리니어 모터 시운전 방법

-Linear Motor Commissioning-

Date: 2016.11.24

I Versions

Version	Date	Comment	Edited by
1.0	Nov 24, 2016	First Edition	Dongsu Kim

Table 1: Versions

II Distribution

Name	Company, Department	Amount	Remarks

Table 2: Distribution

III Safety Notices

Safety notices in this document are organized as follows:

Safety notice	Description
Danger!	Disregarding the safety regulations and guidelines can be life-threatening.
Warning!	Disregarding the safety regulations and guidelines can result in severe injury or heavy damage to material.
Caution!	Disregarding the safety regulations and guidelines can result in injury or damage to material.
Information:	Important information used to prevent errors.

Table 3: Safety notices

IV Table of Contents

1 소개

리니어 모터 사용시 필요한 절차에 대해 나열한 문서입니다.

2 하드웨어 구성

2.1 요약

List	Specification (Model name)	Reference
Linear motor	I-force 410	PAKER
Encoder	Lida487	HEIDENHAIN
CPU	5AP1120.121	5PPC2100
Servo Drive	8V1090.00-2	ACOPOS 1090
Interface card	8AC114.60-2 (2ea) 8AC120.60-1 (2ea)	

2.2 모터

I-Force Ironless 410 Series

Performance

Model	Units	410-2	410-3	410-4	410-6	410-8
Peak Force [1]	N (lb)	1041.4 (234.1)	1523.6 (342.5)	2006.3 (451.0)	2967.2 (667.0)	3928.1 (883.0)
Continuous Force [2]	N (lb)	233.1 (52.4)	340.8 (76.6)	448.9 (100.9)	663.7 (149.2)	878.6 (197.5)
Peak Power	W	2835	4050	5265	7695	10125
Continuous Power	W	142	203	263	385	506

1) Peak force and current based on 5% duty cycle and one second duration.
2) Continuous force and current based on coil winding temperature maintained at 100 °C.

Electrical

Model	Units	410-2			410-3			410-4			410-6			410-8		
Winding	Series/Parallel/Triple	S	P	T	S	P	T	S	P	T	S	P	T	S	P	T
Peak Current	A pk sine	19.1	38.2	57.3	18.6	37.2	55.8	18.4	36.8	55.2	18.1	36.2	54.3	18.0	36.0	54.0
	RMS	13.5	27.0	40.5	13.2	23.6	39.5	13.0	26.0	39.0	12.8	25.6	38.4	12.7	25.5	38.2
Continuous Current	A pk sine	4.3	8.6	12.9	4.2	8.4	12.6	4.1	8.2	12.3	4.1	8.2	12.3	4.0	8.0	12.0
	RMS	3.0	6.1	9.1	3.0	5.9	8.9	2.9	5.8	8.7	2.9	5.8	8.7	2.8	5.7	8.5
Force Constant [1]	N/A peak	54.5	27.3	18.2	81.8	40.9	27.3	109.0	54.5	36.3	163.7	81.8	54.6	218.4	109.2	72.8
	lb/A peak	12.3	6.1	4.1	18.4	9.2	6.1	24.5	12.3	8.2	36.8	18.4	12.3	49.1	24.6	16.4
Back EMF [2]	V/m/s	63.0	31.5	21.0	94.5	47.2	31.5	126.0	63.0	42.0	189.0	94.5	63.0	252.0	126.0	84.0
	V/in/s	1.60	0.80	0.53	2.40	1.20	0.80	3.20	1.60	1.07	4.80	2.40	1.60	6.40	3.20	2.13
Resistance @ 25°C (phase-to-phase) [3]	ohms	8.0	2.0	0.9	12.0	3.0	1.3	16.0	4.0	1.8	24.0	6.0	2.7	32.0	8.0	3.6
Inductance (phase-to-phase) [4]	mH	10.0	2.5	1.1	15.0	3.8	1.7	20.0	5.0	2.2	30.0	7.5	3.3	40.0	10.0	4.4
Electrical Time Constant [5]	ms	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Motor Constant [6]	N/W	19.57	19.57	19.57	23.98	23.98	23.98	27.67	27.67	27.67	33.90	33.90	33.90	39.14	39.14	39.14
	lb/W	4.40	4.40	4.40	5.39	5.39	5.39	6.22	6.22	6.22	7.62	7.62	7.62	8.80	8.80	8.80
Terminal Voltage (max.) [7]	VDC	330	330	330	330	330	330	330	330	330	330	330	330	330	330	330

