ELECTRODE MANAGEMENT – INVESTIGATION INTO SOFT BREAKS AT 48MVA FeCr CLOSED FURNACE

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ABSTRACT

Good operation of Soderberg electrodes is dependent upon high quality electrode paste coupled with better electrode management procedures. Without having a good electrode operation, it is not possible to obtain the best outcome from the furnace. In other words that is a good way to say how important the proper electrode operation is. Good electrode performance depends on the slipping rate and current levels, which decides the shape of the baking curve at the level of just below the contact clamps.

Negative curvature of baking zone in the central part is considered dangerous because shrinkage takes place outwardly creating abnormal stresses in the electrode. Soft breakages occur when the baking zone comes below the clamps and the casing cannot take the current.

This paper deals with various factors affecting baking characteristics leading to soft breakages and also presents case studies in a closed 48MVA furnace with smelting for charge chrome.

In case studies in a closed furnace, it has happened that the energy for baking at the low current operation before breakage has been lower than the actual slipping has demanded. At low current there should not be problem, but a problem can occur when the current for some period is raised above the current carrying capacity of the casing. So data for electrode operation in actual period was studied and presented in this paper.

1. INTRODUCTION

The production of metal in the furnace is our real process. However, it is quite justified to call the Soderberg Electrode in itself a process: a " Process within the process" which has several features characteristic for many processes:

- It is continuous
- It requires raw materials, the quality of which is critical to the process
- Monitoring and control are required to ensure optimal operation without disruption.
- The "Product" from the electrode process is the ability to carry current from the electrode holder and down into the smelting zone.

There are four areas in particular that need attention for a good electrode operation.

- The condition for softening and liquefaction of the electrode paste.
- The current load on the electrode, which has its limitation dependent on the electrode diameter.
- Change in operating conditions (reduce load level, shutdown, recovery), which cause the temperature distribution to change and mechanical stresses ("thermal" stresses) to develop, with the risk of hard breakage to occur.
- The electrode consumption, which determines the need for slipping and baking of new electrode. High consumption in relation to the baking capacity may cause the baking zone to get too low, with

the risk of breakage in the un-baked part of the electrode as a consequence: “Soft breakage”.

In general, soft breakage or paste leakage can happen because of the following reasons.

i) Mechanical failure in casing (fig.1)

- Design (thickness, steel quality, “window” size / distance
- Welding

ii) Burning of casing too early (fig.1)

- Too fast slipping
- Too slow baking

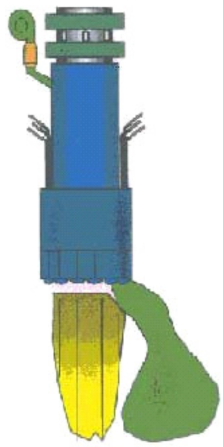

Figure 1

iii) If too high current in steel casing (fig.2)

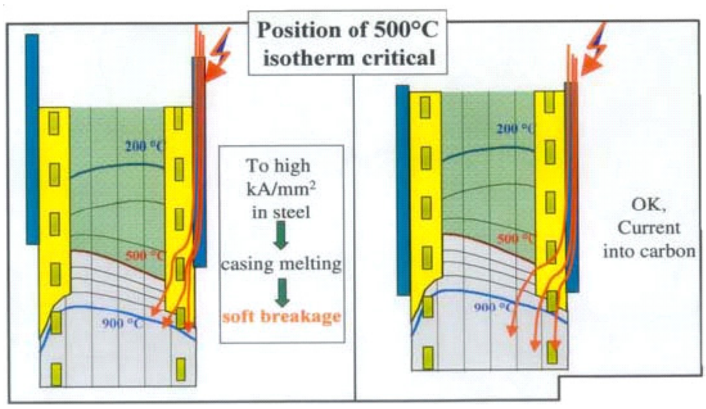

Figure 2

iv) Position of 500 deg. C isotherm (fig-3):

