Manipulator Test

Date Completed: February 4, 2013

Performed By : Keith Slusser

Tested Specification	Description	Critical Value	Nominal Value
Weight	Overall manipulator weight	550 grams	<550 grams
Size	Overall manipulator size	8cmx8cmx8cm	<8cm per axis
Range of Motion	movement per axis	1cm	+/- .1cm

Revision History

Revision	Description	Date
ORG	Document Created	10/29/2012
A	Added Steps 8-9 and table 4 to Test 3; validates previous	11/01/2012
B	Removed weight –based friction test; replaced with angle-based test	02/04/2013

Equipment Needed:

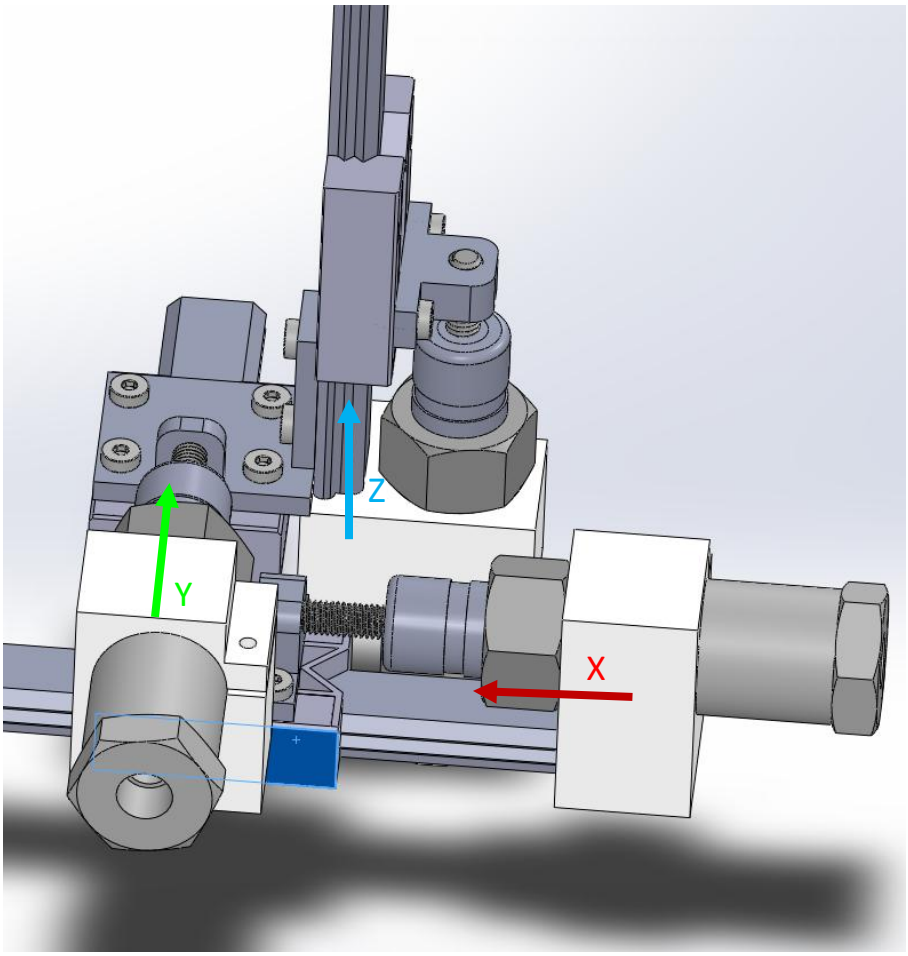
__1. Gram-Scale

__2. Protractor

__3. Metric Ruler

__4. Hydraulic System

__5. Metric Hex Keys



Sections

Test 1 – Weight Test

Test 2 – Coefficient of Friction Test

Test 3 – Size test

Test 4 – Range of Motion Test

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Test 1: Weight Test

_x__1. Remove manipulator system from rest of system

_x__2. With a scale, measure the weight of the entire manipulator system. Record the weight in table 1

__x_3. Get 3 measurements of the manipulator weight and take the average

__x_ 4. Disassemble manipulator into three separate axes, and label with masking tape with the proper coordinate system; x, y, or z axis

Note: x-axis is the bottom, y-axis is stacked on top of x, and z-axis is stacked on top of y

__x_5. With each axis individually, and not hooked to hydraulic system, weigh axis and record in table 2. Be sure to record weight of cylinders and mounts separately

