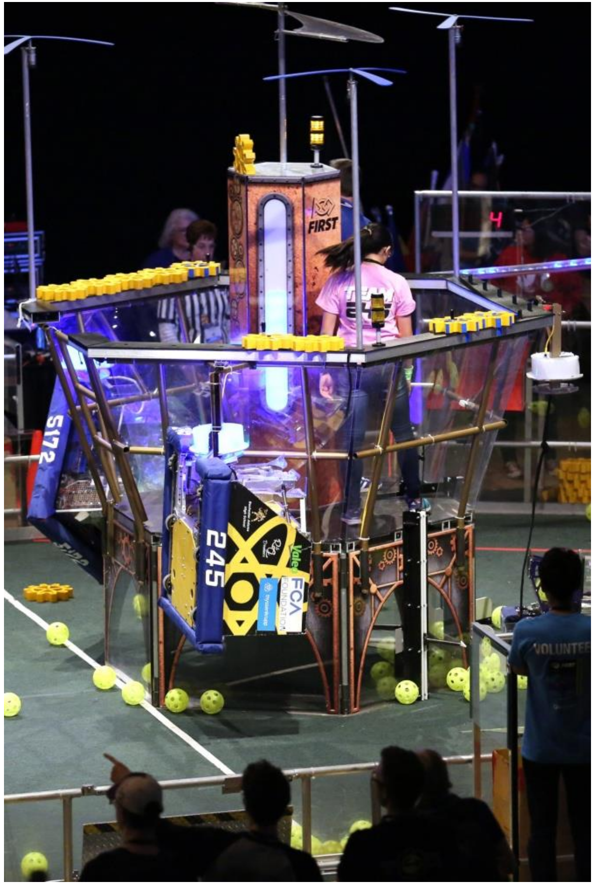
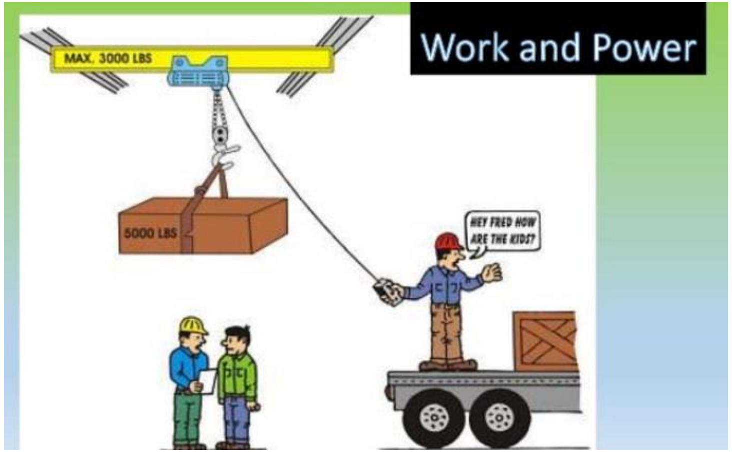
Motor Application to Perform Climbing Task



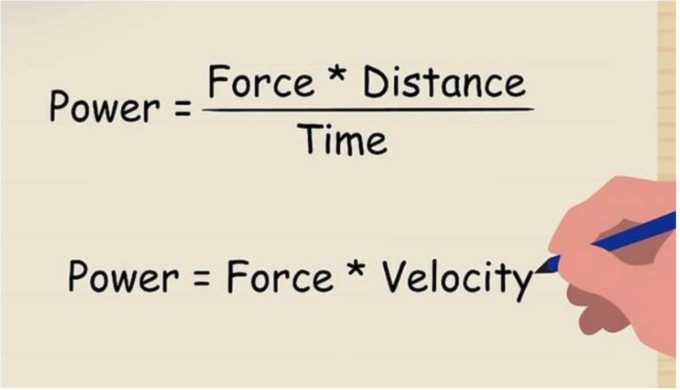
Typical Climb or Lift Requirements

- **Climb Requirement:**
  - Height: 60 Inches (1.524 M)
  - Weight: 150 Lbm (68 Kg)
  - Time: 6 Seconds
- **Lift Requirement:**
  - Height: 48 Inches (1.219 M)
  - Weight: 30 Lbm (13.61 Kg)
  - Time: 3 Seconds

