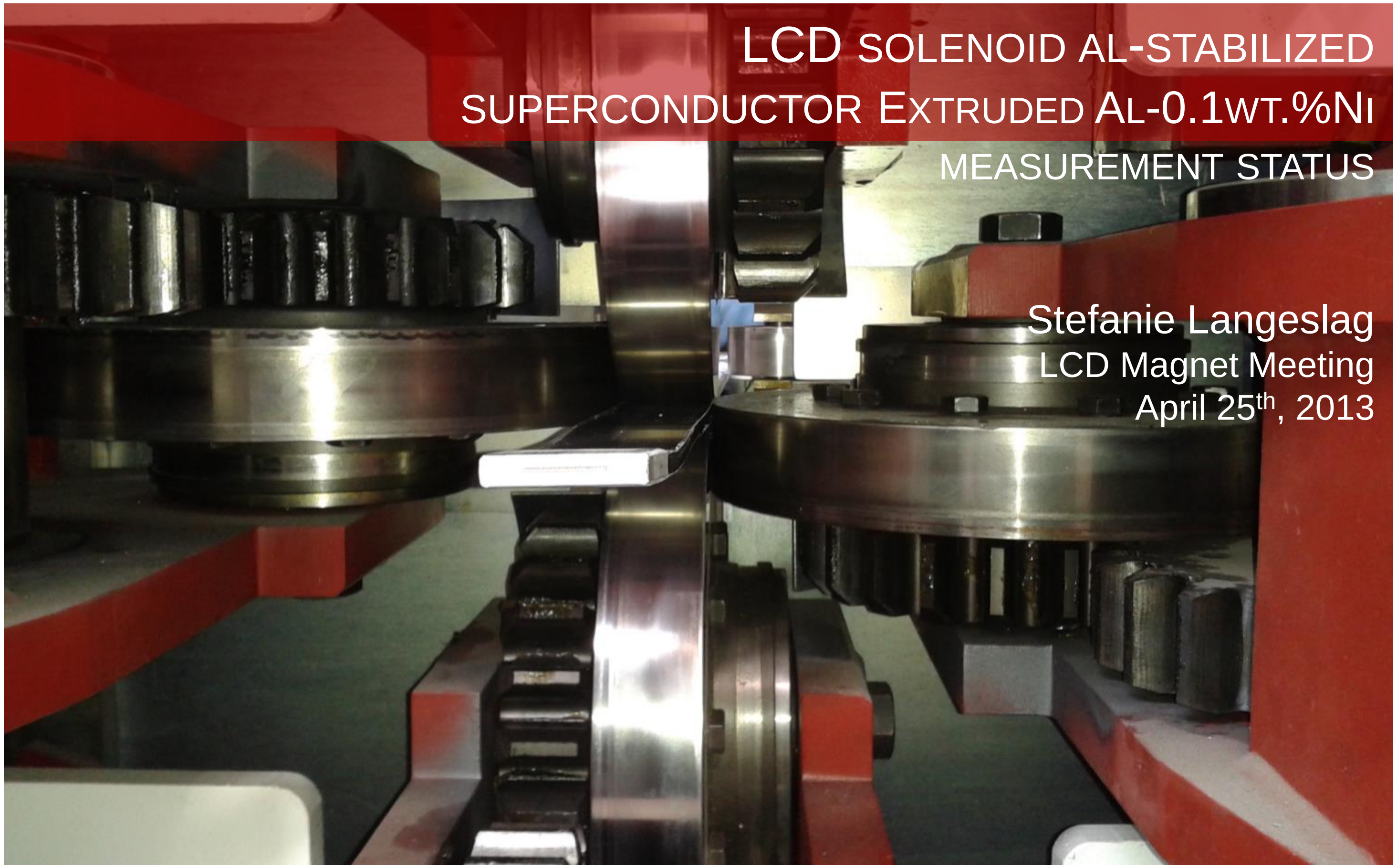
LCD SOLENOID AL-STABILIZED SUPERCONDUCTOR EXTRUDED AL-0.1WT.%NI

MEASUREMENT STATUS

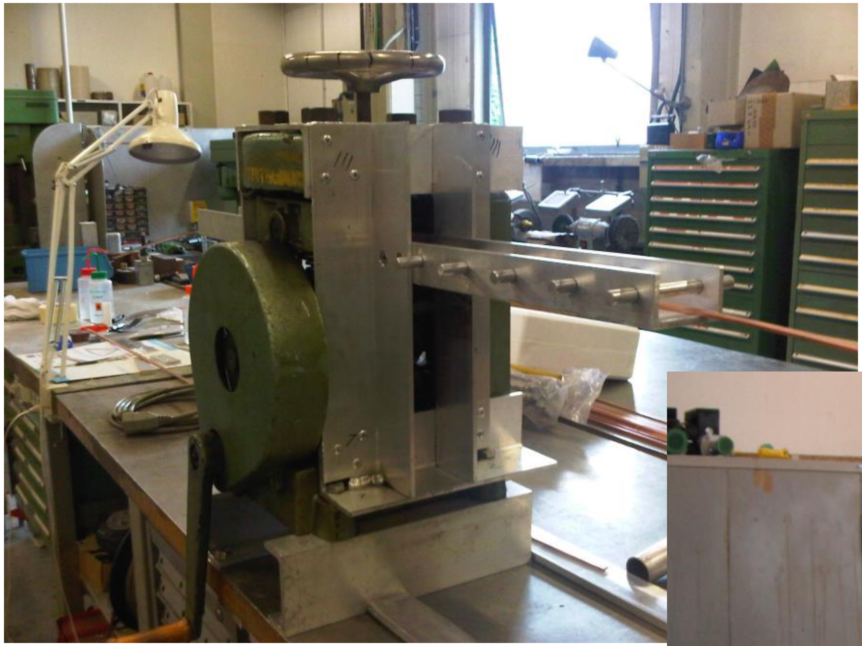


Stefanie Langeslag

LCD Magnet Meeting

April 25th, 2013

LCD SOLENOID ALUMINUM STABILIZED SUPERCONDUCTOR

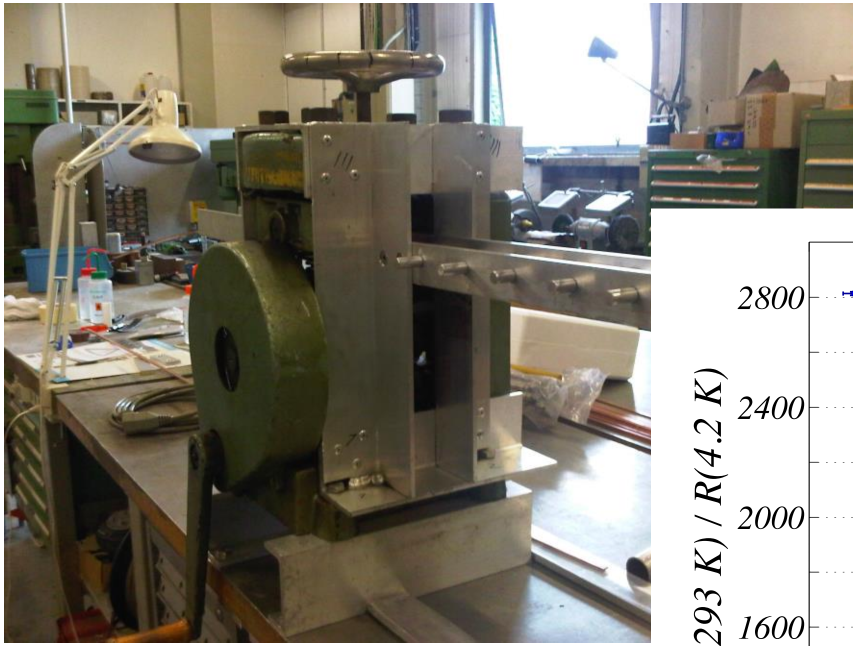


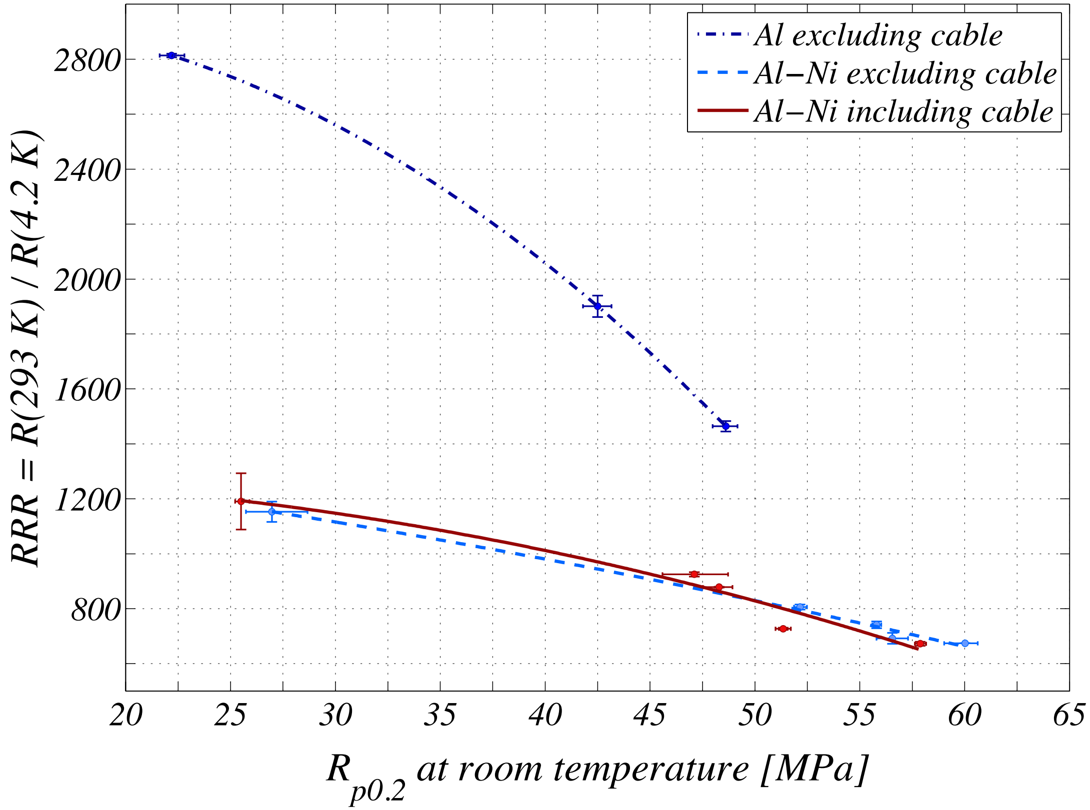
Lab-scaled work hardening here at CERN

S.A.E. LANGESLAG

