Beam Wire Scanner for PS/SPS/PSB

Update on Motor Supplier Investigations - 3

07-August-2015

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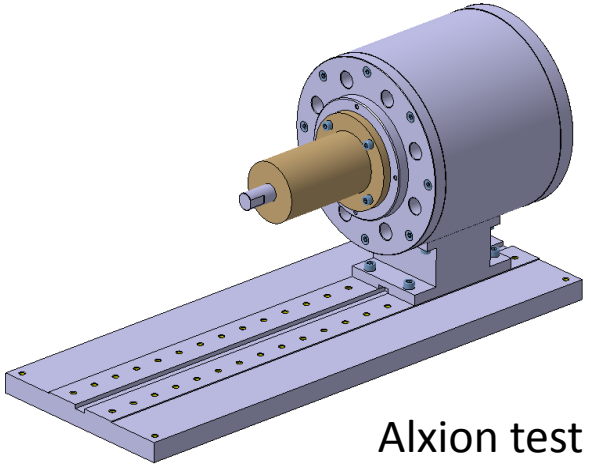
Updates

- Standard motors from Kollmorgen and Alxion have been ordered (DAI **6101373** and **6101381**), P.O. sent, 03.08.2015;

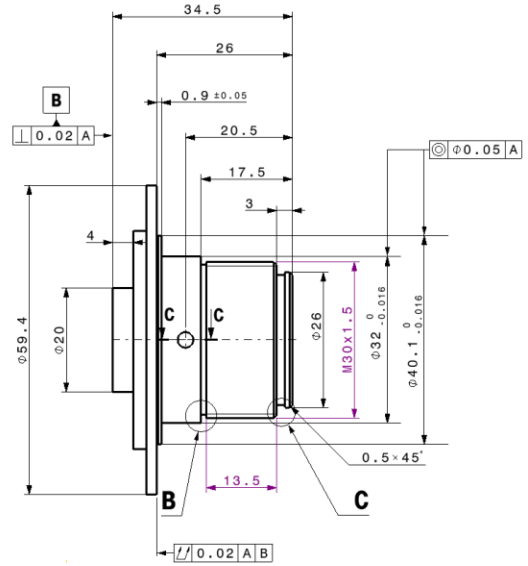
- Customised Alxion motor has been ordered, DAI 07.08.2015;



Alxion test bench

- Design of test benches for electromechanical tests is in progress:

- Glass optical disk holder design optimisation (run-out tolerance) done (*glass disk fixation system installed on prototype 2 reached more than 30000 scans by Friday*); planning to order via MWS for good precision.



- Design of metallic optical disk is in progress (consultations with MWS ongoing)

Mechanical And Vacuum Tests Planned For The Prototype 2

	Test	Time	Location
	First mechanical check	1.5 weeks	**ML labs (control system required)**
	Mechanical reliability (no vacuum)		
	Cleaning	1 week	
Instrument must be vacuum-cleaned !	Mechanical reliability (under vacuum)	6 weeks	
	Reliability of the wire (+ wire type definition)		
	Vacuum tests - Outgassing - RGA		
	Vacuum-mechanical tests - Cold welding (bearings) - Outgassing (bearings)		
	Thermal test	2 weeks	
	Total	**10.5 weeks**	

Electric Motor Requirements

** - The motor currently used is obsolete and will not be available for purchasing*

Parameter	Value		Notes
Motor type	Frameless PMSM		Permanent Magnet Synchronous Motor
Rotor core material	Steel (should be approved by CERN)		
Permanent magnets material	Samarium-Cobalt (Sm_2Co_{17})		
Wire linear speed, m/s	20		
Angular speed, rad/s	110 (PS/SPS)	133 (PSB)	
Acceleration, rad/s^2	10672 (PS/SPS)	15711 (PSB)	Sin-profile is used, spec. coefficient 1.85
Inertia of the load, kg x m^2	8.6E-04* (PS/SPS)	7.29E-04* (PSB)	
Radial air gap (stator ID – rotor ED), mm	0.7		
Ionizing radiation dose, kGy/year	1		