- 500deg. C isotherm can be predicted and controlled

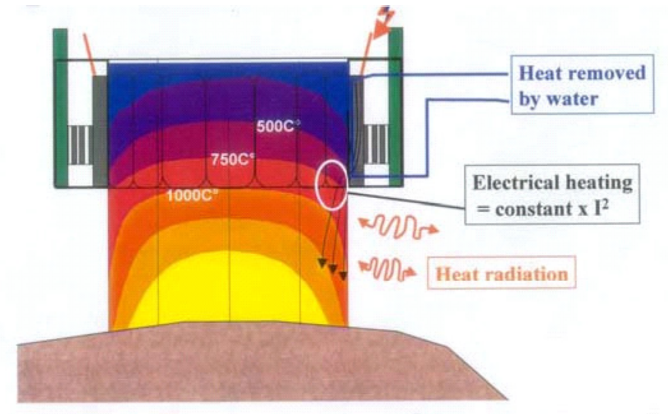

Figure 3: Position of 500deg.C isotherm

In this paper, it is dealt with the case studies of soft breakages including the discussion about the baking and slipping details of electrodes during that time.

DATA OF ELECTRODE AT IMFA, CHOUDWAR:

Electrode Diameter	: 1.55m
Electrode Current, Normal	: 90 kA
Electrode Current, Max.	: 93 kA
Slipping rate, Normal	: 0.5m/day

ELECTRODE CASING:

Type of casing	: Cylindrical
Welding to the electrode column, method	: Welding of fins
Thickness of sheet in casing, mm	: 3.15
Thickness of sheet in fins, mm	: 3.15
Number of fins	: 14
Width of fin, mm	: 310
Fin foot, mm	: 40
Width of windows, mm	: 50
Height of windows, mm	: 130
Steel area outer casing & fin foot, mm2	: 16260
Net steel area fins, mm2	: 10920
Total net steel area casing, mm2	: 27180
Current carrying capacity of casing, kA	: 68

ELECTRODE SLIPPING RATE:

Max. slipping, mm/A2*h	: 2.65E-09
Safe slipping at max. el. current, m/day	: 0.44
Max. slipping at max. el. current, m/day	: 0.55
Current density at normal current, A/cm2	: 4.8
Current density at max., A/cm2	: 4.9

Two cases have been chosen for study of **soft breaks** and the details are given case wise.

2. CASE – 1

2.1 Description of electrode condition at the time of soft break (date of breakage 11th Sep'02)

On 11th Sep'02, at 12:30hrs. black fumes marked over the top of the casing. During inspection after furnace was switched off, it was observed that liquid paste was leaking just below contact clamp tip from electrode no.2 and spread over all around the furnace top. Paste level was measured and found minus side 0.6mtr (i.e. below top of the contact clamp). Furnace was partially dug out to clear the molten paste which was spread all over. A new casing in conical shape was welded from the bottom for rebuilding of the electrode before restart of the furnace. It took total 06 days furnace shutdown to make ready for switching on.

Relevant data for electrode operation in actual period and one day before of breakage is submitted along with Electrode model.

2.2 Critical data for electrode operation

Table 1

Date	*Time*	*E1*	*E2*	*E3*	*Time*	*E1 slipping*	*Time*	*E2 slipping*	*Time*	*E3 slipping*
	In hrs.	*kA*	*kA*	*kA*	*In hrs.*	*In mm*	*In hrs.*	*in mm*	*In hrs*	*in mm*
10th Sep'02	06.00am	94	95	94			6.15	20		
	7.00	94	95	95	7.15	20	7.30	20	7.00	20
	8.00	94	96	96	8.30	20	8.45	20		
	9.00	96	96	96	9.45	20			9.00	20
	10.00	96	95	96			10.00	20		
	11.00	94	94	96	11.00	20	11.15	20	11.00	20
	12.00	94	92	96	12.15	20	12.30	20	12.30	20
	13.00	94	92	94	13.30	20	13.45	20		
	14.00	94	92	90	14.45	20			14.00	20
	15.00	92	95	91			15.00	20	15.15	20
	16.00	88	93	94	16.00	20	16.15	20	16.30	20
	17.00	95	92	96	17.15	20	17.30	20	17.45	20
	18.00	93	92	94	18.30	20	18.45	20		
	19.00	90	95	88	19.45	20			19.00	20
	20.00	95	95	93		20	20.00	20	20.15	20
	21.00	94	94	94	21.00	20	21.15	20	21.30	20
	22.00	95	96	93	22.15	20	22.30	20	22.45	20
	23.00	95	93	93	23.30	20	23.45	20		
	24.00	87	95	90	24.45	20			24.00	20
	1.00	95	96	79	2.10	20	1.00	20	1.15	20
	2.00	84	96	96	2.30	20	2.15	20	2.30	20
	3.00	90	92	96	3.15	20	3.30	20	3.45	20
	4.00	92	79	78	4.30	20	4.45	20		
	5.00	94	84	78	5.45	20			5.00	20
	6.00	90	84	80			6.00	20		
11th Sep'02	06.00am	90	84	80					6.15	20
	7.00	88	80	70	7.00	20	7.15	20	7.30	20
	8.00	92	93	93	8.15	20	8.30	50	8.45	50
	9.00	88	88	80	9.30	20	9.45	20		
	10.00	92	88	92	10.45	20			10.00	20
	11.00	96	80	86			11.00	20	11.15	50
	12.00	96	84	88	12.00	40	12.15	20	12.30	20