1) Force constant is peak of resistive force produced by 1.0 amp thru one motor lead and 0.5 amps thru other two leads.
Also, Back EMF (V/in/sec) * 7.665 = Force constant (lb/amp).
2) Back EMF measured between any two motor leads while moving at constant velocity. Value is amplitude or 0-Peak of sine wave produced.
3) Resistance measured between any two motor leads with motor connected in Delta winding at 25 °C. For temperature at 100 °C, multiply resistance by 1.295 (75 °C rise * 0.393%/°C).
4) Inductance measured using 1 Kz with the motor in the magnetic field.
5) Electrical time constant is time it takes for motor value to reach 63% of its final current after a step change in voltage.
6) Motor constant is a measure of efficiency. Calculated by dividing the force constant by the square root of the motor resistance at maximum operating temperature.
7) Consult factory for use with non-Parker amplifiers.

2.3 엔코더(Encoder)

3 튜닝 방법(Tuning)과 결과

3.1 Servo Drive, Encoder interface card 배선 체크

멀티미터기로 각 장치들의 정격 전압이 출력되는지 확인합니다.

3.2 ACOPOS Parameter Table 입력

Linear motor 의 경우 Parameter table 에 Motor Parameter 값을 입력해주어야 합니다.
Parameter table 에 값을 넣어주기 위해 Motor 의 데이터시트를 참고하여 자사의 엑셀 시트에 작성을 합니다. (Help 에 양식 있음. GUID: c472ed70-2413-4cf1-930b-efb9f9729000)

> Motion > Reference manual > ACOPOS drive functions > Motor > Synchronous Linear Motor > Parameter conversion from linear motor to synchronous motor

1) 엑셀시트 작성

Parameter conversion from linear motor to synchronous motor

An is provided to help with the parameter conversion:

Name	Value	Unit
MOTOR_POLEPAIR_WIDTH	0,0281	m
MOTOR_LINEAR_SPEED_NOMINAL	5	m/s
MOTOR_LINEAR_SPEED_MAX	5	m/s
MOTOR_FORCE_STALL	10,5	N
MOTOR_FORCE_RATED	10,5	N
MOTOR_FORCE_MAX	21	N
MOTOR_LINEAR_VOLTAGE_CONSTANT	4,00	V_{rms}/(m/s)
MOTOR_FORCE_CONST	60	N/A_{rms}
MOTOR_MASS	4,7	kg
ENCODER: Line length	1000	µm/Line
MOTOR_BRAKE_FORCE_RATED	860	N
Input fields: Enter values		
Output fields		

↦

Name	Value	Unit
τ Reference length = τ_p*2_p [m]	0,281	m
MOTOR_POLEPAIRS	10	-
MOTOR_SPEED_RATED	1068	min^{-1}
MOTOR_SPEED_MAX	1068	min^{-1}
MOTOR_TORQ_STALL	0,47	Nm
MOTOR_TORQ_RATED	0,47	Nm
MOTOR_TORQ_MAX	0,94	Nm
MOTOR_VOLTAGE_CONST	18,73	mV/min
MOTOR_TORQ_CONST	2,683	Nm/A_{rms}
MOTOR_INERTIA	0,0094005	kgm^2
SCALE_ENCOD_INCR	4603904	Inc/p_p
MOTOR_BRAKE_TORQ_RATED	38,46	Nm

2) Encoder Setting

- 작성된 엑셀 시트의 Motor reference length 의 결과 값을 이용합니다.
- Units = Motor reference length(m)
- Rev = 1
- 단위 변경시에는 Motor reference length 의 단위를 um, mm 혹은 nm 로 변경후에 입력합니다.

