WINCH SYSTEM - 2014
CONTINUOUS IMPROVEMENT
CYBER BLUE – FRC 0234

WINCH DESIGN – V2 (Continuous Improvement) – MARCH 2014

INTRO

Note 1: Please refer to our previous paper "Cyber Blue FRC 234 2014 Winch Design Definition". This is linked from ClickFRC.com, and Chief Delphi, Paper 2935.

Note 2: R1 is the designation for our Prototype Robot - R2 is the designation for our Competition Robot.

During our first regional competition, we began to experience issues with our winch system where the system would not pull the launcher down completely for it to latch and lock. Without the ability to latch and lock the launcher, we could not launch a game piece into the high goal. We had limited testing time on the competition winch (R2) and robot before competition, so we believed it was something unique to the winch system or the robot itself. After attempting some modifications early in the event, we decided to trade the winch for our spare. After making the swap, we disassembled the winch and motor assembly and inspected both, including dis-assembling the reducer gearbox. Nothing seemed out of the norm.

We had a second winch system and had been using it on our (R1) prototype robot. We had not had any issues with it that we knew of, so we believed that installing it would solve the problems. We installed this spare winch and it worked for some matches, then we began to experience the same issues with the spare - but they were more intermittent. During the elimination tournament matches, we lost all ability to retract the launcher and prepare for a "second launch" and had to rely on other robot capabilities to compete. We began troubleshooting between matches, and noticed that the winch motor was tripping a 40 amp breaker when we were trying to lower the launcher. We concluded there was something unique with the (R2) competition robot causing the issues.

Before bagging the robot at the end of the competition, we removed the spare winch system so we could troubleshoot it and determine the root cause of the problem.

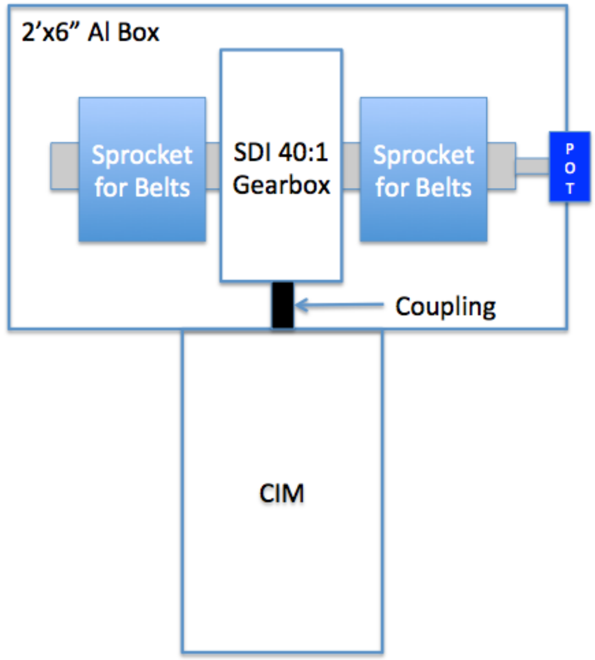
DESIGN INFORMATION

The winch system works by pulling belts around a 2" roller / sprocket to lower the launcher arm. A trunk latch then latches the arm into place and the belts are retracted from the rollers by reversing the motor (a potentiometer controls the stops). When ready to launch, a pneumatic cylinder releases the trunk latch. Surgical tubing connected to the launcher arm and each of the collector arms provides the force and acceleration to score the game piece in the high goal or over the truss.

<u>Basic Components of the Winch System Design</u>

Housing – 2" x 6" x 1/8" wall aluminum "box", 8" long
Motor – 1 CIM
Gearbox – StockDrive 40:1 / 90 degree reducer gearbox
Sprockets – AndyMark (Gates) Previous Kit of Parts 2" Sprockets
Coupling – Machined Steel Coupling with 4 set screws

Below are sketches and pictures of the system.



This sketch shows the general arrangement of the winch system. The CIM is connected to the 40:1 reducer gearbox. Two 2" spools are connected to the output shaft of the gearbox. Two drive belts are connected – one end to one of the 2" spools and one end to the launcher plate. The motor and gearbox spool down to pull the launcher to the locked position. The control system detects when the motor stops and turns off power to the motor. Then using the potentiometer as a limiter, the motor then reverses and the belts are loose in the system. Separate belts stop the launcher at the desired angle to avoid a hard pull on the winch system.

EVALUATION AND DECISION STEPS

After returning from the event, we began to capture information about the robot, the winch and the design to help us solve the problem.