Black fumes observed at E2 casing at 12.57hrs.

2.3 Electrode Current and slip hours before breakage (fig-4)

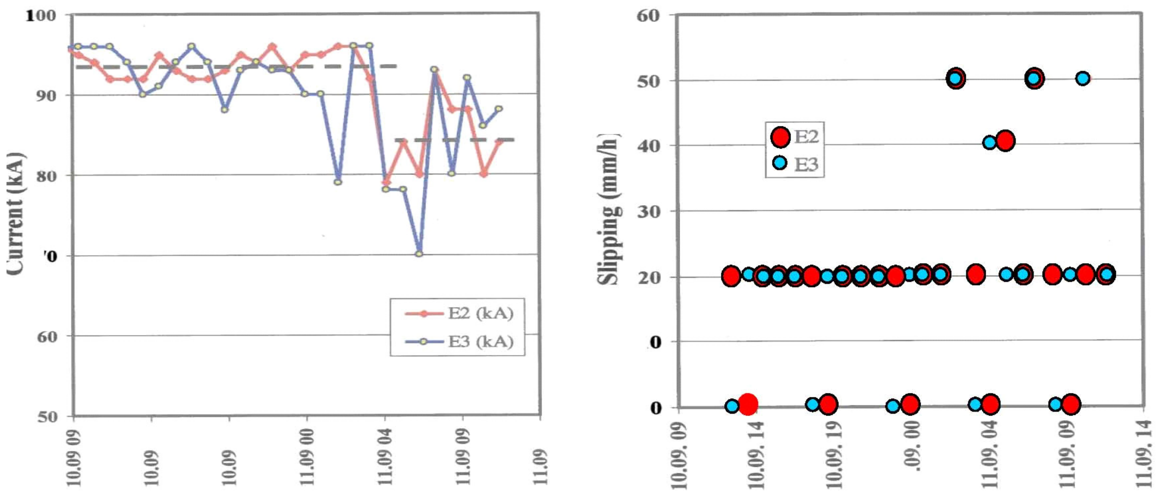

Figure 4

2.4 Calculated slip index "last 8 hours" (fig –5)

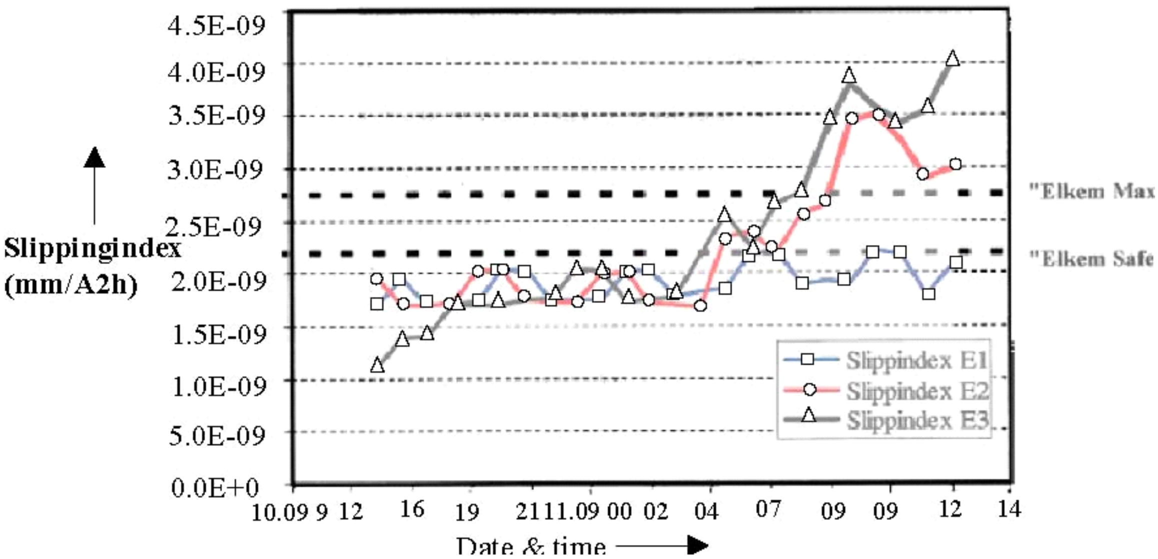

Figure 5

2.5 Temperatures calculated with Elkem electrode model for electrode -2 (fig – 6)

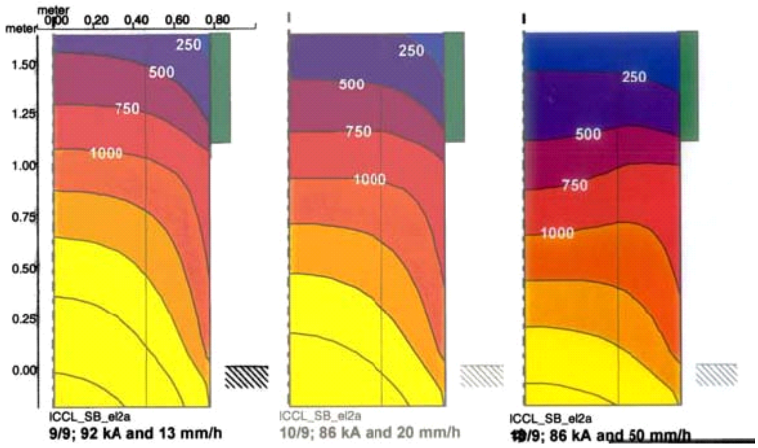

Figure 6
(The temperature of the electrode model is calculated on day average current basis)

2.6 Electrode 2 Vs. Electrode 3 (fig – 7)

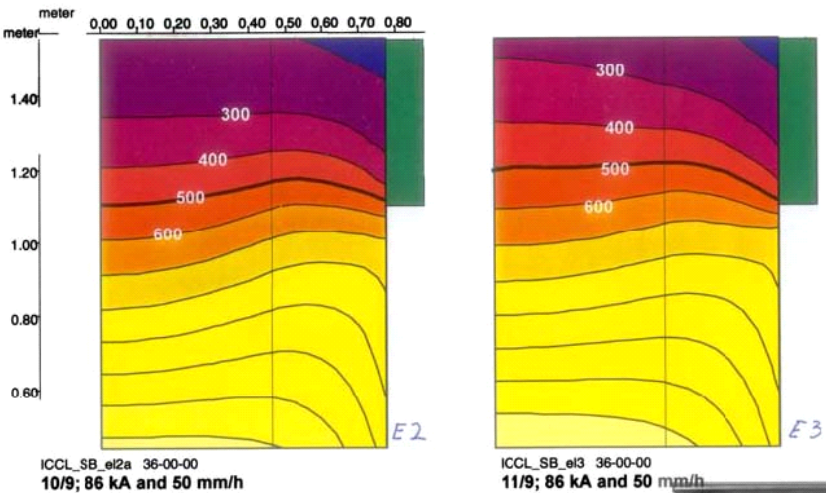

Figure 7
(The temperature of the electrode model is calculated on day average current basis)

2.7 Conclusion (CASE-1)

It is clearly evident from the above analysis that the soft breakage has happened due to:

- Slipping faster than baking rate
- 500deg.C isotherm has moved towards tip of the holder
- Current in casing and fins higher than tolerated
- .Steel casing / fin melted
- Paste flown out and baked part fallen down
- Except the above, remaining all electrode management parameters like casing design, paste management found maintained as per requirement.

