P09023 Air Muscle Artificial Limb: Next Generation

Test Plans & Test Results

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MSD I: WKS 8-10 TEST PLAN

*Note to Teams: The **Test Plan** is due at the completion of Senior Design 1 (Week 10) and is inclusive of both the systems specifications and specifications within and between the major sub-systems. Particular attention should be paid to the interfaces between the sub-systems since different team members may be testing each. Since the chosen technologies and associated specifications are complete at the end of Senior Design 1, the test needs should be easily comprehended and documented below.*

1.1. Introduction; Overview; Summary; Purpose; History, etc.

This is a second generation project aimed at developing a scalable robotic hand. The first generation created three fingers with complete range of motion. The hand could be scaled down for microsurgery, and it could also be scaled up for deep sea maintenance applications.

1.2. Project Description; Sub-Systems/ Critical Components Being Tested

The design consists of two major components, mechanical and controls. The mechanical subsystem consists of the hand itself and the mechanical operation of the air muscles. The controls system consists of the computer interface, computer hardware, and air muscle control. Figure 1 shows a diagram of the system.

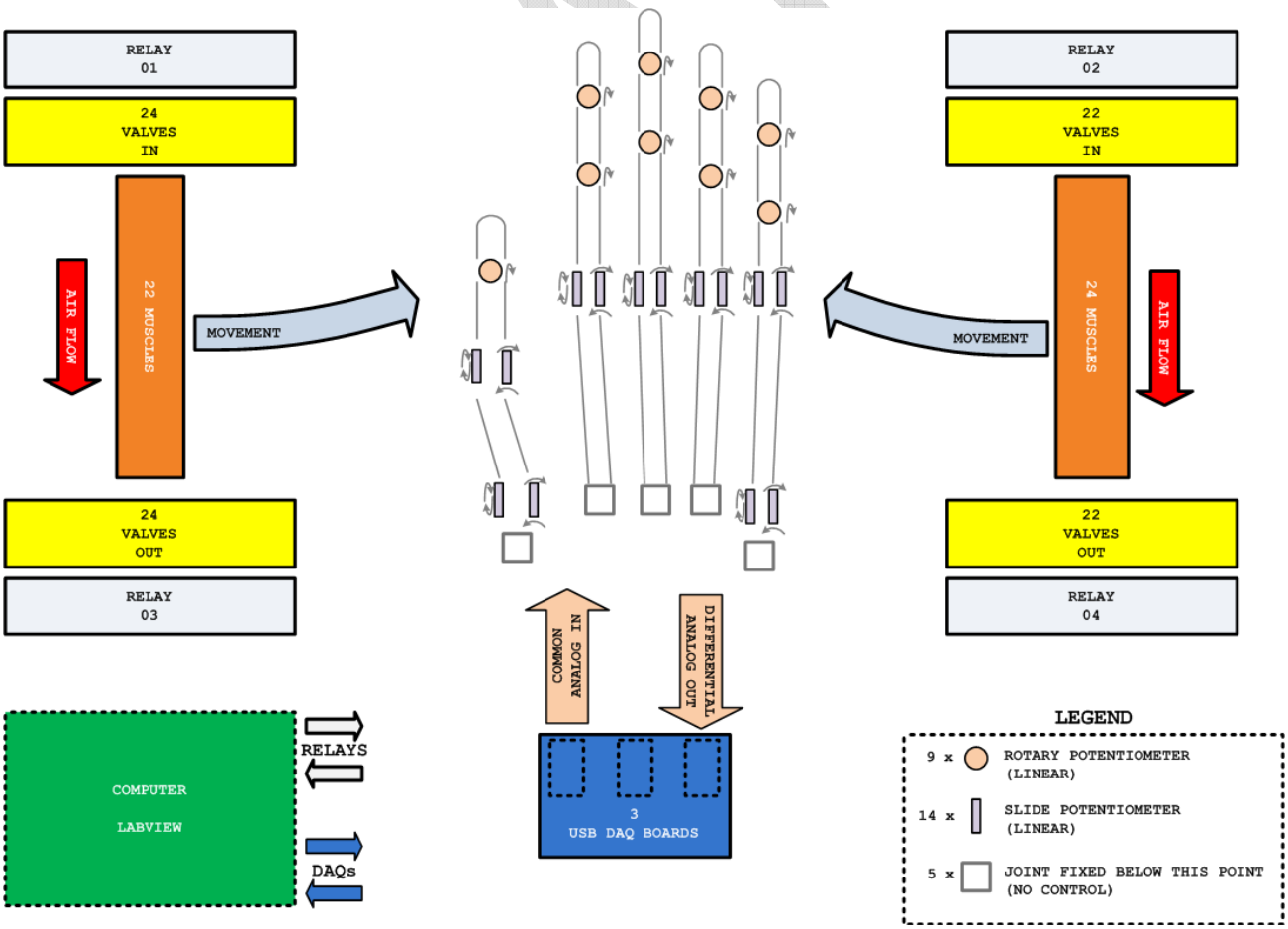

Figure 1: Block Diagram

The mechanical team will be responsible for carrying out all mechanical subsystem testing, and the controls team will be carrying out the controls testing. The specific items to be tested are lined out below.

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1.2.1. Mechanical

The mechanical testing will involve testing air muscles to verify data from P08023 and P08024. Reliability testing will also be conducted to determine lifecycle and develop a periodic maintenance schedule.

1.2.2. Controls

The controls team will be responsible for testing valve timing as well as testing anything related to the electromechanical control of the hand. For a complete description, see section 1.4.2.

1.3. Approval; Guide, Sponsor