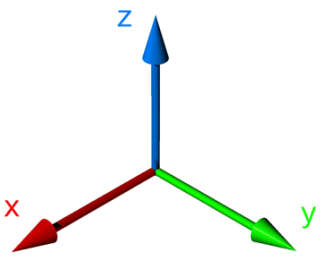
Note: Include any screws that are attached to the axis

	Weight of Manipulator (grams)
1	689.03
2	690.01
3	688.05
Average	689.03

Table 1 – Overall Weight of Manipulator

	Weight of Manipulator (grams)
Axis 1 (x)	57.48
Axis 2 (y)	51.86
Axis 3 (z)	44.34
Cylinders	535.35

Table 2 – Individual Axis Weights



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Test 2 – Coefficient of Friction test

_x__1. Retrieve a protractor

__x_2. If they aren't already, disassemble the manipulator into 3 separate axes as done for **Test 1**

__x_3. With one single axis (track, carriage and brackets—exclude the cylinder and cylinder mount), move the free end of the track at the center of the protractor

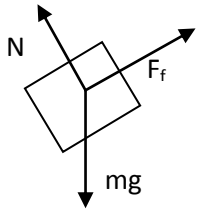
__x_4. On a flat surface, begin to raise the axis until the carriage, and its components, freely fall down the track.

__x_5. Once fluid motion occurs, stop raising the track and record the degree at which the motion occurred in Table-set 3

__x_6. Repeat Steps 3-5 a total of 5 times for a single axis

__x_7. Repeat Steps 3-6 for the remaining two axes

__x_8. The Static coefficient of friction is the tangent of the "fluid motion angle". Calculate and record the coefficient of static friction for each trial and take the overall average in table 4



$$\sum F_x = F_f - mg\sin(\theta) = 0 \quad (1) \qquad \sum F_y = N - mg\cos(\theta) = 0 \quad (2)$$

$$\mu N = F_f = mg\sin(\theta) \quad (3) \qquad N = mg\cos(\theta) \quad (4)$$

From (3) and (4): $\mu = \tan(\theta)$

Axis	Axis 1	Axis 2	Axis 3
θ1	30	30	31
θ2	25	26	30
θ3	30	30	30
θ4	26	30	30
θ5	27	30	26

Table 3 – Fluid Motion Angle

Axis	Axis 1	Axis 2	Axis 3
μ1	.577	.577	.600
μ2	.466	.488	.577
μ3	.577	.577	.577
μ4	.488	.577	.577
μ5	.504	.577	.466

Overall Average	**.547**

Table 4 – Coefficient of Friction

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Test 3 – Size test

__ x _1. If the axes aren't already together, re-assemble the manipulator into one unit.

__x _2. With a metric ruler, measure the LxWxH of the entire system and record below in table 5. Take 2 measurements for each to be sure

L (mm)	W (mm)	H (mm)
130	130	130
130	130	130

Table 4 – Manipulator Dimensions

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Test 4 – Range of Motion Test

_x__1. If the axes aren't already together, re-assemble the manipulator into one unit.

_x__2. With a metric scale, measure the maximum distance the carriage can travel by pulling on the carriage until the plunger in the brass cylinder reaches the top of the cylinder.

_x__3. Record the "dry-run" distance in table 6 for each axis.

_x__4. Fill the hydraulic lines with water and attach them to the three bronze cylinders on the manipulator.

_x__5. Bleed the hydraulic system to ensure there is no air within the closed-system.

_x__6. With a metric scale, measure the maximum distance the carriage can travel by fully depressing the thin brass cylinder on the end of the hydraulics.

_x__7. Record the full Range of Motion in table 7

Axis	Maximum Distance Traveled (mm)
Axis 1 (x)	11
Axis 2 (y)	11
Axis 3 (z)	11

Table 6 – Dry-Run Range of Motion

Axis	Maximum Distance Traveled (mm)
Axis 1 (x)	11
Axis 2 (y)	11
Axis 3 (z)	11

Table 7 – Range of Motion Attached to Hydraulics

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Notes: Difference of 45.3% for friction coefficient compared to prototype 1.

Roughly 35% overweight; all weight is from cylinders (535g total)

Smaller cylinders to come down to 500g

60% larger size than spec; all from cylinders (10cm from cylinders); smaller cylinders to solve

Range of Motion right on Spec