PREVENTION OF SERVOMOTOR BURN BY REPLACING MOTOR WITH HIGHER TORQUE

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ABSTRACT

Pick and Dump (PnD) is a Western Digital designed machine that follows the process of Final Auto Visual Inspection (FAVI). All NG Head Gimbal Assembly (HGA) output from FAVI will be sorted by PnD.

PnD is run by a program where position of HGA to be picked and dumped from and to trays will be commanded. Its main assembly uses three servomotor axes: X, Y, and Z (horizontal, vertical, and height) to move in position specified.

For the past 3 years of PnD production having a total of 23 machines, 18 of these used AKM11E-SSMN2-03 motor in Z axis. 17 of it were shipped to Customer and have encountered 4 times motor burn incident. To eliminate such problems, AKM21G-SSMNEH02 motor is used in all axes of tools with overheat/burn problems, and the PnD #19 up to current build.

This paper features the solution done to PnD machines encountering motor burn during operation by replacing motor used by a higher torque. As a benefit, stability and productivity of the machine is increased.

1. 0 INTRODUCTION

1.1 Pick and Dump Machine

Pick and Dump is a 58cm x 62cm x 65cm size machine weighing 65kg. Its power rating is 220V and has a short circuit current rating of 2.5kA. During machine operation, full load current is 1.25A.

Figure 1: Pick and Dump Machine

PnD machine has three servo motor axes: X(horizontal), Y(vertical), and Z(height). For PnD Nos. 1-18, all Z axes used AKM11E-SSMN2-03. And for 19 – onwards, AKM21G-SSMNEH02 is used in all axes.
PnD uses Galil Controller as the multi-axis driver of the motors connected. The Galil contains four transconductance, PWM amplifiers for driving brushless or brush-type servo motors. Each amplifier drives motors operating at up to 7 Amps continuous, 10 Amps peak, 18–60 VDC (available voltage at the motor is 10% less). The gain settings of the amplifier are user-programmable at 0.4 Amp/Volt, 0.7 Amp/Volt and 1 Amp/Volt. The switching frequency is 60 kHz.

Figure 2:
AKM11E-SSMN2-03

Figure 3:
AKM21G-SSMNEH02

The adjustment and testing of Pick and Dump consists of Program Loading, Motor Tuning, Teaching, and Testing.

1.2 The Problem

Last May 2021, during motor tuning at P. IMES, the motor keeps turning on and experienced motor burn once at Z-Axis. During mass production run at Customer side, one of the machines stops and encountered overheating/burning of motor in Z Axis. Total of 4 burned motor in Customer line.

1.3 Solution

For Z servo motor burn incidents, changing motor from AKM11E-SSMN2-03 to AKM21G-SSMNEH02 is used as a counter-measure. This motor has higher torque value and also achieved substantial performance improvement requiring a different motor bracket.

One must always have more than one of the same level heading. That is, if there is a 1.1, then there should at least be a 1.2 sub-major heading.

2.0 METHODOLOGY

2.1 Materials

Motor, Danaher Motion (AKM21G-SSMNEH02)
High Torque Pulley

High Torque Timing Belt, 84 Teeth
Z Motor Connector Plate
Z Motor Connector Plate Cover
B18.3.4M-6 x 1.0 x 16 SBHCS—N
B18.22M- Plain Washer 6mm
B18.3.1M-3 x 0.5 x 8 Hex SHCS
B18.3.4M-3 x 0.5 x 6 SBHCS—N

2.2 Software

Galil Tools
WSDK

2.3 Motor Parameters

Servo tuning can be accomplished by several methods, but the most common way and used in PnD is to use a PID algorithm. The PID algorithm uses three feedback gains—proportional gain, integral gain, and derivative gain—to compare the commanded position (or velocity) with the actual value and issue commands to correct errors between the two.