UNIVERSITY OF TWENTE.

LCD SOLENOID ALUMINUM STABILIZED SUPERCONDUCTOR





Effect of lab-scaled work hardening on the mechanical and transport properties of Al and Al-0.1wt.%Ni.

S.A.E. Langeslag

UNIVERSITY OF TWENTE.

CERN

Conclusion of the results

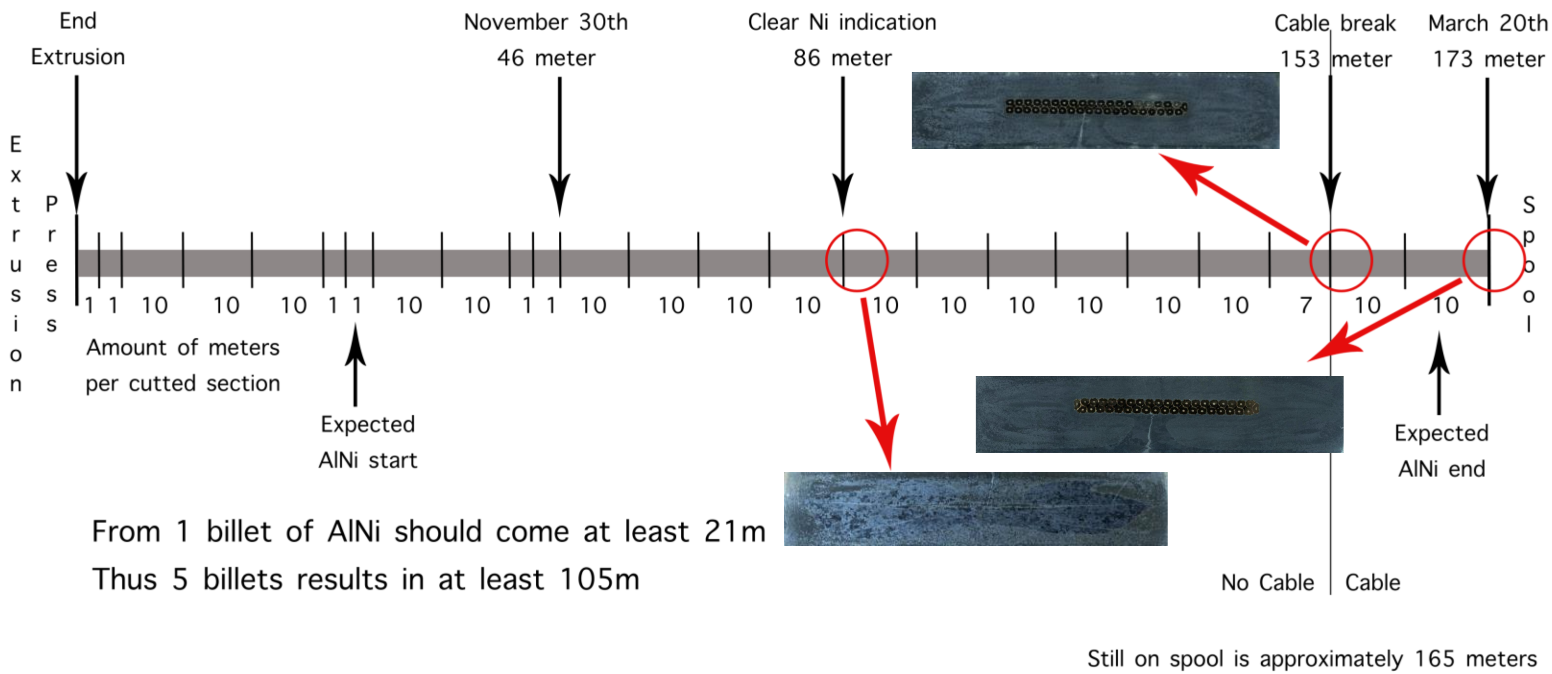
- The Al-Ni alloy extruded with Rutherford cable exhibited in the highest cold worked state of 30% an $R_{p0.2}$ of 58 and RRR of 673, which will result in an $R_{p0.2}$ of 87 MPa at 4.2 K [1].
- The obtained values are slightly lower than the gross of measurements conducted on Al-0.1wt%Ni extruded in smaller cross-sections in the development of the ATLAS and CMS solenoid conductor [1-4].
- A cautious conclusion to be further verified is that increased cross-section extrusions result in decreased work hardening effects.