3) Parameter table 작성

- 엑셀시트의 Output field 에 있는 값들을 Automation studio 의 Parameter table 에 기입합니다. (Unit 확인 필요)
- 하기 의 파란색 표시된 MOTOR_COMMUT_OFFSET 값을 제외한 모든 Parameter 값들을 입력합니다.

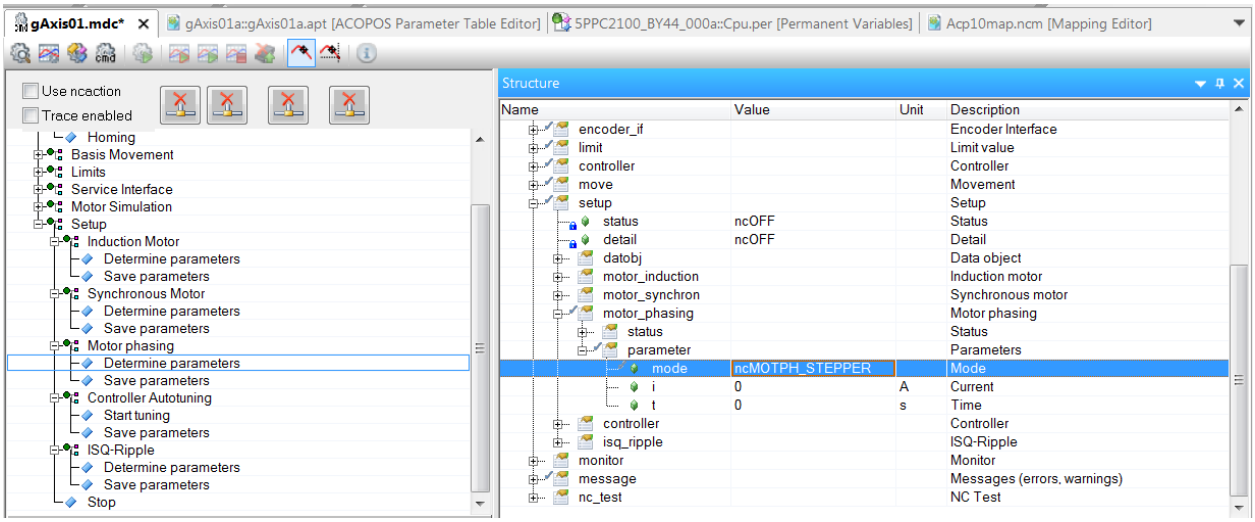
<Linear motor calculation 엑셀시트>

LinearMotor_Calculation.xls

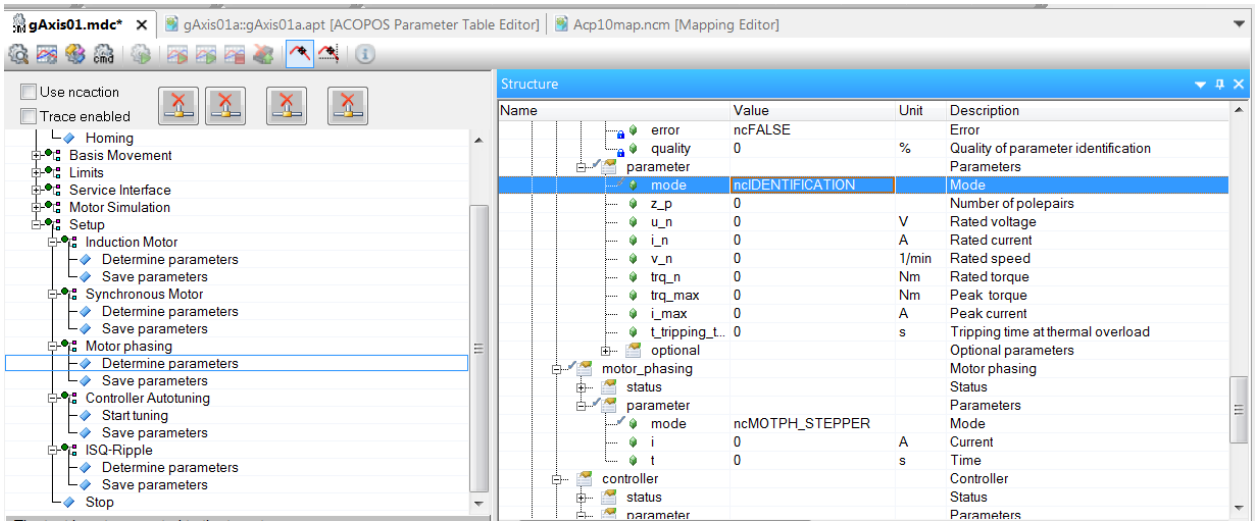
gAxis01a::gAxis01a.apt [ACOPOS Parameter Table Editor]

