. To be able to accommodate its relatively long cylinders, it needs to increase its initial arm angle to about 45°, making its tall launcher arm vulnerable to horizontal spinners. Note the curved strap under Toro's arm that limits the stroke of the cylinders, avoiding their self-destruction when reaching their maximum stroke.

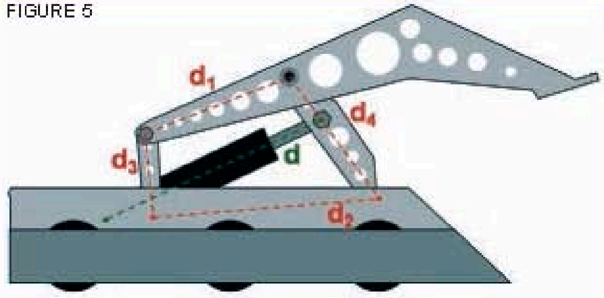


FIGURE 5

To properly simulate the launch, it is likely that you'll need some dynamic simulation software. Or, you can use the spreadsheet from **www.hassockshog.co.uk/flipper_calculator.htm** which has nice launcher models (as pointed out in the March '09 edition of Combat Zone).

As far as scoop design, a long scoop at the end of the launcher arm (as seen in the middleweight Sub Zero, **Figure 4**) makes sure that contact between the robots won't be lost during the entire stroke of the launcher arm. Be careful though — a very long scoop will be vulnerable to drumbots and undercutters which may bend it until it loses functionality (like not being able to get under robots with low ground clearance).

For range launchers, the ideal launch angle of the arm to maximize the range for very low profile opponents is 45°. If you can't get under such very low profile opponents and your arm has a very short scoop, then the best launch angle to maximize the reach would be 30° (with respect to the horizontal). (The preceding paragraph grossly condenses a very technical series of discussions and calculations. Combat Zone STRONGLY recommends reading the full text in the tutorial before deciding on arm and scoop angles.)

Since most combat robots tend to have a low profile — to keep their center of gravity low — we can draw several conclusions about range launchers. If the launcher can only provide a small scoop compared to the arm length, then it is better to set its arm such that its launch angle is about 36° from the horizontal, to reach a maximized range. If the scoop is about 25% of the arm length, then

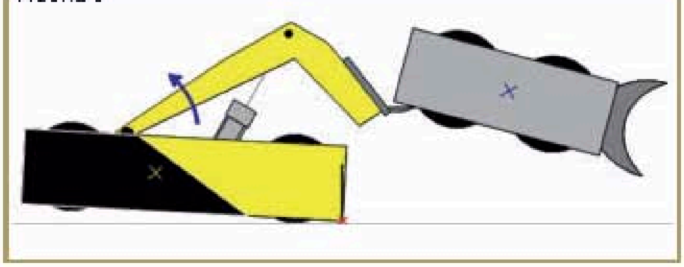


FIGURE 6

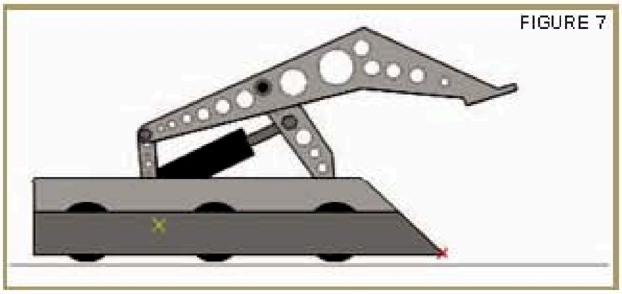


FIGURE 7

a steeper 41° launch angle would be a better option. Finally, if the launcher has a wedge to get under the opponent, or if you decide to use a very long scoop in its arm, then the best choice would be a 45° launch angle. With these values, you spend most of the launch energy throwing the opponent instead of making it spin. Ideally, you should try to keep the opponent's spin as low as possible to maximize the launch range.

Four-Bar Mechanisms

The problem with most range launchers with three-bar mechanisms is that they usually end up with a tall chassis if they want to throw opponents at the ideal launch angles from 36° to 45°.

One alternative is to use four-bar mechanisms. The four bars (as seen in **Figure 5**) consist of part of the launch arm (d1); part of the chassis (d2); and two auxiliary links (d3 and d4). Technically, these launchers have a five-bar mechanism because the pneumatic cylinder (d) counts as a fifth link.

Four-bar mechanisms have two advantages. First, if well designed, they can be completely retracted inside the robot, allowing the use of a low profile chassis. If the constant lengths d1, d2, d3, and d4 are appropriately defined, it is possible to generate optimal trajectories for the arm tip. You can, for instance, make the arm tip trajectory become almost a straight line, with a desired optimal angle (which for range launchers would probably be between 36° to 45° with respect to the horizontal). The four-bar mechanism calculations are too lengthy to be shown here, but you can make them using a free static simulation program that can be found in the tutorials on Team Insanity's website at **www.totalinsanity.net/tut/mechanical/4barfrontbar.php**.

Launcher Stability

During the launch, the arm should not tilt forward too much or be pushed backwards. Otherwise, it will lose its effectiveness.

Due to the very high forces involved during the launch, it is very likely that height launchers will tilt forward until they touch the ground at their foremost point (shown in **Figure 6**). To avoid tilting forward even more and becoming unstable, the launcher's center of gravity should be as far back as possible.

Another concern with height launchers is with the stiffness and damping properties of their front wheels. During the launch, these wheels are really compressed against the ground, storing a great deal of elastic energy. Towards the end of the launch — when contact with the opponent is almost gone — these wheels will spring back. If their damping is low — like with foam-filled rubber wheels — they may launch the launcher and even make it flip backwards.

Range launchers may tilt forward as well, but it is very unlikely they will lose stability in this way. This is because the line that contains the launch force vector usually meets the ground within the launcher footprint (or very close to its foremost point) due to the shallower launch angles.

Range launchers have a problem with very shallow launch angles because the horizontal component of the force may become too large for the wheel friction to bear, pushing it backwards. Tire friction is very important to prevent range launchers from being pushed backwards; decreasing the contact time with the opponent and the effectiveness of the launch. A typical high traction tire is usually enough for a 45° launch angle. For the 36° or 41° angles — which maximize the launch range for the small scoop to arm values — you might need a higher friction tire. If this is not achievable, then the best option is to adopt a higher launch angle.

It is also a good idea for range launchers to locate their center of gravity as far back as possible (see **Figure 7**) to prevent them from even touching their foremost point on the ground; this point will probably have a coefficient of friction with the ground lower than the tires. If some tilting is inevitable, then it might be a good idea to install some anti-sliding material on the bottom of the robot such as a rubber strip to increase friction.

Summary

As you can see, height launchers can benefit from a long scoop, while range launchers should choose average impulse/launch angles between 36° and 45° — depending on the opponent's aspect ratio — as long as they have enough tire friction to not be pushed backwards. **SV**