Approved by:

Team Members

Jim Breunig – Team Lead - Mechanical Engineer
Eva Ames – Mechanical Engineer
Tommy Keane – Electrical Engineer
Alex Bird – Mechanical Engineer
Kelly Scarbrough – Mechanical Engineer
Christopher Music – Industrial Engineer

Guide – Dr. Lamkin Kennard

Sponsor – RIT

1.4. Test Strategy

1.4.1. Product Specifications, Block Diagram, and Pass/ Fail Criteria

Figure 2 and figure 3 below show the design specifications used during concept development. These are the specifications that must be tested.

P09023 DESIGN METRICS — **CUSTOMER NEEDS**

	METRIC	QUALITATIVE	QUANTITATIVE	UNITS	IMPORTANCE	RISK OF FAILURE	SAFETY	SCALABLE	ADD ALL FINGERS AND THUMB	OPTIMIZE MECHANICS	OPTIMIZE CONTROLS	ROBUST	EASY TO USE	EXTENSIBLE	
1	Air Muscle Pressure	Maximum Required Pressure	70	PSI	HIGH	VERY LOW	X	X	X	X	X	X		X	1
2	Air Muscle Air Flow	Maximum Available Flow Rate	TBD	cc/s	MEDIUM	MEDIUM	X	X	X	X	X	X		X	2
3	Air Muscle Force	Maximum Load Value	TBD	N	HIGH	MEDIUM	X	X	X	X	X	X		X	3
4	Repairable	Maximum Time to Fix Muscle	30	min	HIGH	LOW	X		X	X		X	X	X	4
5	DIP Joint DOF	Range Of Human Motion	SEE TABLE	deg	VERY HIGH	MEDIUM	X	X	X	X	X	X		X	5
6	PIP Joint DOF	Range Of Human Motion	SEE TABLE	deg	VERY HIGH	MEDIUM	X	X	X	X	X	X		X	6
7	MCP Joint DOF	Range Of Human Motion	SEE TABLE	deg	VERY HIGH	MEDIUM	X	X	X	X	X	X		X	7
8	Thumb IP Joint DOF	Range Of Human Motion	SEE TABLE	deg	VERY HIGH	MEDIUM	X	X	X	X	X	X		X	8
9	Thumb Basal Joint DOF	Range Of Human Motion	SEE TABLE	deg	VERY HIGH	MEDIUM	X	X	X	X	X	X		X	9
10	CMC Joint DOF	Range Of Human Motion	SEE TABLE	deg	VERY HIGH	MEDIUM	X	X			X			X	10
11	Valve Opening Time	LabView Signal to Air Flow	12	ms	HIGH	VERY LOW	X	X			X		X	X	11
12	Valve Closing Time	LabView Signal to Air Stop	12	ms	HIGH	VERY LOW	X	X			X		X	X	12
13	Air Muscle Fill Time	Delay From Empty to Full	1.00	s	MEDIUM	LOW	X	X			X		X	X	13
14	Air Muscle Leakage	Amount of Air Lost at SS	1.00	%/s	HIGH	MEDIUM	X	X			X		X	X	14
15	Air Muscle Vent Time	Delay From Full to Empty	1.00	s	MEDIUM	LOW	X	X			X		X	X	15
16	Position Control	Settling Time	< 20.00	ms	HIGH	MEDIUM	X	X			X	X	X	X	16
17	System Operation Time	Command to Steady State	< 2.00	s	LOW	LOW	X	X			X		X	X	17

