


Roboteam 8D Kick Actuator

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DEMCON

Step 1: Team

- Chris Krommendijk
  RoboTeam, mechanical engineer, contactperson.
- Csongor Buzogany
  RoboTeam, electrical engineer.
- Peter Krechting
  Demcon MSE, contactperson.
- If required: Demcon specialists.

Step 2: Problem

A problem can be defined in one of three ways. The first being, anything that is a deviation from the standard. The second could be the gap between the actual condition and the desired condition. With the third being an unfilled customer need.

In order to best clarify the problem, you have to see the problem with your own eyes. This gives you the details and hands-on experience that will allow you to move forward in the process.

The kick actuator of the new robot delivers a maximum of 4.5m/s (ball) kick speed instead of the projected 8m/s.

This reduces the competitiveness of the robot football team.

The team wants to be able to reach a kick speed of at least 6.5m/s (the maximum allowed speed in the competion) to have a maximum game advantage.

The game advantage of the kick speed can be defined as the capability to shoot the ball as quickly (ms) over a distance of 2.5m, in order to reduce the response time for the opponent as much as possible.

Step 3: Temporary solution

The kick actuators are operational, and deliver 4.5m/s kick speed. The team can work with this performance provisionally.

Step 4: Root cause analysis

This is a vital step when problem solving, because it will help you identify the actual factors that caused the issue in the first place. More often than not, there are multiple root causes to analyze. Make sure you are considering all potential root causes and addressing them properly. A proper root cause analysis, again involves you actually going to the cause itself instead of simply relying on reports.

The kick actuator is built according an open-source design.

The design is capable to reach 8m/s kick speed according the open-source information.

The actual actuator has some changes w.r.t. the open-source design:

- Top plate is thicker.
- End rods are removed.
- Plunger parts are not connected touching in axial direction.
- More windings of thinner wire is used (Open source: ∅0.63mm – 380-450 turns, Roboteam: ∅0.50mm – 546 turns).
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Step 4: Root cause analysis

Potential (partial) causes:

1. Plunger does not hit the ball on the optimal height. Shall be either on COG or above (to inject energy in the rotation).
2. Plunger COG is not optimal behind the impact point.
3. Plunger absorbs energy in the connection.
4. Ball is more absorbing than reference ball.
5. (Test) springs absorb too much energy. SMALL EFFECT
6. (Test) springs cause friction due to asymmetric force application. SMALL EFFECT
7. End stop hits and brakes Plunger before full energy transfer to the ball has taken place.
8. Inferior magnetic properties of the plunger and yoke (C45).
9. Sub-optimal actuator.
10. Current peak is before/after maximum traction position of the actuator.
11. Losses in electrical circuit.

Step 4: Analysis

The effect is LARGE. Which causes could be LARGE: #7, #8, #10.

#7: Camera?

#8: C45 can be bad magnetically if tempered in some form: https://eshop.walmagmagnetics.com/Page/en-US/10

A reason to use this material could be a high electrical resistivity, but it has no unique performance on this property (0.2-0.25 μΩ*m) .

Test:

- Replace yoke parts by low carbon structural steel ('pisbakken staal').
- Measure K(x,I) with force sensor, and compare to design information.

C45	1,0503	3,20%	Moderate	85%
			Tempered	50%

#10: The current pulse could be wrong in timing.

Tests:

- Vary start position of yoke.
- Various number of turns.
- Measure current profile (stroomtang+scope) vs motion (high speed camera).
- Lumped model.

Step 4: Static kick setup with ball speed measurement

A static test setup with ball speed measurement can provide insight in several (minor) potential causes.

- Height adjustment to test #1 ⇒ Height adjustment.
- Plunger head variation to test #2 ⇒ Variants available.
- Plunger modification to test #3 ⇒ Plunger modified.
- Test with various balls to test #4 ⇒ Various types of balls and/or the real competition ball.
- Spring update to test #5 and #6 ⇒ Correct springs available.
- End stop modification and high speed movie to test #7 ⇒ End stop removed. Smartphone with high speed mode.
- Motion timing with high speed camera for #10 ⇒ Smartphone with high speed mode.
- Some insight in timing optimization by varying the stroke/starting position for #10 (K increases with position) ⇒ Adjustable return position.
- Current pulse measurement?
- Wrong material plunger
- Electrical setup

Step 4: Actuator setup

Measure actuator force as function of current and position.

Force cell (compression against yoke). Range ~20-50N.

Compare to actuator model results (Is a model available?).

Simulation of current pulse (Is a model available?).

Step 4: Root Cause

- Height adjustment to test #1 ⇒ Small effects +-0,1 m/s
- Plunger head variation to test #2 ⇒ Large effects between 0.3 and 1.5 m/s slower. Could be because of earlier hitting the ball and then less energy can be transfered.
- Plunger modification to test #3 ⇒ Not tested
- Test with various balls to test #4 ⇒ Small effects +-0,2 m/s
- Spring update to test #5 and #6 ⇒ Not tested springs were not available
- End stop modification and high speed movie to test #7 ⇒ End stop removed. Smartphone with high speed mode.
- Motion timing with high speed camera for #10 ⇒ Smartphone with high speed mode.
- Some insight in timing optimization by varying the stroke/starting position for #10 (K increases with position) ⇒ Large effects, less energy could be generated when

- Current pulse measurement? ⇒ Not Tested
- Wrong material plunger ⇒ Not Tested
- Electrical setup ⇒ Original setup has 4 times lower capacitance then reference design. Shoots with 4.5 m/s. Increasing to similar capacitance increases kick speed to 6.5m/s +-0.1m/s

Step 5: Find a solution

Step 5: Develop Countermeasures

Once you've established your root causes, you can use that information to develop the countermeasures needed to remove the root causes. Your team should develop as many countermeasures needed to directly address any and all root causes. Once you've developed your countermeasures, you can begin to narrow them down to the most practical and effective based off your target.

- Increase the capacitance of the actuator. This showed an increase of shot power during the root cause analysis.

Step 6: Implement solution

Now that you have developed your countermeasures and narrowed them down, it is time to see them through in a timely manner. Communication is extremely important in step six. You'll want to seek ideas from the team and continue to work back through the PDCA cycle to ensure nothing is being missed along the way. Consider implementing one countermeasure at a time to monitor the effectiveness of each.

You will certainly make mistakes in throughout your problem solving processes, but your persistence is key, especially in step six.

When implementing capacitors with increased capacitance, we managed to shoot with 7.8m/s ~-0.1m/s.

Step 7: Secure solution

Now that you've encountered success along your problem solving path, it is time to set the new processes as the new standard within the organization and share them throughout the organization. It is also a good time to reflect on what you've learned and address any possible unresolved issues or troubles you have along the way. Ignoring unresolved issues will only lead to more problems down the road.

Finally, because you are a true Lean organization who believes continuous improvement never stops, it is time to tackle the next problem. Start the problem solving process over again and continue to work towards perfection.

- Look in combination with testing at the specs of your design. Also try to compare you design with other teams (with maybe a similar design) to see the differences.

Step 8: Congratulate and thank the team

Done