[1] S. Sgobba, D. Campi, B. Cure, P. El-Kallassi, P. Riboni, and A. Yamamoto, "Toward an improved high strength, high RRR CMS conductor," in IEEE Transactions on Applied Superconductivity, pp. 521–524, ETH, CH-8092 Zurich, Switzerland, 2006.
[2] K. Wada, S. Meguro, H. Sakamoto, T. Shimada, Y. Nagasu, I. Inoue, K. Tsunoda, S. Endo, A. Yamamoto, Y. Makida, K. Tanaka, Y. Doi, and T. Kondo, "Development of high-strength and high-RRR aluminum- stabilized superconductor for the ATLAS thin solenoid," IEEE Transactions on Applied Superconductivity, vol. 10, no. 1, pp. 373–376, 2000.
[3] K. Wada, S. Meguro, H. Sakamoto, A. Yamamoto, and Y. Makida, "High-strength and high-RRR Al-Ni alloy for aluminum-stabilized superconductor," in IEEE Transactions on Applied Superconductivity, pp. 1012–1015, Furukawa Elect Co Ltd, Nikko, Japan, 2000.
[4] A.Yamamoto, Y.Makida, K.Tanaka,and Y.Doi, "Development towards ultra-thin superconducting solenoid magnets for high energy particle detectors," Nuclear Physics B, vol. 78, pp. 565–570, 1999.