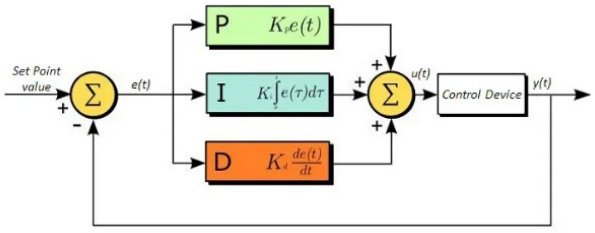
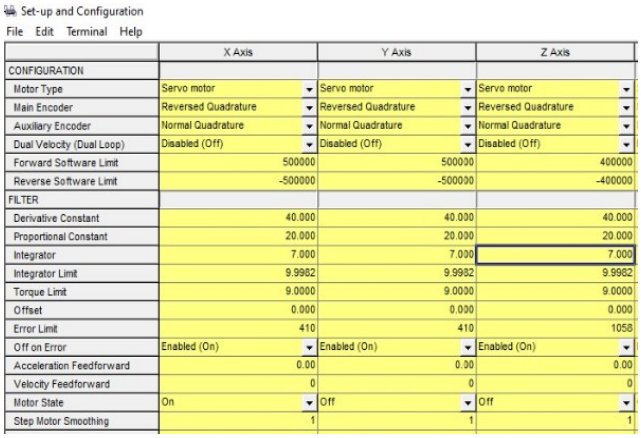


Figure 4:
AKM11E-SSMN2-03

For the time overheating/burn incident encountered during the motor tuning at the production, countermeasure was to decrease the value from 7 of the Integrator before proceeding to the tuning test.



	X Axis	Y Axis	Z Axis
CONFIGURATION			
Motor Type	Servo motor	Servo motor	Servo motor
Main Encoder	Reversed Quadrature	Reversed Quadrature	Reversed Quadrature
Auxiliary Encoder	Normal Quadrature	Normal Quadrature	Normal Quadrature
Dual Velocity (Dual Loop)	Disabled (Off)	Disabled (Off)	Disabled (Off)
Forward Software Limit	500000	500000	400000
Reverse Software Limit	-500000	-500000	-400000
FILTER			
Derivative Constant	40.000	40.000	40.000
Proportional Constant	20.000	20.000	20.000
Integrator	7.000	7.000	7.000
Integrator Limit	9.9982	9.9982	9.9982
Torque Limit	9.0000	9.0000	9.0000
Offset	0.000	0.000	0.000
Error Limit	410	410	1058
Off on Error	Enabled (On)	Enabled (On)	Enabled (On)
Acceleration Feedforward	0.00	0.00	0.00
Velocity Feedforward	0	0	0
Motor State	On	Off	Off
Step Motor Smoothing	1	1	1

Figure 5: Setup and Configuration of Motor

The Integral Gain (K_i) is how aggressive the Proportional changes are. The Integral Gain has the main purpose of adding more correction over time based on how much error is present.

Parameter Increased	Rise Time	Overshoot	Settling Time	Steady-State Error	Stability
K_p	Decrease	Increase	Small Change	Decrease	Degrade
K_i	Decrease	Increase	Increase	Decrease Significantly	Degrade
K_d	Minor Decrease	Minor Decrease	Minor Decrease	No Effect	Improve (for small K_d)

Table 1: Effects of Parameter Changes on Motor Performance

Using Z-Motor (AKM11E-SSMN2-03) connected to Galil with the value of KD = 40, KP = 20, KI = 7
Result: Motor turns on

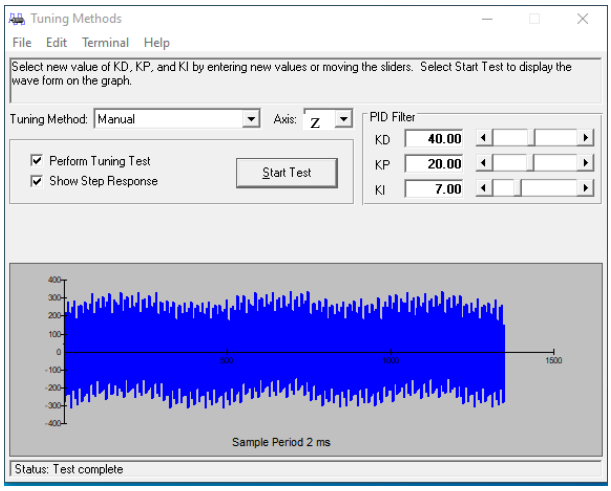


Figure 6: No Good Motor Tuning Results

Using Z-Motor **(AKM11E-SSMN2-03)** connected to Galil with lower KI.
Result: Motor was able to proceed on tuning, but still not in best condition