- **Must identify motor and gear ratio options that will achieve these goals keeping within limitations:**
  - 40 Amp Max Current per motor
  - Minimum Mass
  - Minimum Packaging

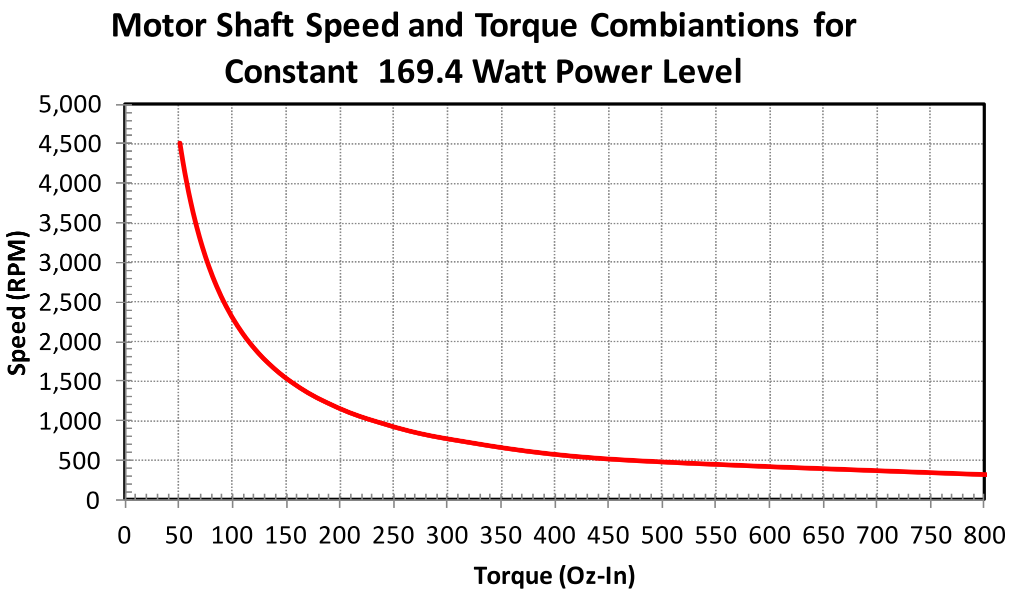


Power Requirement



- **Power requirement for a lift is easily calculated**
  - **Power = Force x Distance ÷ Time Required**
  - **Height: 60 Inches (1.524 M)**
  - **Weight: 150 Lbm (68 Kg)**
  - **Time: 6 Seconds**
  - **Force: 68 Kg x 9.81 M/Sec^2 = 667.08 N**
  - **Power (Watts) = F x D / Sec = 667.08 x 1.524 / 6 = 169.4 Watts for Climb example**
  - **Power for Lift example is 13.61 x 9.81 x 1.219 / 3 = 54.3 Watts for Lift example**
- **Power requirement by itself is not sufficient to identify motor and transmission combinations**
  - **Almost any motor can provide needed power for any combination of shaft speed and torque output**
  - **Need to identify motor and gear ratio to make an informed design selection**

Speed and Torque vs Power



169.4 Watt power output occurs at any location on the curve

What is the correct speed and Torque operating point to achieve desired Climb performance Targets ??

What Motor and Gear Ratio Combination will give us desired Results ??