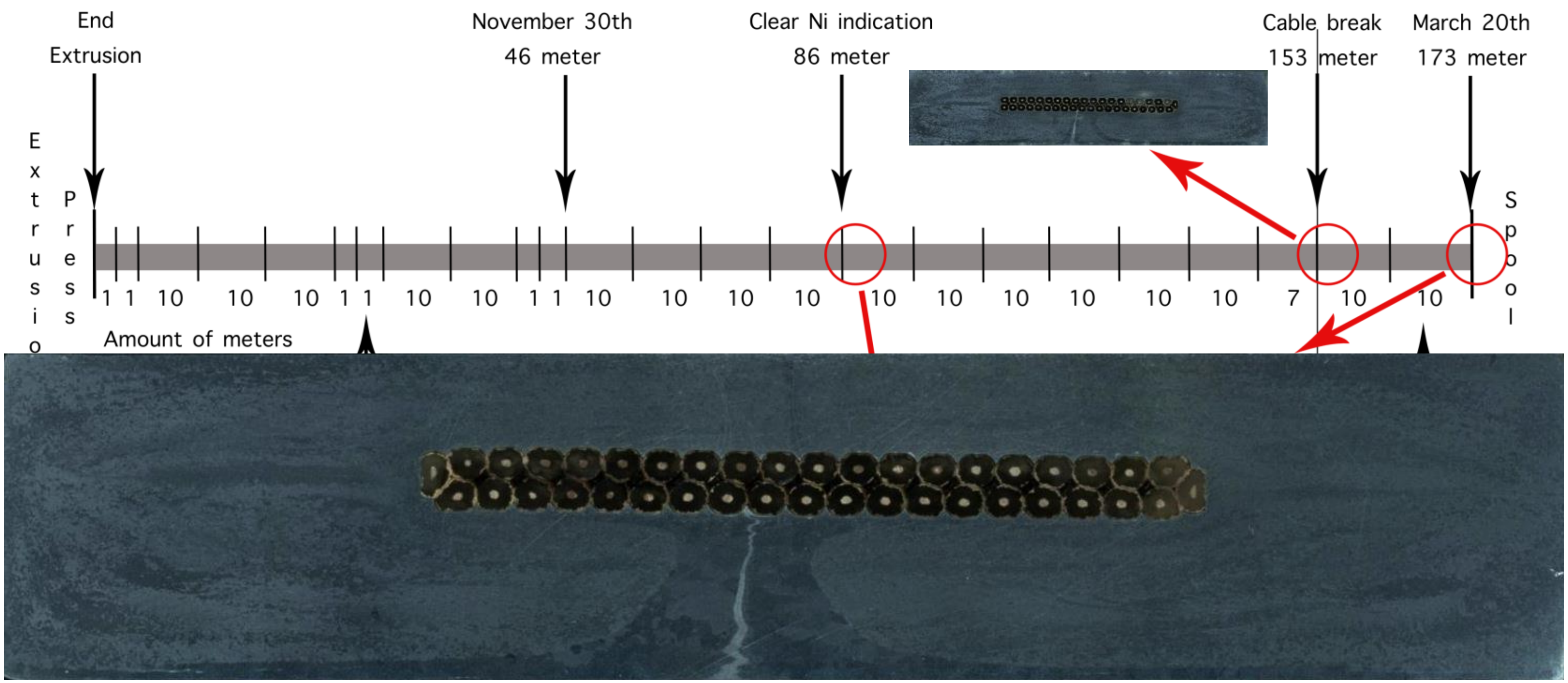
Conclusion of the measurements

- For an initial determination of work hardening on the properties of the material the current work-hardening method proved to be sufficient.
  - However, for a determination of bonding characteristics and critical current degradation with cold work, a more industrial scale work-hardening method should be found.
- For a more satisfying specification of properties of the entire conductor, microstructure and hardness measurements along the entire cross-section should be made.
  - Grain sizes should be determined in at least two planes in a highly cold-worked state.

LCD SOLENOID ALUMINUM STABILIZED SUPERCONDUCTOR

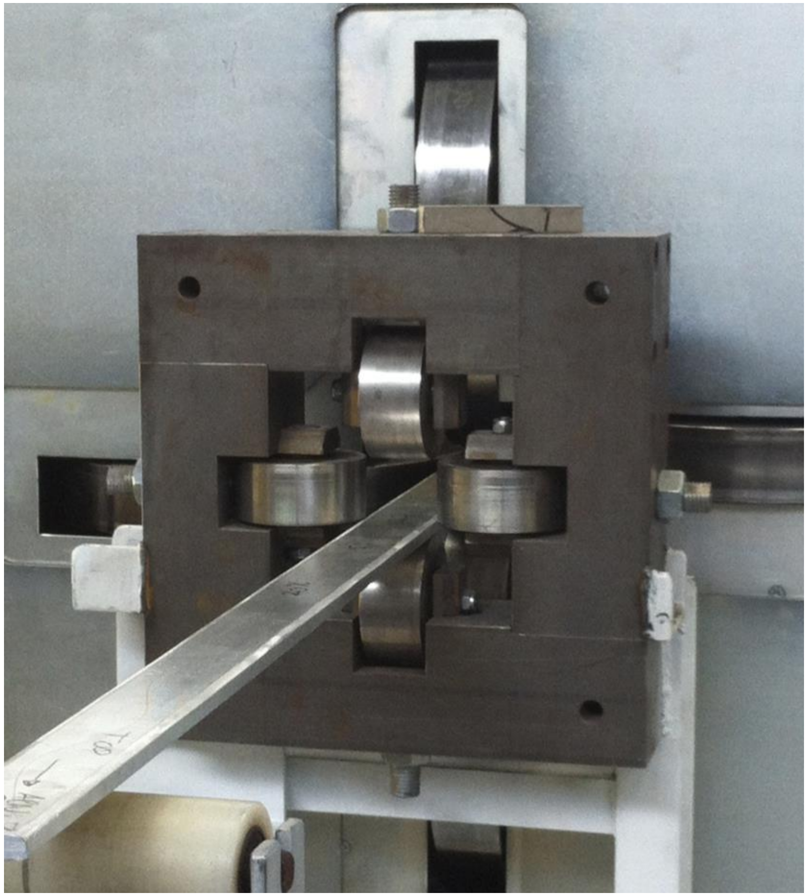


LCD SOLENOID ALUMINUM STABILIZED SUPERCONDUCTOR



Cold work; Industrial scale

- Cryotech, Chivasso (Italy)
- ENEA; Antonio della Corte
- 11 samples (1,5 meter)