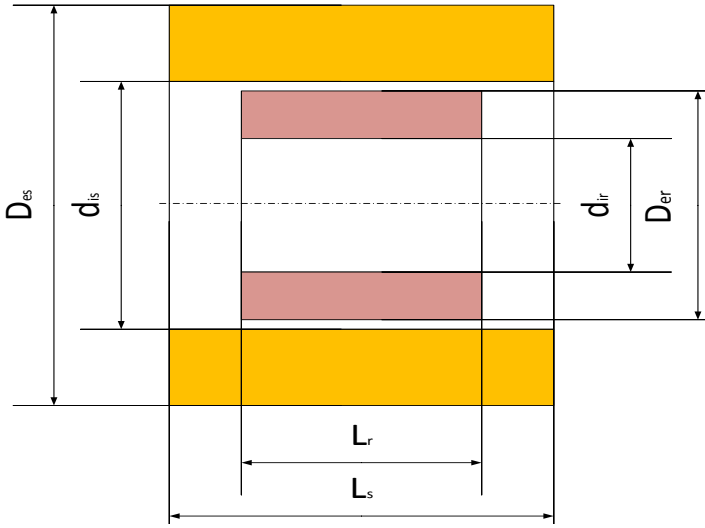
New motor will be the same in beam wire scanners for PS/SPS/PSB so should provide torque sufficient to accelerate the wire to linear speed 20 m/s in both configurations: 182.5 mm (PS/SPS) and 150 mm (PSB) mm forks;

- The desired motor should be based on the standard market solution which will be available for many years;
- The rotor will be located in vacuum and must be vacuum compatible; the use of any glue, other adhesives or insulating materials is not possible. Solid core rotor should be used.
- The moment of inertia of the rotor should be minimized in order to reduce the required acceleration torque;
- Features for mounting the rotor on the shaft (key-slots, holes, etc.) should be considered in the design;

*-values will be optimized during the next mechanical design phase

Potential suppliers and models

Supplier	Model	Rotor Inertia, kg x m^2	Peak torque, N x m	Required torque PS/SPS, N x m	Required torque PSB, N x m	Dimensions, $d_{ir}xD_{er}xD_{es}xL_rxL_s$
Alxion	145STK2M	1.28E-03	55.00	20.07	27.48	56x77.7x145x86x119
Kollmorgen	KBM-35X02	2.50E-03	58.4	35.86	50.73	65x86.9x140x76x109
Parker	NK620	9.80E-04	26.60	18.63	25.57	26x71x111x60x106
Alxion	145STK4M	2.37E-03	110	34.5	48.7	56x77.7x145x140x173



3 companies are interested

Potential suppliers and models. Prices

Supplier – Model	Price for prototype, EUR	Price for series, EUR	Additional cost	Delivery time, weeks	Total, prototype x1	Total, prototype x2
Parker - **NKD620EKxR1000**	3154		-	10	3154	6308
Kollmorgen - KBM-35X02	5294	3566	3700 (NRE)	16	8994	14288
Alxion - 145STK2M	5250	1860	2700	14	7950	13200
Alxion - 145STK4M	5710	2280	2900	14	8610	14320

See next slide for details

Parker - NK620

Rotor banding (done by Alxion)

Supplier – Model	Price for 1, EUR	Price for 2, EUR
Parker - **NKD620EKxR1000**	---	---
Kollmorgen - KBM-35X02	1078	2157
Alxion - 145STK2M	2710	4060
Alxion - 145STK4M	3150	4880

Delivery time for standard models: Alxion – by 30.10; Kollmorgen – app. 7 weeks.

** - ALXION will be closed for vacation from August 3rd until August 21st included*

Quotation from Parker

- Still no official offer received
- Torque margin for the proposed model is minimal (4%), the model with higher torque was requested in June
- Offer sent for the model **NKD620EKxR1000 (R1000?)**
- Waiting for reply from engineering department of Parker

Parker - NK620

Conclusions and questions

- One or two prototypes? Do we buy from 1, 2 or 3 suppliers? *Test data can be used later as a justification fro purchase of series*.
- More time needed to receive final quotation from Parker (however the delivery time is 10 weeks vs. 14/16 for other suppliers)
- Price difference is minor for prototypes (Kollmorgen vs. Alxion) but becomes significant for series
- Standard models can be purchased for first electromechanical tests (faster and cheaper)
- New test bench should be designed and built for electromechanical tests of new motors

Thank you for your attention!