3. CASE – 2

3.1 Description of electrode condition at the time of soft break (date of breakage 26th Apr'05)

In this case also, liquid paste was observed leaking through the casing holes below the contact clamp tip where casing was punctured. Paste level was measured and found minus 0.2mtr i.e. below the contact clamp top position. This time, it took 04 days to clear total leaked paste all around the electrode to switch on the furnace with all necessary arrangements.

3.2 Data presented before the breakage relating to currents, slipping and paste temperature

Table 4

Date	*Time in Hrs*	*Electrode current (kA)*			*Slipping in mm In hrs. (Slipping/time in hrs)*		
		E1	*E2*	*E3*	*E1*	*E2*	*E3*
24/04/2005	6:00	64	74	62	20	20	
	7:00	60	60	60			20
	8:00	73	72	65		20	
	9:00	72	73	67			20
	10:00	70	65	65	20	20	
	11:00	75	77	76			20
	12:00	77	72	68		20	
	13:00	80	80	65			20
	14:00	66	71	67	20	20	
	15:00	80	79	70			20
	16:00	75	61	67		20	
	17:00	72	67	65	20		20
	18:00	64	64	59		20	
	19:00	75	81	63			20
	20:00	81	60	52	20	20	
	21:00	83	73	78			20
	22:00	73	83	73		20	
	23:00	78	82	75	20		20
	0:00	80	80	78		20	
	1:00	76	76	65			20
	2:00	70	69	56	20	20	
	3:00	80	71	66			20
	4:00	73	79	43		20	
	5:00	65	73	50	20		20
	6:00	61	66	40		20	
25/04/2005	6:00	61	66	40		20	
	7:00						
	8:00	46	48	12			20
	9:00	60	70	30	20	20	
	10:00	64	72	24			
	11:00	62	70	22		20	20
	12:00	60	46	24	20		
	13:00	52	62	32		20	
	14:00	64	68	36			20
	15:00	66	70	50	20	20	
	16:00				(15:30)		

Table 4 (Continued)

Date	*Time in Hrs*	*Electrode current (kA)*			*Slipping in mm In hrs. (Slipping/time in hrs)*		
		E1	*E2*	*E3*	*E1*	*E2*	*E3*
	17:00	72	65	58		20	20
	18:00	65	75	74	20		
	19:00	70	77	83	(18:30)	20	20
	20:00	78	78	78			
	21:00	76	65	63	20	20	20
	22:00	77	65	67	(21:30)		
	23:00	56	60	75		20	20
	0:00	74	67	65	20		20
	1:00	65	77	85	(00:30)	20	(00:45)
	2:00	72	67	68			20
	3:00	75	70	68	20	20	(02:30)
	4:00	69	73	70	(03:30)		20
	5:00	72	64	68		20	(04:30)
	6:00	73	66	64			
26/04/2005	6:00	73	66	64	20		20
	7:00	72	60	62	(06:30)	20	(06:30)
	8:00	76	70	78			20
	9:00	60	68	72	20	20	(08:30)
	10:00	56	58	62	(09:30)		20
	11:00	72	68	80		20	(10:15)
	12:00	80	82	77	20		20
	13:00	65	60	62	(12:30)	20	
	14:00	78	58	68			20
	15:00	66	50	64	20		
	16:00	74	65	66			
	17:00	62	54	66			
	18:00	66	72	60			
	19:00	70	68	60			
	20:00	72	66	68			
	21:00	70	72	68			
	22:00	62	62	64			
	23:00	71	61	77			
	0:00	84	70	65			
	1:00	68	69	83			
	2:00	64	64	75			
	3:00	69	58	84			
	4:00	Shutdown for E-3 green breakage at 03:40 hrs					
	5:00	-	-	-	-	-	-
	6:00	-	-	-	-	-	-

(E1-Electrode 1, E2-Electrode 2, E3-Electrode 3)