Figure 2: Product Specifications

Phalangeal Range of Motion (Degrees)

Joint Name	Abbreviation	Direction	First	Middle	Ring	Pinky	Thumb
Distal Interphalangeal Joint	DIP	Flexion	75	85	75	80	90
		Hyperextension	10	15	10	10	30
Proximal Interphalangeal Joint	PIP	Flexion	120	115	115	115	
		Hyperextension	20	20	20	15	
Metacarpophalangeal Joint	MCP	Flexion	85	90	90	95	
		Hyperextension	30	30	25	25	
		Abduction	30	30	15	25	
		Adduction	25	20	20	30	
Basal Joint		Flexion					45
		Hyperextension					0

Figure 3: Phalangeal Directions of Freedom

1.4.2. Functions (hardware) and Features (software, customer needs)

Specification	Description	Component Embodying the Specification
Maximum Required Pressure	The Pressure Delivered to Each Air Muscle is Critical	Phalangeal Articulation
Maximum Available Airflow	The airflow delivered to each air muscle must be controlled used solenoid valves	Phalangeal Articulation
Maximum Load Value	The fingers are going to be able to exert a maximum force based on air muscles.	Hand Grip Force
Maximum Time to Fill Air Muscle	The valves will be opened and closed rapidly to control how much air goes into the air muscles. The time to fill the air muscles will give us an idea of how much delay time is allowable.	Overall Hand Articulation and Speed
Range of Motion	The range of motion is the angle of the bone on the proximal side of the joint with respect to the bone on the distal side of the join.	All Phalanges and Metacarpals
Labview Signal to Airflow	The signal from the computer to the valve telling the valve to open will have an associated delay time.	Articulation
Labview Signal to Air Stop	The signal from the computer to the valve telling the valve to close will have an associated delay time.	Articulation
Delay from Empty to Full	The time required to fill the muscle plus the amount of time delays in the system.	Articulation
Amount of Air Lost at Steady State	The air muscles will leak causing the hand to relax over time.	Robust
Delay from Full to Empty	The amount of time it takes to empty the air muscles including all time delays.	Articulation
Settling Time	The amount of time after the valve is told to close that the system reaches 99% steady state.	Articulation
Command to Steady State	The command sent by the computer sending the hand to a steady state.	Articulation