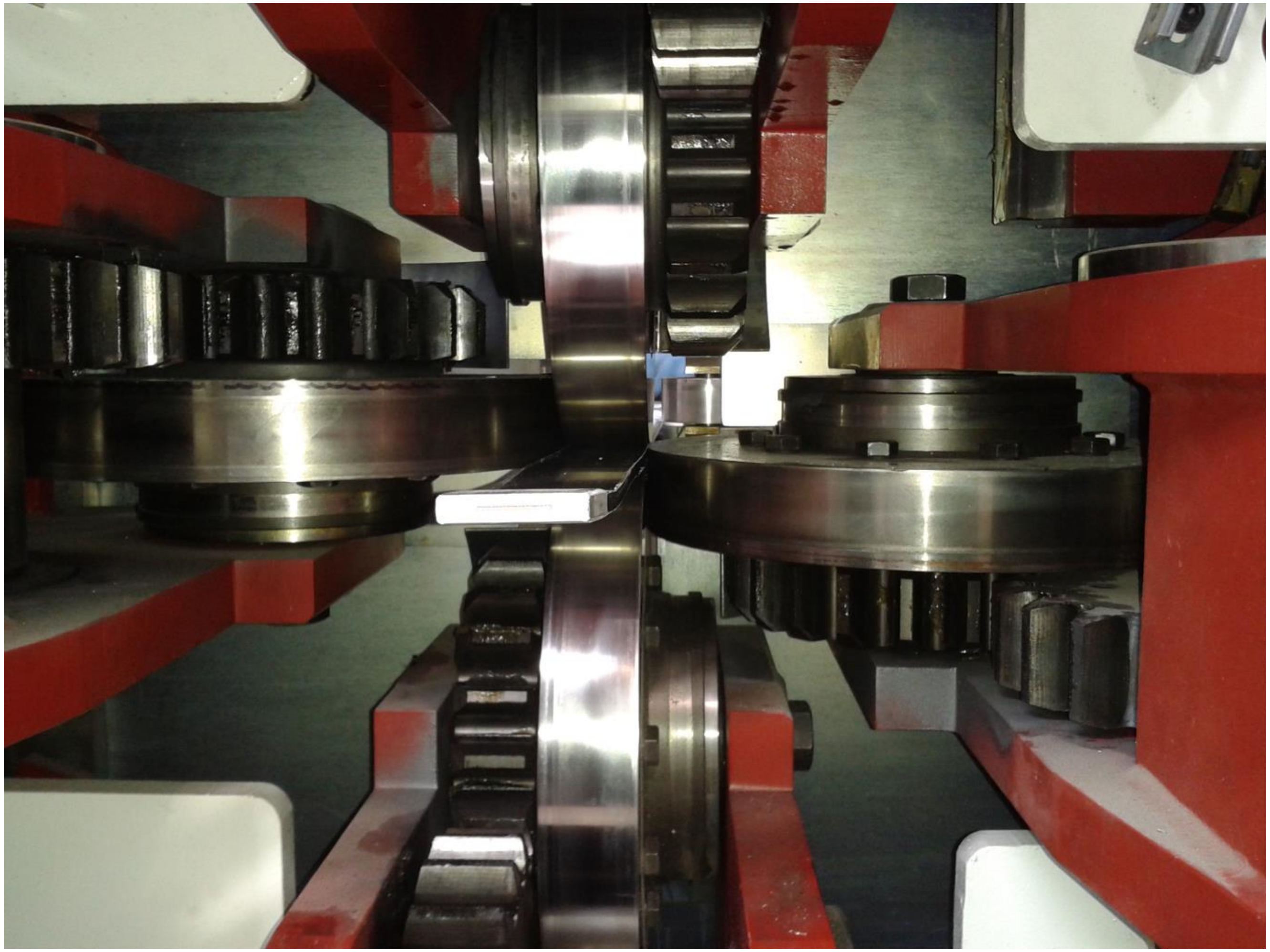
Inlet Turk-head rolling machine Cryotech, Chivasso (IT)