1. PROTOTYPE. Initially we believed the winch on the prototype was not having any issues. After re-thinking the last week of practice time, however, we remembered that we were getting a very short usage time out of the batteries. On some occasions, we would have to stop driving to lower the winch. When this was happening, we had concluded that it was because we were not getting a good charge on the batteries due to the high levels of practice time and the short charge cycle intervals.
    a. DATA. The prototype robot was indicating a potential issue but we did not identify it.
2. POWER. Our power required from the winch was re-validated. Based on the motor and gearbox selection, the CIM should not have been operating at current levels high enough to trip a 40 amp breaker.

    a. DATA. The motor and gearbox had power margin and this was not likely the cause of the issues.
3. PART INSPECTION. We looked at the removed (prototype) gearbox and noticed the bottom of the box was showing signs of deflection and bowing. This was about a 1/16" curvature, and could cause a misalignment with the motor and gearbox input shaft (they were coupled with a 1" long, rigid steel coupling with 4 set screws).
    a. DATA. The curvature could cause misalignment of the motor and gearbox, increasing the load on the motor and driving down efficiency.
4. PART INSPECTION. We looked at the competition gearbox and it did not have the same curvature.
    a. DATA. The curvature issue was not common to both gearbox housings.
5. POTENTIAL CAUSE. The pulling force required to lower the launcher could be high enough that the reducer gearbox was "lifting" and causing a misalignment of the motor to gearbox shaft, increasing the load.
6. POTENTIAL CAUSE. The system was designed so that rubber belts stopped the arm at the end of the launch and prevented the winch belts from absorbing the shock. The winch belts were not as long on the competition robot as on the prototype, and if they were not retracted all of the way it out it was possible that the winch sprockets and gearbox were absorbing some of the shock. This could increase the misalignment.
7. ELECTRICAL TEST. To determine the load on the motors, we conducted electrical tests to determine the amp draw of the motors as installed and connected.
    a. R1 Winch – 10 amp Steady, 19 amp Peak (only load is gearbox)
    b. R2 Winch – 8.5 amp Steady, 14 amp Peak (only load is gearbox)
    c. R2 Motor Alone – 2.5 amp Steady, 3 amp Peak (no load)
8. DISASSEMBLY. We kept R2 intact, but disassembled the assembly from R1 that had been on our competition robot during the elimination tournament. We noted a horizontal shaft misalignment between the CIM output shaft and the reducer gearbox input shaft.
9. DISCUSSIONS. Through discussions within the team and with other FRC mentors and engineers, we came to a few conclusions and potential solutions.
    a. Misalignment, either from the initial assembly of the parts or from an impact-type of load from the launcher action was creating an excessive side load on the CIM shaft to CIM bearing. *(Note: This bearing is actually a bronze bushing.)*
    b. A method to isolate the CIM shaft from the reducer gearbox input shaft was a strong candidate to solve the issues.
    c. Many teams avoid a direct coupling of the CIM output to a load to avoid side loading the output bearing.
    d. Since the winch and launcher system had worked very well though most of the build season and prototype robot driving and practicing, a small, simple solution might be all that was needed.

10. DESIGN OPTIONS
    a. Incorporate a flexible coupling between the CIM output shaft and the reducer gearbox to isolate the CIM shaft.
    b. Create an off-set gearbox to allow the CIM to be separated from the driveshaft connecting to the reducer gearbox.
    c. Change the rubber belts used for retracting the launcher to nylon strapping material possibly reducing the load on the gearbox.
    d. Consider addition of a second CIM to increase the power to the winch system.
11. TESTING
    a. A flex coupling was used in the connection from the CIM to the reducer gearbox. This coupling is McMaster-Carr PN 9861T51 and is rated for 25 in-lbs torque, slightly above the stall torque of the CIM. This design was installed, tested on the tabletop, and tested for electrical load and subjected to 2 days of driver practice at a local practice field. *(Note: This coupling was used to test the design idea since it was a near direct size replacement for the rigid coupling that was installed. If this solution was successful, we knew we would need to make small adjustments to the assembly to allow for an increased capacity coupling.)*
        i. Electrical load on this design, uninstalled, was 6.3 amps steady and 6.8 amps peak.
        ii. Electrical load on this design, installed, actually pulling down the launcher, was 6.5 amps steady with a start up peak of 14 amps.
        iii. This design was tested for about 5 – 6 hours of robot time and on the order of 100 – 150 cycles on the winch system.
        iv. This design is quiet, fast and appears to be durable and repeatable.
    b. An offset gearbox was designed, fabricated and installed on the same winch system. This gearbox used 2 AM 35 tooth gears (PN AM 2460) in a 1" x 2" aluminum rectangle tube housing. The gearbox was a 1:1 design to not impact speed or torque of the winch.
        i. Electrical load on this design, uninstalled, was 5.0 amps Steady and 6 amps Peak.
        ii. Electrical load on this design, installed, actually pulling down the launcher, was 7 amps Steady and 12 amps Peak.
        iii. Also using a flex coupling, this design change was tested for about 4 hours of robot time and on the order of 75 – 100 cycles on the winch system.
        iv. This design is quiet, fast and appears to be durable and repeatable.

DECISION AND RATIONALE

12. DECISION
    a. Based on our interpretation of the data and what we believe to have been the issues with the winch system at our first event, we are incorporating the following changes for our next event. This design will continue to be tested on the prototype robot.
        i. Improved alignment between CIM output and reduction gearbox input shaft.