Test Number	Test	Description	Reason for Test	Specification Affected
1	Leak Test	The air muscle length under a given load will be measured over time at a given pressure to determine if the air muscles leak.	The air muscles must not leak. If there are leaks, this must be accounted for.	4, 5-10, 14, 16, 17
2	Force	The amount of force that an air muscle exerts should be measured with respect to the deflection length.	This will be needed to determine air muscle sizing	5-10, 14
3	Displacement	P08023 and P08024's data should be verified. Displacement will be measured as a function of pressure. A specified load should also be applied to the air muscle. Air muscle lengths will vary.	Verify P08023 and P08024's data to aid in air muscle sizing.	1, 5-10,
4	Valve Testing part 1	The valves need to be tested to assure that they can be rapidly controlled.	The valves must be able to be opened and closed fast enough to control air muscle deflection	1, 2, 5-10, 11, 12, 15
5	Valve Testing part 2	The air muscle fill time must be measured for different orifices.	This will aid in the decision of the valve orifice size	1, 2, 5-10, 11, 12, 15
6	Diameter Changes	The diameter of each air muscle will be measured as a function of pressure.	This will determine our packaging constraints	3
7	Reliability	The air muscles will be cycle tested under a load.	Determine air muscle life span and develop a periodic maintenance schedule	3, 4
8	Pressure Rates	The air muscle pressure will be recorded as a function of time during discharge.	This will aid in plenum sizing	15
9	Flow Rates	The flow rates flowing out of the air muscle must be determined. Dr. Kozak will help with this.	This will aid in plenum sizing	13, 15
10	Cable Durability	The cables will be cycle tested with a particular load.	Determine cable life span and develop a periodic maintenance schedule	4
11	Spring Durability	The springs will be tested to determine maximum deflection before it enters the plastic region.	This will aid in determining the spring sizes.	4

Test number	Test	Description	Reason for Test	Specification Affected
12	Angle Testing	A Goniometer will be used to determine the joint angle	The joint angles need to be measured to determine how well the project meets customer needs	5-10

1.4.3. Test Equipment available

1. Voltmeter
2. Computer
3. Calipers
4. Stopwatch
5. Force Gage

1.4.4. Test Equipment needed but not available

1. Relay Boards
2. Power Supplies
3. Air Muscle Test Stand

1.4.5. Phases of Testing

1.4.5.1. Testing to Determine Component Specifications

- Force
- Valve Testing part 1
- Valve Testing part 2
- Displacement
- Diameter Changes
- Pressure Rates
- Flow Rates

1.4.5.2. Integration

After the above testing is complete, the specified design parameters can be determined, and the corresponding parts can be installed.

1.4.5.3. Reliability Testing

- Leak Test
- Reliability
- Cable durability
- Spring Durability

1.4.5.4. Customer Acceptance

The final test will be the goniometer test on the finished hand. This test will be used to satisfy the directions of freedom requirement.