Table 1: Samples for Turk-head rolling at Cryotech, Chivasso

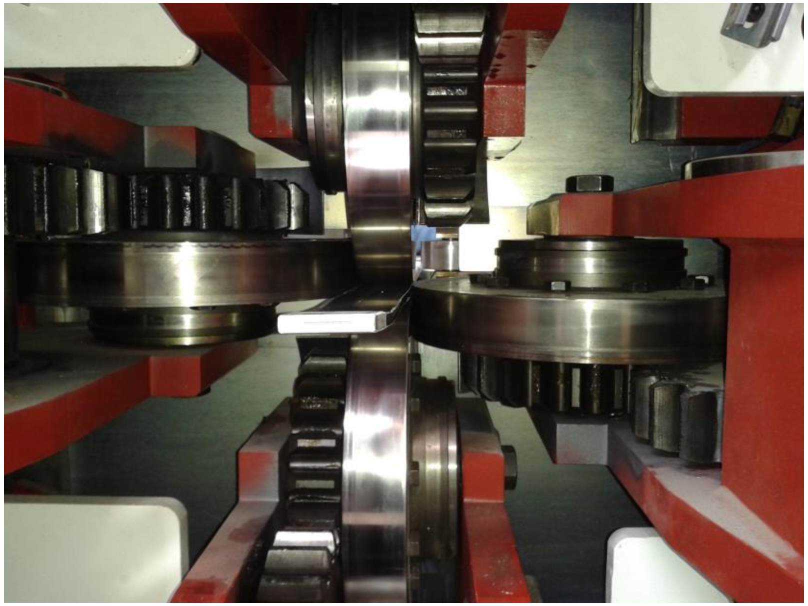
Material	Sample	CW	Passes	Reduction distribution	Experiment
$AlNi^{+1}$	PT1	35% reduced	1 pass	confined width	effect of % reduction
	PT2	30% reduced	1 pass	confined width	effect of % reduction
	PT3	25% reduced	1 pass	confined width	effect of % reduction
	PT4	20% reduced	1 pass	confined width	effect of % reduction
$AlNi^{+2}$	PT5	20% reduced	2 passes contra	confined width	effect of directionality and amount of passes
	PT6	20% reduced	2 passes 1 contra & 1 extr. dir.	confined width	effect of pass direction
	PT7	20% reduced	1 pass	homogeneously reduced	effect of reduction direction
	PT8	15% reduced	1 pass	confined width	effect of % reduction
	PT9	-	-	-	spare
ATLAS BT	PT1	20% reduced	1 pass	confined width	reference
	PT2	-	-	-	equipment adjustment & spare

LCD SOLENOID ALUMINUM STABILIZED SUPERCONDUCTOR

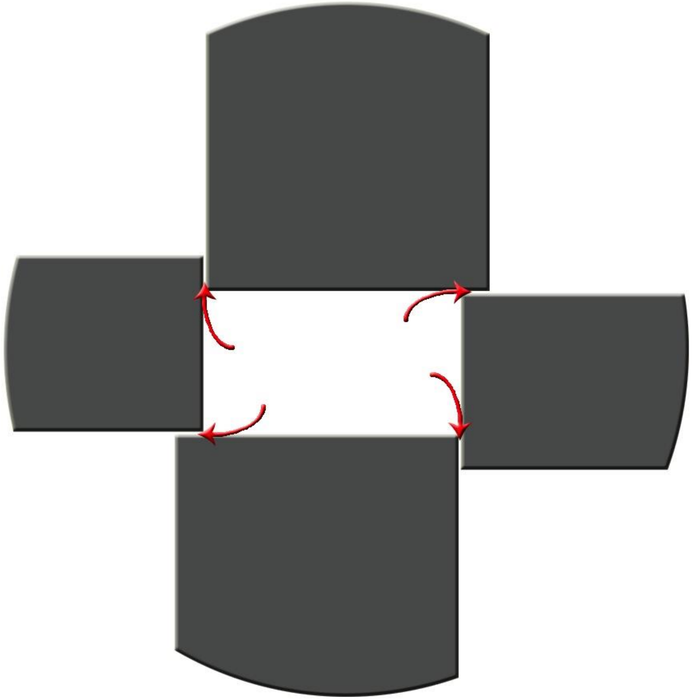
LCD SOLENOID ALUMINUM STABILIZED SUPERCONDUCTOR



LCD SOLENOID ALUMINUM STABILIZED SUPERCONDUCTOR



Schematic drawing of sample with burrs.