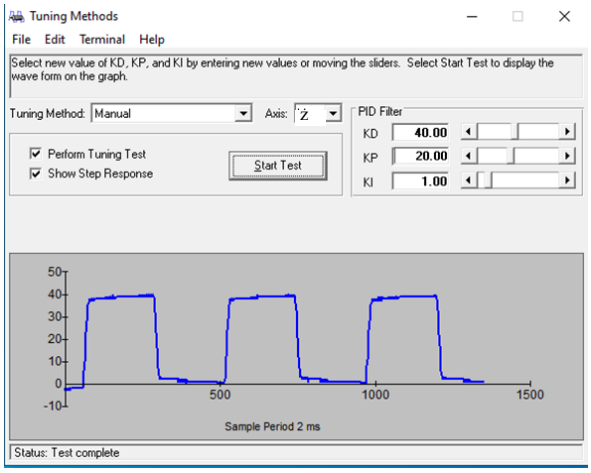


Figure 7: Acceptable Motor Tuning Results

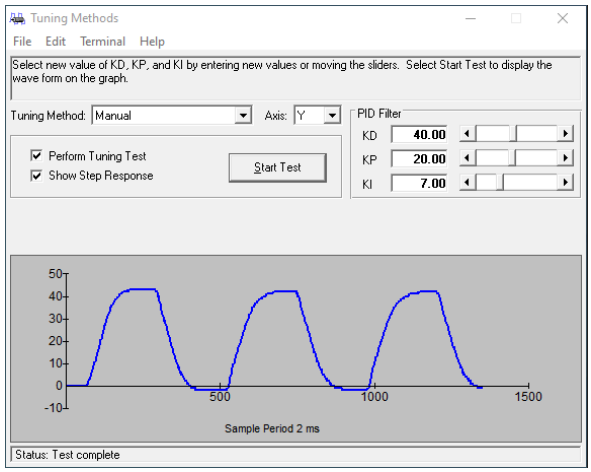


Figure 8: Example of Good Motor Tuning Results

2.4 Motor Specifications

Pick and Dump during full automation has actual current load of 1.25 A.

Main Supply:
• 48Vdc power supply / 6.7A
• 24Vdc power supply / 2.5A

Actual Load:
• AKM21G Motor – 75VDC/0.19kW/1.44Ohms@25degree Celsius
• AKM11E Motor – 75 VDC/0.11kW/3.11 Ohms@25degree Celsius

End Effector Weight:
• 270.5 grams

Actual Speed and Torque Limit:

SPEED			
	X	Y	Z
ACCELERATION	1200000	1200000	900000
DECCELERATION	1500000	1500000	900000
SPEED	700000	700000	250000

TORQUE LIMIT			
	X	Y	Z
FORWARD	500000	500000	400000
BACKWARD	-500000	-500000	-400000

Table 2: Speed and Torque Limit

2.6 Motor Load Capacity

Motor	Max. Allowable Load (lb)	Max. Allowable Load (kg)
AKM11E-SMN2-03	5.31	2.40
AKM21G-SSMNEH02	13.4	6.00

Table 3: Max. Allowable Load for Both Motors

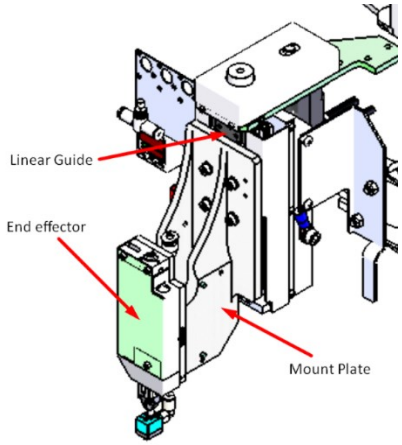


Figure 9: Z-Axis Assembly Parts

Linear Guide w/ cover – 0.95 kg.
End Effector w/ cover – 0.65 kg.
Mount Plate – 0.85 kg.

Total Weight: 2.45 kg.

Since the total weight of the parts that carried the motor was 2.45 kg and the motor's max. allowable load was 2.40 kg. (refer to Table 3). The AKM11E-SMN2-03 motor didn't meet the specification required to Z-axis assembly.

2.5 Z-Axis Assembly Conversion

Changing the Z-axis assembly of the Pick and Dump Machine.