1.5. Definitions; Important Terminology; Key Words

1.5.1. Hand Anatomy

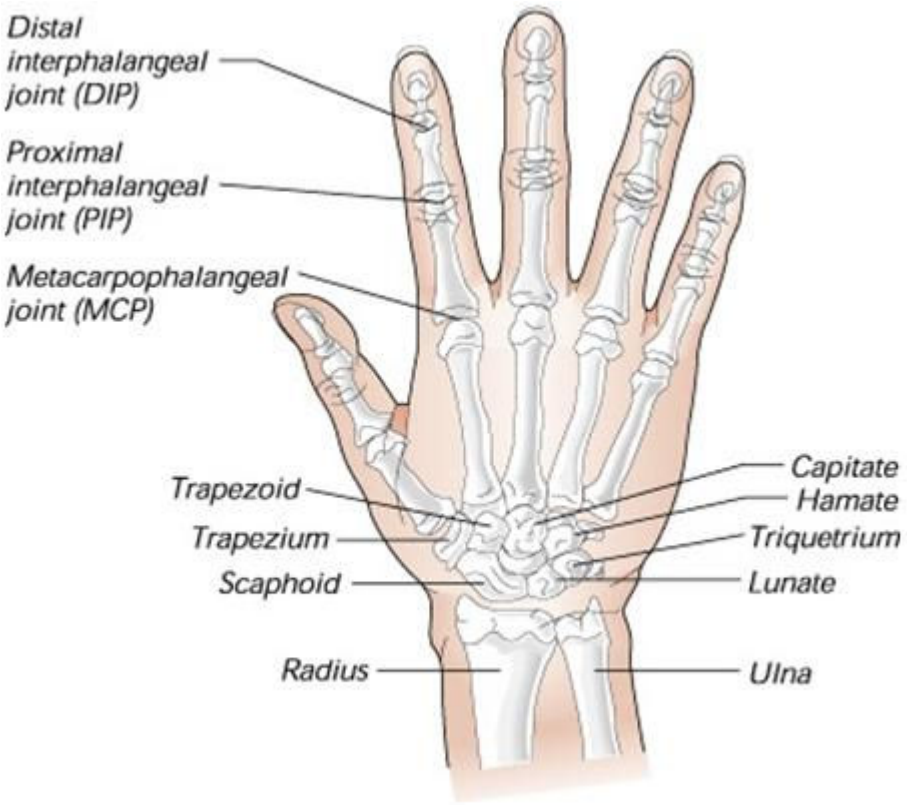

Figure 4: Hand Anatomy (Courtesy of http://www.cs.unc.edu/~kirstin/Comp236/)

1.6. References

1.6.1. http://www.cs.unc.edu/~kirsten/Comp236/

2. MSD II WKS 2-4: - FINAL TEST PLAN

Introduction: Testing needs to be completed to determine individual component specifications. Testing also needs to be conducted to prove that the final design meets customer needs.

2.1. Data Collection Plan

2.1.1. Test Scheduling and Results

Test Number	Description	Test Date	Result
1	The air muscle length under a given load will be measured over time at a given pressure to determine if the air muscles leak.	1/30/2009	
2	The amount of force that an air muscle exerts should be measured with respect to the deflection length.	12/19/2008	
3	P08023 and P08024's data should be verified. Displacement will be measured as a function of pressure. A specified load should also be applied to the air muscle. Air muscle lengths will vary.	12/12/2008	
4	The valves need to be tested to assure that they can be rapidly controlled.	12/5/2008	
5	The air muscle fill time must be measured for different orifices.	12/5/2008	
6	The diameter of each air muscle will be measured as a function of pressure.	12/19/2008	
7	The air muscles will be cycle tested under a load.	1/9/2009	
8	The air muscle pressure will be recorded as a function of time during discharge.	1/9/2009	
9	The flow rates flowing out of the air muscle must be determined. Dr. Kozak will help with this.	1/16/2009	
10	The cables will be cycle tested with a particular load.	1/23/2009	
11	The springs will be tested to determine maximum deflection before it enters the plastic region.	1/30/2009	
12	A Goniometer will be used to determine the joint angle	2/13/2009	

The forms for each test are located on the edge website under testing.

2.1.2. Sampling Techniques

Sampling techniques are dependent on the test being ran. Please refer to the individual testing instructions for sampling techniques.

2.1.3. Sample Size

Whenever possible, a sample size of 20 will be used to create a student T distribution. In instances where it is not feasible to get 20 measurements, fewer measurements will be made.

2.2. Measurement Capability, Equipment

2.2.1. Air Muscle Test Stand

An air muscle test stand must be made to test air muscles. An air muscle tester does not currently exist, so the team must design one. This design must allow an air muscle attached to a load to hang and operate.

2.3. Setup Instructions

2.3.1. Air Muscle Test Stand

The test stand will be clamped to the edge of the table, and the air muscle will be suspended from the top rod. The air muscle will be controlled via labview. More specific details will be determined when the test stand is built.