Roller configuration

Measurement goals

- Verifying results lab-scaled work hardening
- Effect of Turk-head rolling
- Grain directionality with rolling direction
- Bonding quality assessment with work hardening
  - Empa; Jürg Neuenschwander
  - Ultrasonic testing
- Verifying enhancement mechanical properties at cryogenic temperature
- Heat treatment effects
  - Treatment below recovery temperature
  - Solid solution heat treatment -> Quenching -> Precipitation hardening

LCD SOLENOID ALUMINUM STABILIZED SUPERCONDUCTOR

TEST	WHAT TO ACHIEVE	SAMPLES						SPECIMEN total
RRR	Check results of lab-scaled CW	15% (wc,1p)	20% (wc,1p)	25% (wc,1p)	30% (wc,1p)			14
	RRR with amount of CW steps	20% (wc,1p)	20% (wc,2c)	30% (wc,1p)	30% (wc,3c)			
	RRR with CW at 35%	35% (wc,1p)						
	RRR lapse with heat treatment	HT 100°C	HT 130°C	HT 160°C	HT 200°C	HT SS->PH		10
TENSILE	Check results of lab-scaled CW	15% (wc,1p)	20% (wc,1p)	25% (wc,1p)	30% (wc,1p)			18
	Stress-strain with amount of CW steps	30% (wc,1p)	30% (wc,3c)					
	Stress-strain with CW at 35%	35% (wc,1p)						
	Relation s-s warm vs. s-s cold	0%	20% (wc,1p)	30% (wc,1p)				15
	Stress-strain with heat treatment	HT 100°C	HT 200°C					6
BONDING	Bonding quality with CW	0%	15% (wc,1)	20% (wc,1p)	25% (wc,1p)	30% (wc,1p)	35% (wc,1p)	16
	Bonding quality with amount of CW steps	20% (wc,1p)	20% (wc,2c)	30% (wc,1p)	30% (wc,3c)			
	Bonding quality with application direction CW	20% (wc,1p)	20% (ho,1p)					
OPTICAL	Check results of lab-scaled CW	Al 20% (wc,1p)	20% (wc,1p)					5
	Microstructure with application direction CW	20% (wc,1p)	20% (ho,1p)					
	Microstructure with rolling direction	20% (wc,1p)	20% (wc,2c)	20% (wc,2ce)				
	Microstructure with heat treatment	HT 100°C	HT 130°C	HT 160°C	HT 200°C	HT SS->PH		5
VICKERS	Hardness mapping along cross-section	0%	20% (wc,1p)	Al 0%	Al 20% (wc,1p)			5
HARDNESS	Hardness mapping with application direction CW	20% (wc,1p)	20% (ho,1p)					
	Hardness with heat treatment	HT 100°C	HT 130°C	HT 160°C	HT 200°C	HT SS->PH		5

LCD SOLENOID ALUMINUM STABILIZED SUPERCONDUCTOR

April 22 Drop-off material first batch	23 Determine HT Prepare LCD presentation	24 Determine HT Prepare LCD presentation	25 Prepare material HT Heat treatment LCD workgroup presentation	26 Prepare material HT Heat treatment
29 Heat treatment	30 Pick-up samples first batch Heat treatment	May 1 Labour Day	2 Prepare material Empa Heat treatment	3 Send material Empa Heat treatment Prepare second batch material
6 Drop-off second batch material RRR first batch Tensile tests RT first batch	7 RRR first batch Alex using tensile machine	8 RRR first batch Tensile tests RT first batch	9 Ascension Day	10 RRR first batch Tensile tests RT first batch
13 ESLM meeting	14 Alex using tensile machine 1 dewar helium ordered	15 Alex using tensile machine	16 Cryogenic tensile tests 1 dewar helium ordered	17 Cryogenic tensile tests
20 Pentecost Roparun	21 Roparun	22 Roparun	23 RRR second batch Tensile tests RT second batch	24 RRR second batch Tensile tests RT second batch
LC workshop 27 RRR second batch Tensile tests RT second batch	LC workshop 28 Talk LC workshop	LC workshop 29	LC workshop 30 RRR second batch Tensile tests RT second batch	LC workshop 31 RRR second batch Tensile tests RT second batch
June 3	4	5	6	7
10	11	12	13	14
CEC/ICMC 17	CEC/ICMC 18	CEC/ICMC 19	CEC/ICMC 20	CEC/ICMC 21