Factors Required to Size Motor & Gear Ratio Selection

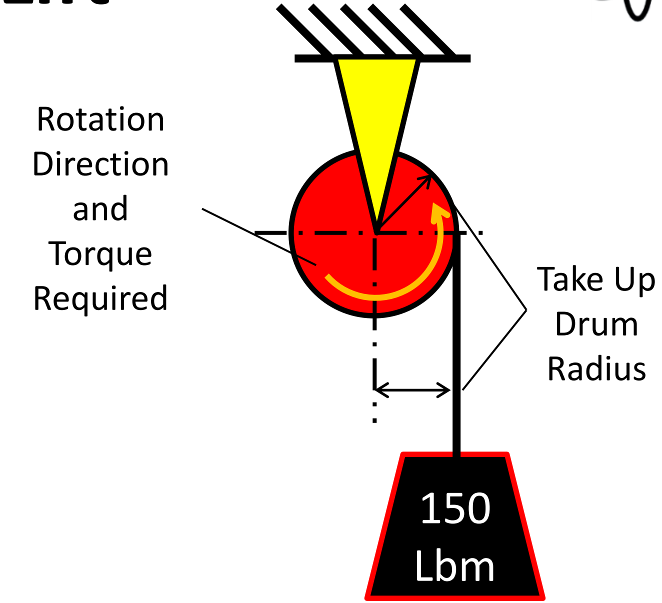
- These factors needed to begin selection of motor and gear ratio selection
  - Lift Force
  - Time to complete lift
  - Distance of lift
  - Torque required:
    - Radius where force is applied
    - Typically is radius of take up spool, or radius of gear for chain drive on arm or lift mechanism
  - Max Current limit for motor circuit
  - Working voltage for motor
  - Power transmission efficiency for gear train and/or lift mechanism
  - Limitations on available gear ratios
    - Available transmission gear ratio's for parts that will package
    - Sprocket diameter ratio for chain drive that will fit into package

RED = Design Assumptions or System Limitations

BLUE = Design Selection Variables

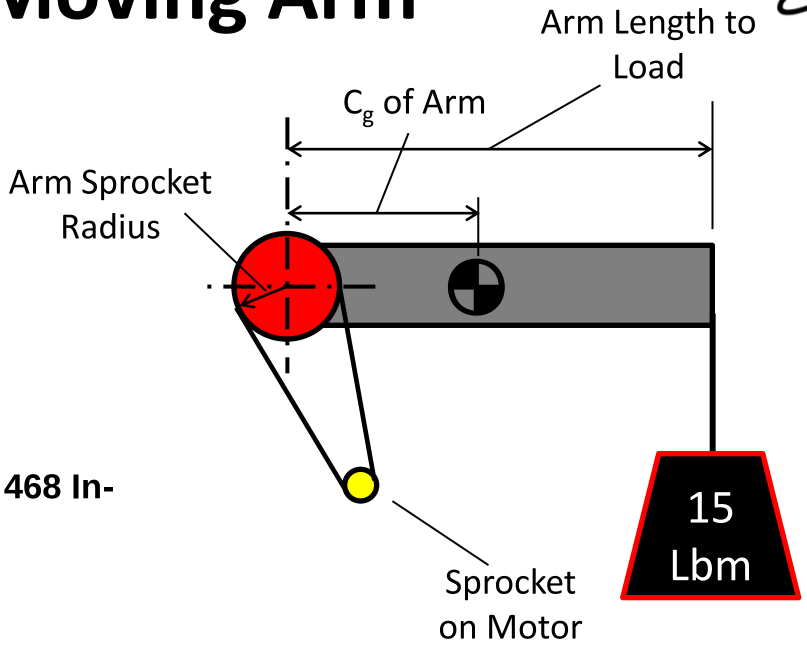
Torque Requirement: Dead Lift

- **Torque results from force (Weight) needed and geometry**
  - ➢ **Weight/Force = 150 Lb**
  - ➢ **Radius of Take-Up Drum: 3 Inches**
    - **Need to account for effective changes in take up radius as cord wraps on previous rows of cable as more cord is would on drum or reel**
    - **Ending radius may be larger that starting radius that will increase torque**
    - **Must account for this if cord will double wrap on reel**
  - ➢ **Required Torque: 150 Lb x 3 Inch = 450 Inch-Lb**
    - **450 Inch-Lb = x 16 Oz/Lb = 7,200 Oz-Inch**