2.4. Test Procedure, Work Breakdown Structure, Schedule

Test number	Test	Reason for Test	Specification Affected	Person In Charge of Test
1	Leak Test	The air muscles must not leak. If there are leaks, this must be accounted for.	4, 5-10, 14, 16, 17	Chris
2	Force	This will be needed to determine air muscle sizing	5-10, 14	Chris
3	Displacement	Verify P08023 and P08024's data to aid in air muscle sizing.	1, 5-10,	Kelly
4	Valve Testing	The valves must be able to be opened and closed fast enough to control air muscle deflection	1, 2, 5-10, 11, 12, 15	Tommy
5	Valve Testing part 2	This will aid in the decision of the valve orifice size	1, 2, 5-10, 11, 12, 15	Tommy
6	Diameter Changes	This will determine our packaging constraints	3	Kelly
7	Reliability	Determine air muscle life span and develop a periodic maintenance schedule	3, 4	Alex
8	Pressure Rates	This will aid in plenum sizing	15	Alex
9	Flow Rates	This will aid in plenum sizing	13, 15	Eva
10	Cable Durability	Determine cable life span and develop a periodic maintenance schedule	4	Eva
11	Spring Durability	This will aid in determining the spring sizes.	4	Kelly
12	Angle Testing	The joint angles need to be measured to determine how well the project meets customer needs	5-10	Alex

NOTE: The above table is only meant as a guide. Every team member will have a role in every test.

2.5. Assumptions

2.5.1. Assumptions will be added as testing commences

3. MSD II – WKS 3-10 DESIGN TEST VERIFICATION

3.1. Test Results

Testing Results can only be determined after testing. This section will be updated accordingly

3.1.1. Testing to Determine Component Specifications

- Force
- Valve Testing part 1
- Valve Testing part 2
- Displacement
- Diameter Changes
- Pressure Rates
- Flow Rates

3.1.2. Reliability Testing

- Leak Test
- Reliability
- Cable durability
- Spring Durability

3.1.3. Customer Acceptance

The final test will be the goniometer test on the finished hand. This test will be used to satisfy the directions of freedom requirement.

3.2. Logistics and Documentation

The test results will be documented in each individuals logbook as well as on an excel spreadsheet. That spreadsheet will then be posted on the edge website.

3.3. Pass / Fail Criteria

A successful test is determined according to each individual test plan. Please refer to the test plans to view the pass/fail criteria.

3.4. Contingencies/ Mitigation for Preliminary or Insufficient Results

If a test provides insufficient results, retesting will be necessary. Depending on the situation, the test may need to be redesigned. The entire team will be involved in this process.

3.5. Analysis of Data – Design Summary

Each person is responsible for analyzing their data for the test. Depending on the test, statistical methods will be used to determine pass or fail. This will then be used to either confirm or disprove a design method.

3.6. Conclusion or Design Summary

Conclusions will be reported in individual logbooks as well as on the edge website. There will be a testing conclusion document as well. This document will include all of the tests, brief descriptions, results, and interpretation of the data. This data can then be used by future design generations.

3.7. Function/ Performance Reviews

Reviews tentatively will be held bi-weekly. This gives the teams enough time to complete the tests, but will keep the team on track. These reviews will not involve powerpoint presentations. The purpose is to speak with the guide to make sure that testing is being done properly and prudently.

3.7.1. Debriefing your Guide and Faculty Consultants

Test results will be discussed with the guide and faculty consultants throughout MSDII. The results will also be reported in formal documentation that can be found on the edge website.

3.7.2. Lab Demo with your Guide and Faculty

Tests will be performed in front of the guide and faculty. This will be done to confirm that our method of testing is acceptable.

3.7.3. Meeting with Sponsor

There will be meetings with the sponsor throughout the project. At the end of senior design II, the final project will be shown to Dr. Lamkin-Kennard and validation testing will be done to show that the design meets customer needs.

3.8. References

References will be added here as applicable.

3.8.1. Add here or remove as applicable.

3.9. Appendices

Appendices will be added here as applicable.

3.9.1. Add here or remove as applicable.