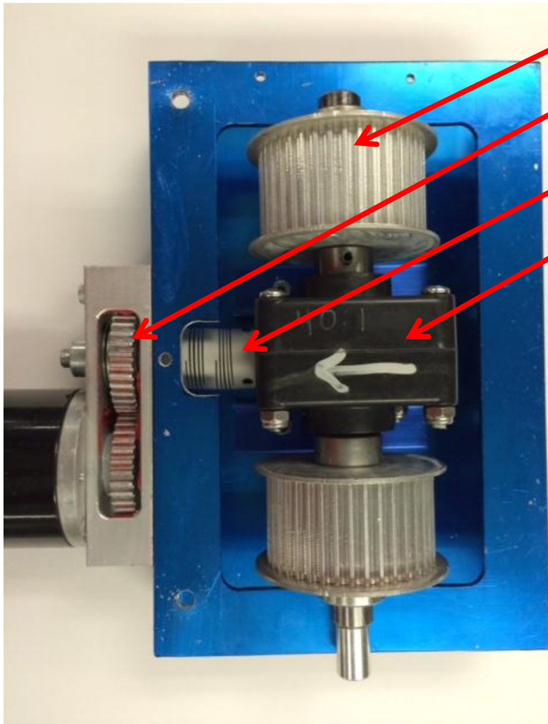
ii. Addition of a Flex Coupling for the connection (McMaster-Carr PN 986T71)
   1. This coupling has a torque rating of 63 in-lbs.
   2. This coupling is slightly longer and larger diameter than the part that was tested.

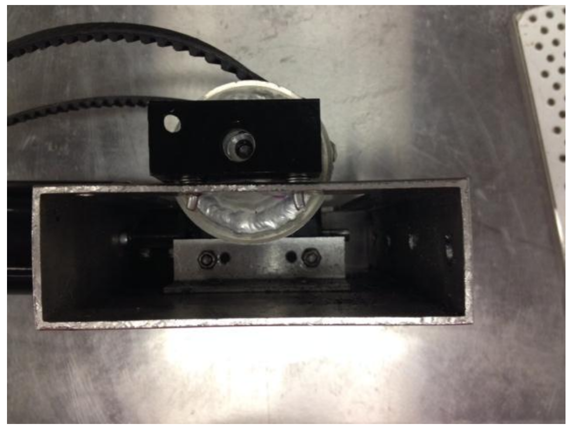
iii. Increased length retraction belts for the winch to assure no load is transferred into the gearbox sprockets at launch.

13. RATIONALE
    a. The flex coupling addresses much of the concern with any offset or misalignment.
    b. The flex coupling is rated to 3x the stall torque of the CIM.
       i. CIM = 21 in-lbs at Stall, Flex Coupling rating = 63 in-lbs)
    c. The flex coupling is a simple replacement for the existing rigid coupling.
    d. The flex coupling option is weight-neutral.
    e. The off-set gearbox provides just a small additional improvement by isolating the motor shaft.
    f. The off-set gearbox adds failure points in 2 gears, two keyed shafts and 2 bearings as well as the mounting bolts.
    g. The off-set gearboxes add approximately 1.5 pounds to the robot.
       i. We had only ½ pound weight margin at Crossroads, so adding this gearbox would mean removal of another component.
    h. The off-set gearboxes can be built and ready to install and quickly added if needed as a back-up option.

DATA TABLE

Winch System	Configration	AMPS - SS	AMPS - Peak	Notes
R1	From Comp. Assemble. No Belts	10	19	This assembly had several practice hours and hundreds of cycles and was also used in most of the regional competition
R2	From Comp. Assembled. No Belts	8.5	14	This assembly had limited practice hours and cycles and was used for a portion of the regional competition
R2	CIM Only	2.5	3	
R1	Flex Coupling. Assembled. No Belts	6.3	6	Almost 40% reduction in load (from original R1) just from coupling change
R1	Flex Coupling, Assembled. Installed with Belts	6.5	14	Almost 40% reduction in load. Peak as winch starts.
R2	Offset gearbox + Flex Coupling. Assembled. No Belts	5	10	Almost 40 percent reduction in load (from original R2) with combination
R2	Offset gearbox + Flex Coupling. Assembled. Installed with Belts.	7	12	Difficulty obtaining data due to speed and test hardware.
R2	Flex Coupling. Assembled. Installed in Comp	TBD	TBD	Competition configuration to be collected at event.

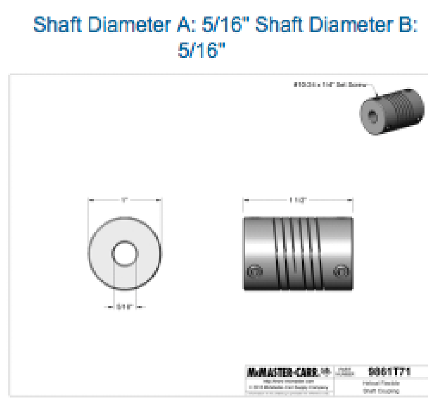




Option 2 – Offset Gearbox and Flex Coupling

R1 Original Assembly – Major Components

SDI – 40:1 Reducer Gearbox



McMaster-Carr FLEX Coupling

RESULTS

The design change decision was successful. The change to incorporate the flex coupling was completed quickly at Queen City and the winch and system performed throughout the competition without issue.