Name	ID	Value	Unit	Description
Parameters				
UDC_NOMINAL	390	220	V	CTRL DC bus: Nominal voltage
SGEN_SW_END_IGNORE	128	1		Limit values: Ignore SW end positions
ALC6000 - Gantry Linear Motor [X Axis]				
General parameters				
Brake parameters				
Thermo sensor parameters				
Motor parameters				
MOTOR_VOLTAGE_RATED	48	220	V	Motor: Rated voltage
MOTOR_VOLTAGE_CONST	49	56.70	mV*min	Motor: Voltage constant
MOTOR_SPEED_RATED	50	352	1/min	Motor: Rated speed
MOTOR_SPEED_MAX	51	703	1/min	Motor: Maximum speed
MOTOR_TORQ_STALL	52	9.90	Nm	Motor: Stall torque
MOTOR_TORQ_RATED	53	9.01	Nm	Motor: Rated torque
MOTOR_TORQ_MAX	54	40.30	Nm	Motor: Peak torque
MOTOR_TORQ_CONST	55	1.111	Nm/A	Motor: Torque constant
MOTOR_CURR_STALL	56	5.8	A	Motor: Stall current
MOTOR_CURR_RATED	57	5.8	A	Motor: Rated current
MOTOR_CURR_MAX	58	25.6	A	Motor: Peak current
MOTOR_WIND_CROSS_SECT	59	0	mm	Motor: Line cross section
MOTOR_STATOR_RESISTANCE	60	6.0	Ohm	Motor: Stator resistance
MOTOR_STATOR_INDUCTANCE	61	0.0075	Henry	Motor: Stator inductance
MOTOR_INERTIA	62	0.0007969	kgm	Motor: Moment of inertia
MOTOR_COMMUT_OFFSET	63	1.89407	rad	Motor: Commutation offset 4.3317637
MOTOR_TAU_THERM	849	0.251	s	Motor: Thermal time constant
Isolation parameters				
MOTOR_WIND_TEMP_MAX	74	130	?	Temperature sensor: Limit temperature
SS2				8AC120.00
ENCOD_TYPE	97	ncINC		Encoder1: Type
SCALE_ENCOD_INCR	109	69910528		Encoder1: Encoder scaling: increments per SCALE_ENCOD_MOTOR_REV motor revolutions
ENCOD_LINE_CHK_IGNORE	727	0		Encoder1: Ignore check
MOTOR_CURR_ROT_DIR	872	255		Motor: Rotational direction of current
PHASING_MODE	276	2		Motor: Phasing: Mode

- MOTOR_COMMUT_OFFSET 값은 NC Test Window 를 이용하여 Motor Phasing 을 실시해서 값을 찾을 수 있습니다.
- Mode 를 Stepper 를 선택하여 Phasing 을 실시하여 Commute Offset 값을 기입합니다. (Motor 가 약 70cm 정도 움직이므로 주의 필요)
- Phasing 시에 Temperature, Lag error 에 의하여 실패할경우 MOTOR_CURR_ROT_DIR(872)의 로터 디렉션 (0, 255)을 변경하여 Phasing 을 재 실시 합니다.