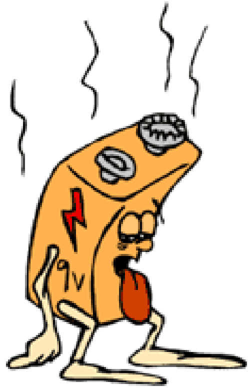
Torque Requirement: Moving Arm

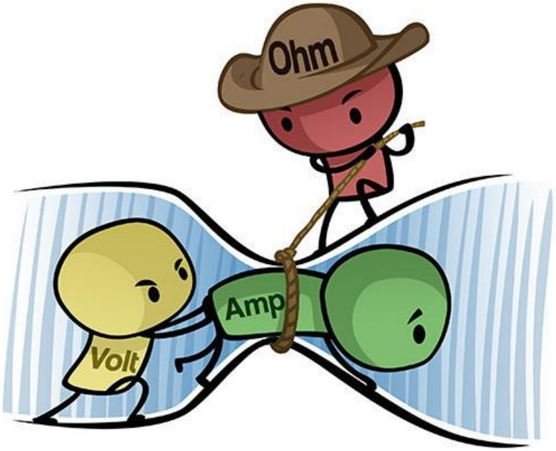
- **Torque results from force (Weight) needed and geometry**
  - **Weight/Force = 15 Lbm**
  - **Arm Length = 28 Inch**
  - **Arm Cg distance to Sprocket = 12 In**
  - **Arm Weight = 4 Lbm**
  - **Torque on Arm = 4 Lb x 12 Inch + 15 Lb x 28 Inch = 468 In-Lb**
  - **Radius on Arm Sprocket = 4 In**
  - **Force on Chain = 468 lb-Lb / 4 in = 117 Lb**
  - **Radius of motor sprocket = 1.5 Inch**
  - **Required Torque at Motor: 117 Lb x 1.5 Inch = 175.5 In-Lb or 2,808 Oz-In**



Voltage to Assume:

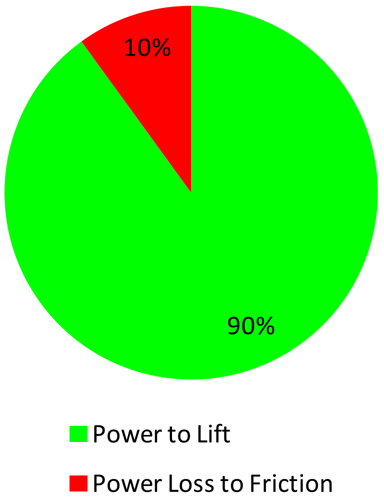
- **Input Voltage at motor terminals for an End of match climb may not be baseline 12 Volts**
  - **Battery could be running low after significant Amp-Second load**
  - **High current draw through motor supply wires will suffer voltage loss due to line resistance**
    - **Ohm's Law: Voltage drop = Current x Line resistance**
  - **Should use voltage other than 12.0 Nominal battery voltage for motor performance for climbing calculations**
    - **Safer to assume 11.0 Input Volts at motor terminal for end of match event**





Power Losses within Mechanism:

- **Power transmission through gear train and friction within the mechanism is not 100% efficient**
  - **Will have different levels of power transmission losses in different components**
  - **Efficiency based losses have impact of increasing torque requirement**
    - **Speed remains the same, but efficiency losses will drive higher torque**
  - **Example:**
    - **Ideal calculations indicate 3,600 Oz-In to lift 150 Lb weight**
    - **Assume 90% power transmission efficiency**
    - **Required Motor torque is: 3,600 / 0.90 = 4,000 Oz-In at nominal speed point**

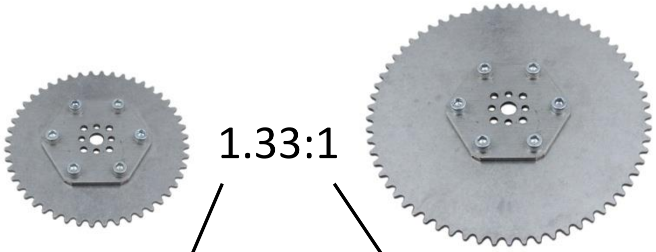


Available Transmission/Sprocket Gear Ratios:

- **Motor transmissions have limited availability for gear ratios**
  - **Often will not have access to ideal ratio needed from calculations**
  - **Must also ensure transmission is capable of handling required power levels**
    - **Will not fail under repeated loading**
- **Sprocket ratio for chain driven elements can also be used to impact gear ratio**
  - **Gear ratio impact is driven by diameter ratio**
  - **Need to make sure sprockets of needed diameter are availabl**
- **Ensure packaging room is available for Motor, Transmission, Sprocket and chain run needed to complete end gear ratio**

63:1

4:1



1.33:1

48 Tooth

64 Tooth

Torque Limit for Motor Transmissions:

- **Motor transmissions have limits for Max Operating Torque**
  - **Operation at torque levels above Max limits risk stripping gears during operation**
  - **Must ensure torque load is consistent with limits for transmissions**
  - **Transmissions usually identify Max torque limit**
  - **VersaPlanetary gear systems have lower Max torque limits are best for driving belt systems or wheels for intake arms**
  - **Larger, more durable transmissions with higher torque limits are better for climbing or driving large arm devices**

		Stage 2					
Motor	**Stage 1**	3:1	4:1	5:1	7:1	9:1	10:1
Mini CIM	3:1	9	12	15	21	27	30
	4:1	12	16	20	28	36	40
	5:1	15	20	25	35	45	50
	7:1	21	28	35	49	63	70
	9:1	27	36	45	63	81	90
	10:1	30	40	50	70	90	100
CIM	3:1	9	12	15	21	27	30
	4:1	12	16	20	28	36	40
	5:1	15	20	25	35	45	50
	7:1	21	28	35	49	63	70
	9:1	27	36	45	63	81	90
	10:1	30	40	50	70	90	100

Application limit for VersaPlanetary Gearbox based on Max operating torque limits

Determine Speed Needed for Take Up Spool/Drum

Example requires:

- **Climb 60 Inches in 6 Seconds with a 3 Inch Diameter Take Up Spool**
  - **Assume width of spool can accommodate 60” of cable at same radius without wrapping cable on previous row**
- **Speed Calculation:**
  - **Circumference of spool: π x 3 = 9.42 Inch**
  - **Revolutions to take up 60 Inch = 6.37 Revolutions**
  - **Required spool speed = 6.37 Rev / 6 sec x 60 Sec/Min = 63.7 RPM**

Speed and Torque Required at Take Up Spool

Requirement:

- Need 4,000 Oz-In at 63.7 RPM or 188.5 Watts
  - Torque losses due to 90% Power transmission efficiency are accounted for

Motor Requirements:

- Select motor and Gear ratio that will:
  - Provide 188.5 Watts at speed greater than 63.7 RPM at 11.0 Motor volts and keeping within 40 Amp Max current draw limitation

Motor Performance at Target Power Level

- **188.5 Watt power out for full size CIM motor at 11 Volts occurs at (Direct from 11.0 Volt Motor Curve)**
  - **66.3 Oz-In**
  - **3,842 RPM**
  - **27.86 Amps**
- **Needed Gear Ratio:**
  - **3,842 / 63.7 = 60.3:1 ratio**
  - **Will climb in 6 Seconds at 27.86 Amps with 60:1 ratio**
    - **Lower Speed reduction ratio will climb faster but will increase current**