Questions?

…Discussion...

Extra slides

Kollmorgen - KBM-35H02-C00 (Standard model proposed)

Technical Details:

Kollmorgen proposes the use of a standard KBM-35H02-C00 modified to meet the environmental requirements specified above. The material changes shall be:

- Convert all lead wires from Teflon insulation to Tefzel per UL 10086. These leads will be covered with Kynar tubing as the leads exit the stator encapsulation epoxy to reduce stress damage in handling.
- Internal Stator winding connections shall be insulated with Kynar tubing for long term insulation stability in the radiation environment.
- Rotor Core shall be constructed of solid 416 series stainless steel.
- Rotor Magnets shall consist of Sm2Co17 magnet material. The magnets shall be secured with a low outgassing adhesive compliant with ASTM 595. This adhesive is used as an assembly aid to secure the magnets to the rotor during grinding and banding operations.
- The magnets shall be retained by a 300 series stainless steel band on the rotor outside diameter and 300 series stainless steel end caps.
- The Rotor Assembly shall be baked at 200°C for 2 hours to drive off volatiles.
- Kollmorgen proposes the use of a full length key to secure the rotor to the CERN shaft.
- Kollmorgen shall provide a materials list and appropriate drawings after order placement.
- Mechanical and electrical interfaces will require further discussion and definition before being finalized.

Alxion - 145STK2(4)M

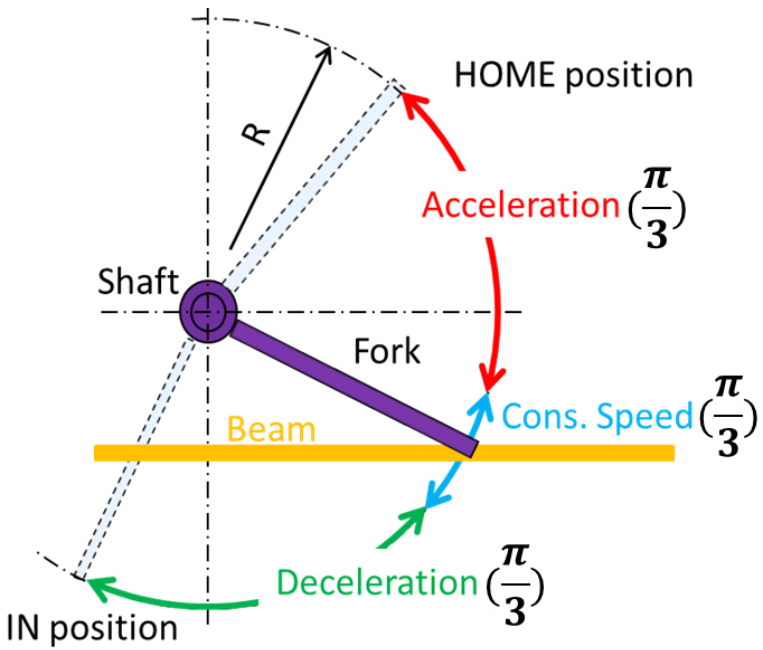
Technical details

Kit of frameless motor 145STK4M, 1500 rpm version with standard stator and special rotor.
The special rotor is constituted of a steel hub with grooves for magnets seats, covered by Sm2Co17 magnets and secured by a stainless steel sleeve on all the length:

- the Sm2Co17 magnets have magnetic characteristics equivalent to our iron-neodymium magnets used in series; they have a special shape different from a tile and have to be manufactured specifically.
- axial blocking rings are shrinked on each extremity
- the airgap has been increased of 0.4 mm at radius for compensating the sleeve thickness and insuring a 0.7 mm airgap at the radius; consequently the torque for a given current decreases of 5 to 10%
- the special rotor inertia is equal to 2.37. 10-3 Kg.m2
- the rotor does not include any glue or varnish or polymer
- the rotor alone can bear a bake-out temperature of 200°C; it is not the case of the stator that can bear 160°C maximum in windings, which is the threshold of temperature alarm through PTC resistor
- we have no idea about the capability related to ionizing radiation dose but you mentioned that a standard stator and a rotor with a steel core and mechanical fixation of the magnets would create no problems

