Team #20

DIY ExoSkeleton Testbench

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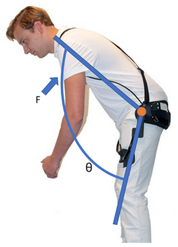
Mentor/Client: Ralph Mungua/Milton Aguirre

Customer Background

Professor Milton Aguirre, an assistant professor in MET, has formed an international team of student engineers to create a Do-It-Yourself Exoskeleton. The DiY Exo uses an elastic band to store and release kinetic energy from the lower body (thigh) to the upper torso (chest).



Problem Statement / Scope of Work

Our team was tasked with designing and building a testing device for our client's DIY exoskeleton. This device would measure the applied force from the exoskeleton based on angular displacement of the human bending motion. The purpose is to aid in the development of exoskeleton technology by analyzing the performance of the energy storage mechanism of the DIY exoskeleton.

Requirements

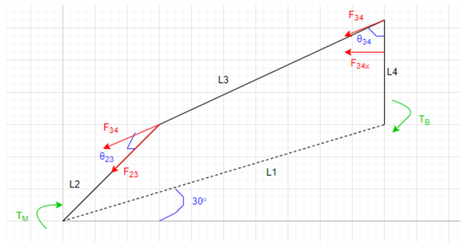
Req. #	Design Requirements	Design Targets	Validation
	Rationale		
1	Test bench is transportable	- Test bench width < 28 inches - Test bench height <80 inches - Test bench weight <150 lbs.	Measure height, width, and weight of the bench
	Test bench must be moveable between lab locations		
2	Test bench resembles a human	- Rotational velocity: 12-17 rpm - Test bench range of motion: 120° - Torso of test bench fits exoskeleton	Measure range of motion, speed of test bench movements, exoskeleton fits securely
	Test bench should look and move similarly to a human		
3	The cyclical condition of the test bench is controllable	- Control # of revolutions in cycle - Starts & stops at standing position (0°)	Trial run to see if rocker linkage stops where it began
	The client wants to enter the # of cycles, and for the bench to start & stop in standing position (0°)		
4	Force & displacement data is captured	- Applied forces acting on torso are captured - Rotational displacement of torso is captured	Trial run to test if data is being acquired
	Client wants to analyze the relationship between force and displacement throughout range of motion		
5	Data is displayed digitally, in real time	- Data displayed within 1 minute of cycle reading - Digitally display sensor data on one graph: displacement on x-axis, force on y-axis	Trial run to test if data is displayed in sufficient time
	Client expects data to be represented in a timely manner		
6	Test bench does not tip over during testing	Design bench so center of gravity is below the pivot point (hip joint)	Weigh the torso and leg section of test bench
	It is important that the bench assembly is stable, so it is safe during use & transportation		

Requirements Matrix

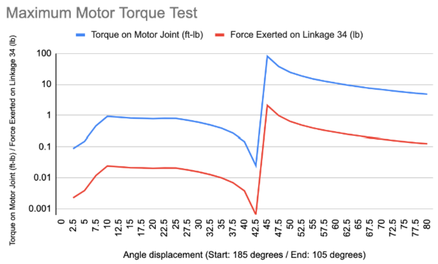
Experimentation & Concepts

Poster Board Experiment:

- Analytical and experimental methods compared four-bar linkage position analyses (R1 + R2 + R3 +R4 = 0)

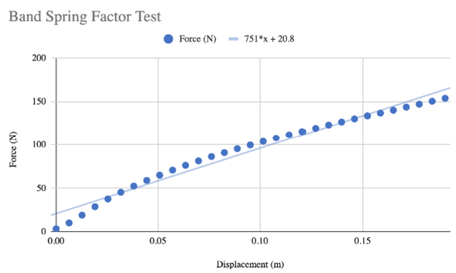


Free Body Diagram



Maximum Motor Torque Test

Testing the torque capacity of the motor was essential to ensure it would have sufficient power to stretch the band through the test bench's full range of motion.



Band Spring Factor Test

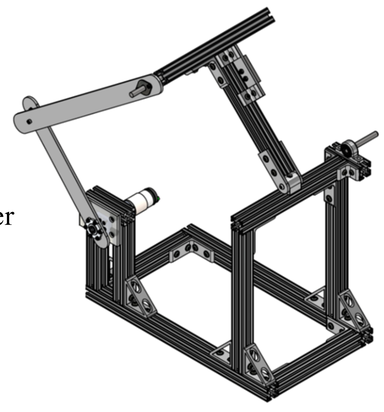
Testing the spring factor of the band allowed us to calculate forces throughout the system and determine what size motor is required to stretch the band to its full potential.