Apr'05

		Paste Level (Mtr.)		*Charging*			*Temperature (Deg. C)*		*Load*	*Current.*	*Remarks*
	El. No	*Before Filling*	*After Filling*	*Cylinder No.*	*Broken Paste (Kg)*	*Cyl Height In Mtr.*	*Fins*	*Cyl. Top*	*Mw*	*Ka*	
23-04-05	E-1	2.8	3.1	-	750	3.3	55	47	37.5	78	Normal
	E-2	3.0	3.1	-	250	5.2	55	46	37.5	75	Normal
	E-3	3.0	3.1	-	250	-	56	50	37.5	63	Normal
24-04-05	E-1	3.0	3.1	-	250	-	55	-	37.5	78	Normal
	E-2	2.8	3.1	-	750	4.6	57	48	37.5	81	Normal
	E-3	2.7	3.0	6	750	8.4	60	32	37.5	68	Normal
25-04-05	E-1	3.0	3.1	-	250	-	57	-	28	70	Normal
	E-2	2.9	3.1	-	500	4.2	57	50	28	74	Normal
	E-3	3.1	3.2	3	250	8.4	60	35	28	30	Slightly liquid
26-04-05	E-1	2.9	3.1	5	500	7.7	58	32	37.5	72	Normal
	E-2	2.9	3.1	2	500	5.5	57	50	37.5	78	Normal
	E-3	3.3	3.3	-	-	6.6	57	36	37.5	70	Normal