- ParID 48~63 값이 기입이 다 되었으면 Identification 을 실시하여 Parameter Quality 를 확인합니다.
- 입력한 Parameter 값이 올바르지 않을 경우에 Quality 값이 낮게 나올 수 있기 때문에 Parameter 값을 재확인 후 다시 Identification 을 실시합니다. (Quality 는 엔지니어 판단 하에 진행)



4) 모터 튜닝

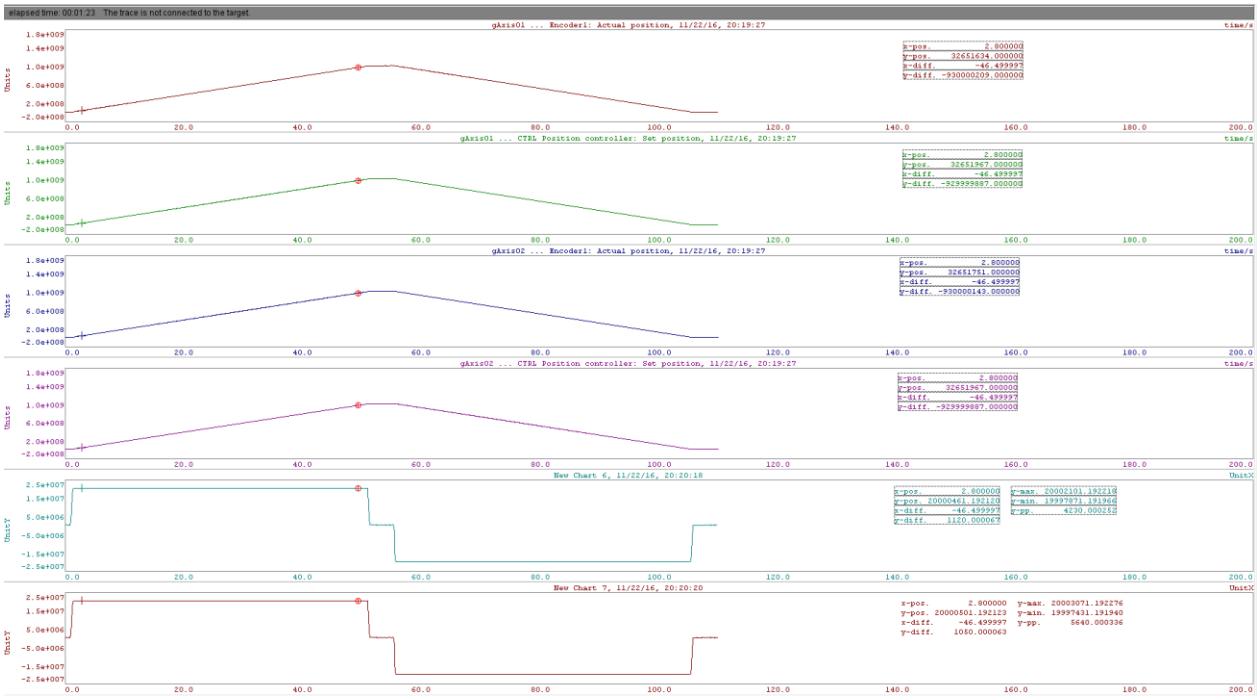
- Speed, Position 에 대한 Auto tuning 을 실시합니다.
- Motor movement 를 통해 튜닝에 대한 평가를 진행합니다.

- 평가 항목 : Lag error, 모터 전류, 온도, Set&Actual Position 에 대한 데이타를 Trace 로 평가합니다.
- 추가적으로 Fine tuning 을 하기 위해 Servo Loop Optimizer 를 실행하여 Gain 값 조정 또는 Filter(BIQUAD, NOTCH 등) 를 사용해 볼 수 있습니다.

* 참고사항: 항상 동일 지점에서 Lag error 가 크게 발생할 시, Parameter 오입력을 가능성이 큼

5) 결과

- - - - - - - - - - - Target- - - - - - - - - - - - - - - - - - -
Target speed : 20 mm/s
Target acc , dec : 100 mm/s^2
Distance : 1 m
- - - - - - - - - - - - Result- - - - - - - - - - - - - - - - - -
velocity ripple : 5.6 um/s (Velocity Max – Min 값)
tracking error : 250 nm (Master 대비 Slave Actual position 차이)
- -



<Trace Data>

LinearMotorTestResult.csv

LinearMotorTestResult.mch