Point of Reference (POR):

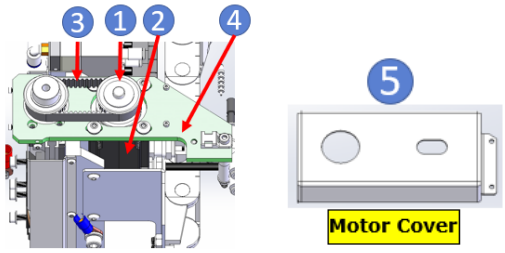


Figure 10: Z-Axis Assembly Using Lower Torque Motor

Item Number	POR DESCRIPTION	POR Part Number
1	TIMING PULLEY, MISUMI	HTPA28S3M100-A-P8
2	MOTOR, DANAHER MOTION (AKM11E)	AKM11E-SSMN2-03
3	HIGH TORQUE TIMING BELT, 60 TEETH, MISUMI	HTBN180S3M-100
4	MOTOR PLATE	M106-101B
5	Z AXIS ASSEMBLY	M106-01C

Table 4: Old Z-Axis Assembly Parts

Upgrade:

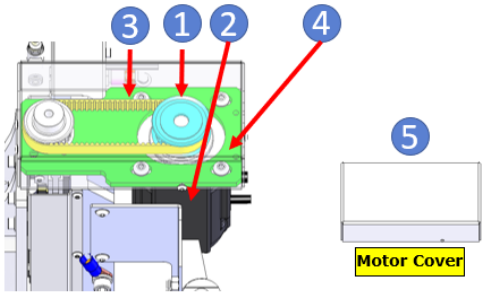


Figure 11: Z-Axis Assembly Using Higher Torque Motor

UPGRADE DESCRIPTION	UPGRADE Part Number	Remarks
PULLEY, HIGH TORQUE, MISUMI	HTPA32S3M100-A-P9	Change Pulley
MOTOR, DANAHER MOTION (AKM21G)	AKM21G-SSMNEH02	Change Motor
HIGH TORQUE TIMING BELT, 84 TEETH, MISUMI	HTUN252S3M-100	Change Timing Belt
Z MOTOR CONNECTOR PLATE	H001782	New Plate
Z MOTOR CONNECTOR PLATE CONNECTOR	H001783	New Cover

Table 5: New Z-Axis Assembly Parts

Parameters	Tolerance	Symbol	Units	AKM11-E	AKM21-G
Max Rated DC Bus Voltage	Max	Vbus	Vdc	75	75
Continuous Torque (Stall) for ΔT windng =100°C	Nom	Tcs	Nm	0.0185	0.5
Continuous Current (Stall)	Nom	Ics	A_{rms}	2.91	4.87
Continuous Torque (Stall) for ΔT windng =60°C	Nom	Tcs	Nm	0.0148	0.4
Max Mechanical Speed	Nom	N_{max}	rpm	8000	8000
Peak Torque	Nom	T_p	Nm	0.611	1.51
Peak Current	Nom	I_p	A_{rms}	11.6	19.5
Torque Constant	±10%	K_t	Nm/A_{rms}	0.064	0.1
Back EMF Constant	±10%	K_e	V/k_{rpm}	4.1	6.6
Motor Constant	Nom	K_m	N-m/√W	0.0296	0.068
Resistance (line-line)	±10%	R_m	ohm	3.11	1.44
Inductance (line-line)		L	mH	2.04	2.18
Inertia (includes Resolver feedback)	±10%	J_m	$kg\text{-}cm^2$	0.017	0.11

Table 6: Comparison of Motor Specifications

Based on these technical specifications, motor application, and machine's requirements, it is best to select the AKM-21G-SSMNEH02.

3.0 RESULTS AND DISCUSSION

The upgraded Z-Motor setup of Pick and Dump Machine was applied to four Pick and Dump at Customer, the Pick and Dump #19-24 shipped starting from March 2022 as well as the machines to be shipped at Customer.
No burning /crashing of the motors were recorded and encountered in these machines.

4.0 CONCLUSION

By considering the actual requirements e.g. torque…of the machine when it comes to servo motor used, it is proven that the AKM21G-SSMNEH02 is a better choice to use in Pick and Dump instead of the AKM-11E-SMN2-03.

5.0 RECOMMENDATIONS

Pick and Dump Machine is mainly composed of servo motors making its efficiency depends on motor's performance. This motor upgrade proves that in designing and developing machines like this, it is very important to identify the actual technical requirements before selecting the parts to avoid low stability of the machine due to under specs/mismatch problem. Also consider the cost and efficiency effects.

6.0 ACKNOWLEDGMENT

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7.0 ABOUT THE AUTHORS

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