3.3 Presentation of above data (in fig – 9 & 10)

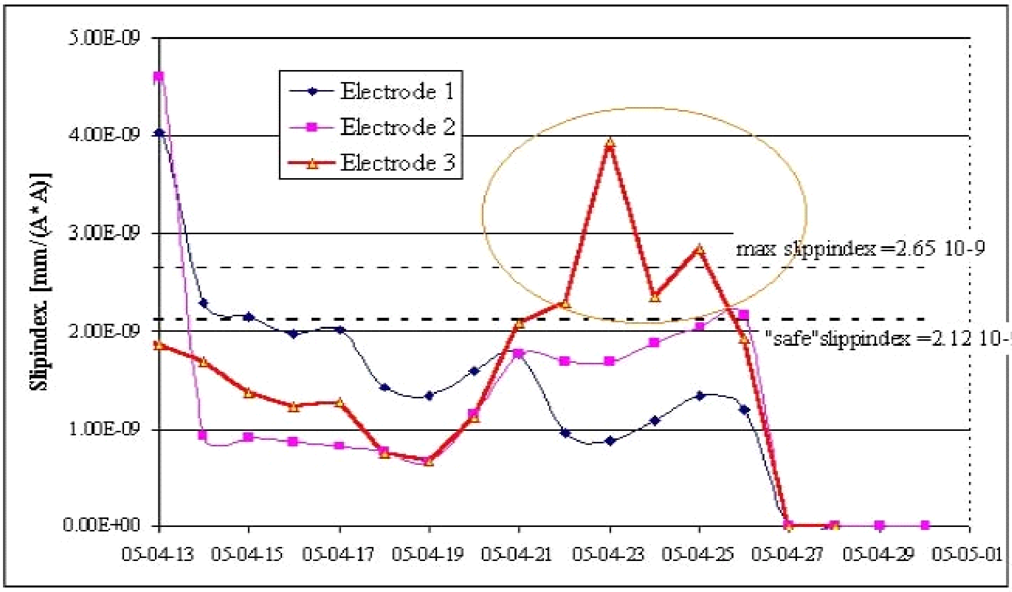

Figure 9

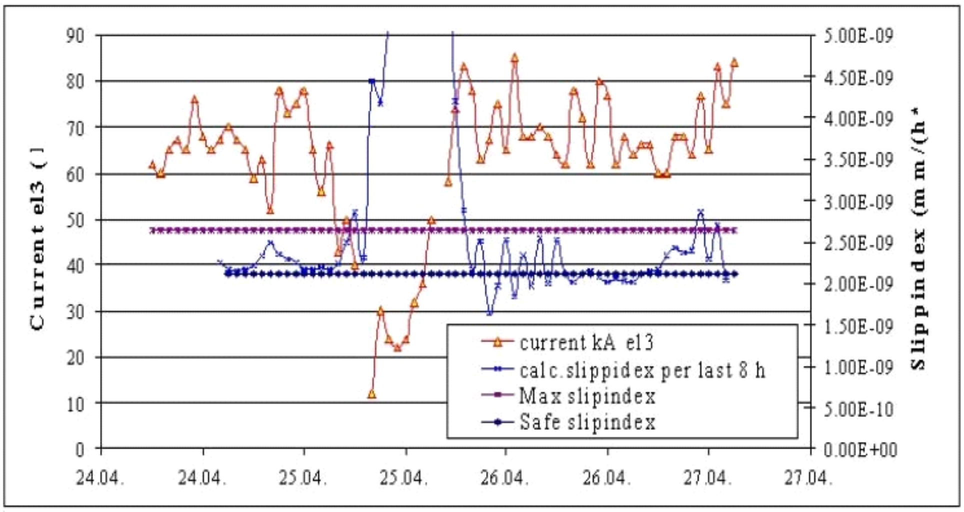

Figure 10

3.4 Discussion of the reasons

The data indicates that baking zone had been in a marginal position for long time before the breakage and when followed with high current peaks for short time before breakage there was burning and some holes formation in casing caused the leakage.

During the 09hours following the short shutdown 25th Apr'05 at 07.00hrs the current on electrode 3 was very low and has contributed to a lowering of the baking zone.

The slipping was not high but it was expected that the baking zone has moved downwards in this period. But problem can arise if the current in a period with low baking zone gets higher than the CCC (Current Carrying Capacity) and that happened also at 19.00 hrs. In the following period (26/4) the current had been close to the CCC with a baking capacity of max. 12mm/hr (max. slipping if every time else is perfect and stable) or 10mm/hr (safe slipping with same tolerances in the other parameters). The average slipping in the period was 11mm/hr and has then been between “safe” and “max”. The baking zone had been in a marginal position.

The current peaks just before breakage, jumping from 65 to 83-84 kA has caused some burning in the casing and then caused the leakage.

During the period of this breakage also, except above deviation remaining electrode management parameters like casing design, paste level etc. were found implemented as per requirement which was clear from the data submitted.

4. CONCLUSIONS

By maintaining proper slip index and current control to maintain the required baking zone positioning, soft breakages can be eliminated as they are very much costly.

Casing jointing and paste charging methods to be implemented as per the laid down procedures mentioned below to ensure better electrode management assuring no electrode breakages of any nature.

Recommended Electrode management procedures:

- Paste cylinders should be stored such that they are protected from the sun.
- Cleaning of the paste after storing (sand, dust etc.) should be done thoroughly.
- Stable number of cylinders should be added.

- If it is only paste briquettes, it is wise to stop charging briquettes for some time until softening of the briquettes can be observed for a control of the soft paste level.
- Electrode heaters and mantle cooling fan damper adjustment plays a vital role to maintain paste temperature.
- When briquettes are used, the top of the dry briquettes will normally be 3 – 5 mtr. above top of holder.
- The slipping rate should not be changed too often (control slip index if current changes).
- Casing design should be appropriate to achieve less loss of power during electrode elongation and better tensile strength to have higher margin against soft breakage.
- Paste temperature at the top of side paste level should be 65 – 70deg. C

At IMFA, CHOUDWAR to elongate the electrodes, forced slipping method is being followed (from jan'03 onwards) in which current is lowered to a level where the steel casing can carry all the current and the electrode is slipped 75mm/hr until needed length. After a recovery with that slipping, the elongated electrode can be slipped as normal.

It is always better to avoid operational condition that resulting unfavorable segregation of the paste and it may be preferred to charge paste briquettes / crushed paste in combination with cylinder for better performance.

At IMFA, CHOUDWAR, all the above procedures are being followed for better electrode management.

REFERENCES

[1] "Introduction to Soderberg Electrode", By Elkem.
[2] "Report on soft breakages at IMFA, CHOUDWAR", By Reidar Innvaer & Bjonar Larsen (Elkem).
[3] "Soderberg Electrode 75th Anniversary Seminar, 1994.