IMPORTANT NOTE: *The key technological problem is to succeed to shrink the magnets with a stainlees steel sleeve with a good repeatability for making series. We have experimented a process that allowed to shrink a stainless steel sleeve on a rotor with our standard iron-neodymium magnets glued on the circular hub, without grooves. for magnets seats. We could not experiment the operation of shrinking a stainless steel sleeve on the special rotor with grooves in the hub for receiving Sm2Co17 magnets without glue as, at this preliminary stage, we could not experiment the assembly of those special magnets needing to be specially orderd and we did not make a special hub with grooves. According to our experience, the Sm2Co17 are brittle, more brittle than the iron-neodymium ones. It is also possible that some magnets break during sleeve shrinking. We have foreseen a certain rate of replacement of magnets but we cannot be 100% sure that no magnets particles or bit will not detach after assembly. Therefore, we shall be 100% sure about the feasibility of the rotor only once we have made the prototype.*

Torque required for acceleration of the wire scanner forks in order to achieve the velocity of 20 m/sec on the distance of 60° ($\frac{\pi}{3}$)



3 different lengths of the fork have been considered:

Option 1: **R1 = 182.5 mm**

Option 2: **R2 = 150.0 mm**

Option 3: **R3 = 100.0 mm**

Equations used for calculation:

$$\omega_f = \omega_i + \alpha t \qquad (1)$$

$$\theta = \omega_i t + \frac{1}{2}\alpha t^2 \qquad (2)$$

$$\omega_f^2 = \omega_i^2 + 2\alpha\theta \qquad (3)$$

$$\theta = \frac{1}{2}(\omega_f + \omega_i)t \qquad (4)$$

Angular speed and acceleration

	Length of the fork, m	Linear speed of the wire, m/s	Angular speed of the wire, rad/s	Acceleration (constant), rad/s^2	Peak acceleration (variable profile, k=1.85*), rad/s^2
Option 1 (R1)	0.182	20	110 (1051)	5790	10711.5
Option 2 (R2)	0.150	20	133 (1270)	8471	15671.4
Option 3 (R3)	0.100	20	200 (1910)	19108	35350.0

** - the coefficient used for calculations of the peak acceleration by C. Grosjean*

Moment of inertia of the shaft and components installed on it (based on data from S. Samuelsson)

Component	J ($kg \times m^2$) for R1 (182.5 mm)	J ($kg \times m^2$) for R2 (150 mm)	J ($kg \times m^2$) for R3 (100 mm)
Bearing 1	1.96E-05	1.96E-05	1.96E-05
Bearing 2	2.45E-06	2.45E-06	2.45E-06
Disc	1.45E-04	1.45E-04	1.45E-04
Disc holder	2.01E-05	2.01E-05	2.01E-05
Fork with fixation ring and screws	**1.56E-04**	**9.03E-05**	**3.81E-05**
Fork with fixation ring and screws	**1.56E-04**	**9.03E-05**	**3.81E-05**
Resolver	4.00E-06	4.00E-06	4.00E-06
Magnetic lock	6.61E-05	6.61E-05	6.61E-05
Rotor (old Parker motor)	3.46E-04	3.46E-04	3.46E-04
Shaft	2.91E-04	2.91E-04	2.91E-04
Total (J_{total})	**1.21E-03**	**1.07E-03**	**9.70E-04**

Summary table of calculated data for torque and acceleration

	Length of the fork, m	Required torque, Nm	Peak acceleration*, rad/s^2
Option 1 (R1)	0.182	**12.96**	10711.5
Option 2 (R2)	0.150	**16.77**	15671.4
Option 3 (R3)	0.100	**34.31**	35350.0

** - calculated by multiplication of constant acceleration by k = 1.85*