Final Design

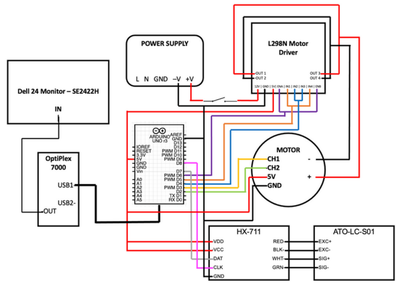
(Your paragraph text)

Subsystems and Components:

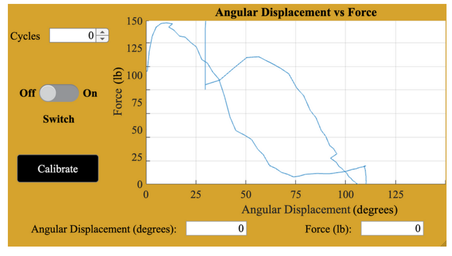
- Four-bar Linkage Mechanism
  - Aluminum Flat Bars
  - Flange-Mount Ball Bearings
- Drive System and Sensors
  - PG977 Gearmotor with Encoder
  - Strain Gauge Load Cell
  - Arduino Uno Rev3
- HMI/Control System
  - Matlab App Designer



Test Bench Design



System Schematic

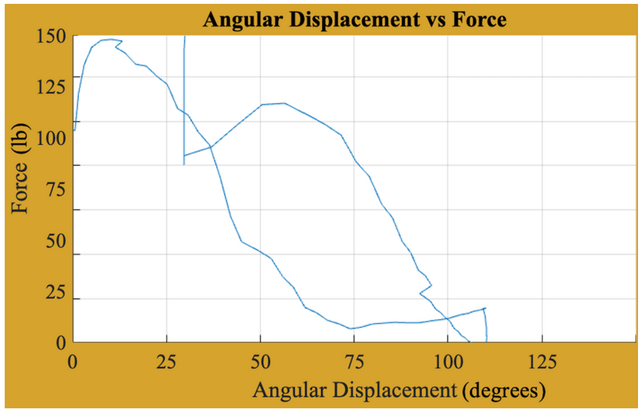


HMI Display

FMEA

FAILURE ANALYSIS (STEP 4)				RISK ANALYSIS (STEP 5)				
1. Failure Effects (FE) to the next Higher Level Element and/or Vehicle End	Severity (S) of FE	2. Failure Mode (FM) of the Focus Element	3. Failure Cause (FC) of the Next Lower Element or Characteristic	Current Prevention Control (PC) of FC	Occurrence (O) of FC	Current Detection Controls (DC) of FC or FM	Detection (D) of FC/FM	DFMEA AP
Motor would run at too high of a speed	10	Linkage Breaks	Inadequate strength of linkages material	FEA Analysis assures adequate strength of linkages	3	Material specifciations match the load being applied	2	60
Test bench will not rotate full ROM	7	Linkage Bends	Inadequate strength of linkages material	FEA Analysis assures adequate strength of linkages	3	Material specifciations match the load being applied	2	42
Linkage is not controlled by joint	9	Joint detatches	Inadeuqate strength of joint material or attachemnt to linkages	FEA Analysis assures the strength of the joints to the linkage.	3	Material specifications match the joint specifications being applied.	2	54
Band allows exo skeleton to function. Band Isn't too loose that	4	Band Snaps	Inadequate thickness and length	FEA Anlaysis assures band is strong and small/long enough to withstand force being applied	2	Material Specifications match the force applied	2	16
Motor deataches can't be used again until	6	Poor assembly	Bolts and screws are't strong enough	FEA Analysis assures bolts and screws are strong enough	4	Material specifications match the motor requirements.	2	48
Test bench does not match the speed of the human	5	Inaccurate data	Motor requirement do not match the application	FEA Anlaysis assures the motor runs at the desired speed	3	Motor speed specifications match the application speed	2	30

Testing



Testing Data

The graph above shows how the force fluctuates as the system bends forward. The two peaks indicate the bending position where the Exoskeleton is applying the most force.