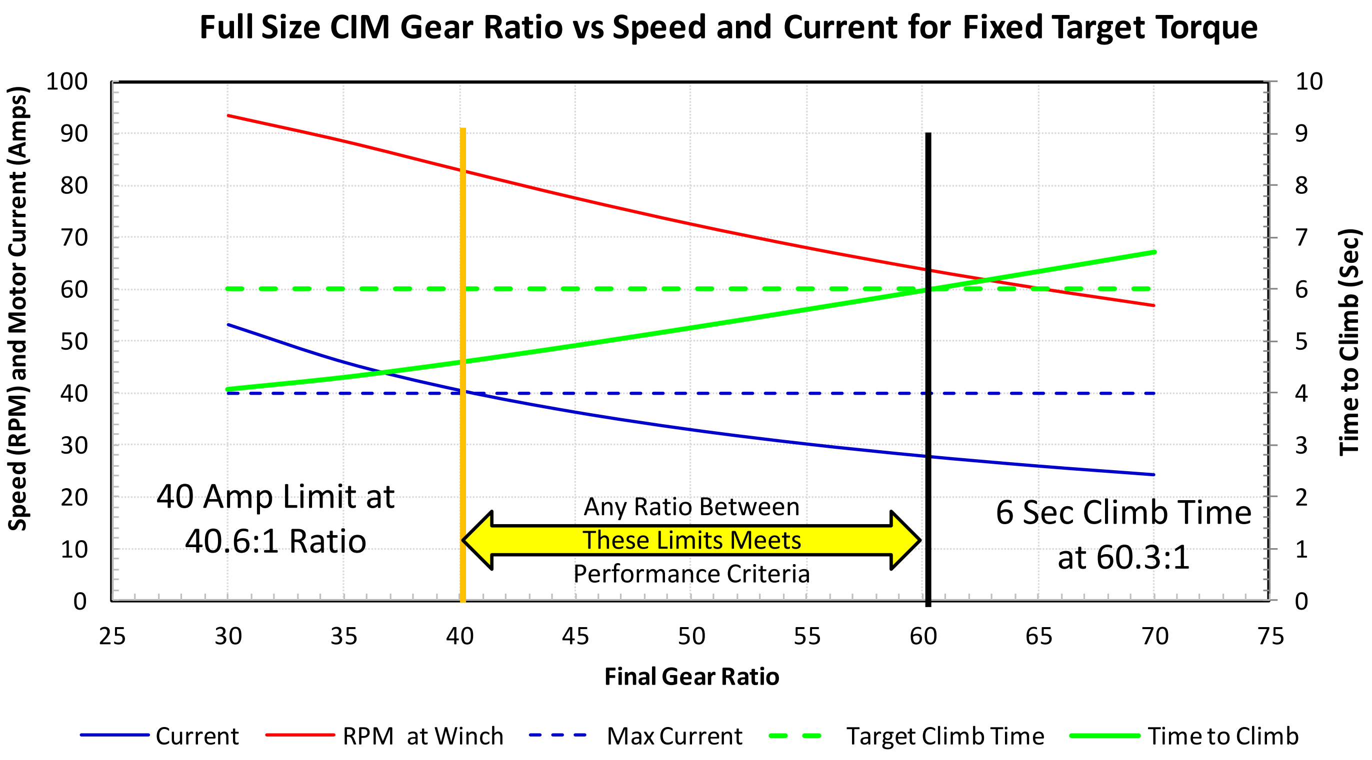
How Fast Can Climb Be Completed keeping a 40 Amp Limit with Full Size CIM? And What is Needed Gear Ratio??

- **40 Amps at 11 Volts occurs at 3,347 RPM and 243.4 Watts (Direct from 11.0 Volt Motor Curve)**
  - **Apply 90% Power Transmission efficiency factor = 219.1 Watts at Take Up Spool**
  - **Time for climb at 219.06 Watts: 667.08 N x 1.524 M / 219.06 Watts = 4.64 Sec**
  - **6.37 Rev in 4.64 Sec = 82.37 RPM**
  - **Needed Gear Ratio = 3,347 / 82.37 = 40.6:1**
- **Full Size CIM can achieve needed climb with 40 Amps and 40.6:1 Gear Ratio**
  - **Not desired to design system at 40 Amp Limit**

Design Calculation with 49:1 Transmission

- **49:1 transmission is available for the CIM Motor and is correct for use in this power range: What is performance with 49:1 Gear Ratio:**
  - **This requires overlay of curves or an iterative calculation within Excel working with motor curves and torque load for different speeds**
- **Performance with 49:1 Gear ratio:**
  - **33.7 Amps and 5.19 Seconds time to climb**
- **What would time be with 2xMotors each working through a 49:1 transmission:**
  - **Run calculations with each motor taking 75 Lb of load**
  - **4.41 Seconds with 36.4 Total Amp Current draw**

Performance vs Gear Ratio for Single CIM @11V



ADAMBOTS Team 245