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ASPECTS OF CHANGE MANAGEMENT AND PROCESS MANAGEMENT AT SOME SMELTERS

Yashuang Gao[1,3], Mark P. Taylor[1,2,3], John J.J. Chen[3], Albert Mulder[1]
[1] Light Metals Research Centre,
2. Product Accelerator,
3. Chemical and Materials Engineering,
The University of Auckland, Private Bag 92019, Auckland 1142, New Zealand

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Abstract

Many smelters are seeking for pathways to achieve breakthroughs in reducing energy consumption and increasing productivity for survival in difficult situations of high power cost and low metal price. Some smelters realize that transformational changes are required for them to progress to a desired future state. These changes can be implemented in one or more of many areas such as Operation procedures, Processes, Systems, Organisational structure, Culture, Work design and so on. Change often inevitably faces resistance from either individuals or groups of people. However, resistance is manageable. This paper discusses the aspects of change management and process management in some smelters during the implementation of changes in Operation and control systems. Implementation of changes including practice and operators' decisions during anode setting was selected as a case study. The results indicate the importance of work design modification and effective feedback in operational quality improvement.

Introduction

Implementation of changes in anode setting procedure was selected as a case study to investigate aspects of change management in aluminium smelters. Due to commercial sensitivity, the smelters will be referred as Smelters A and B in this paper. The purpose of anode setting is to replace spent anodes. This procedure is summarised into 11 steps in Table 1. This summarised procedure shows that in Smelter A, several operators on the floor perform 50% of these tasks manually and the pot tending machine (PTM) only performs the remaining 50% (Table 1, Procedure I). However, in many other modern smelters, only one operator on the floor is required for removing the hoods at the beginning and placing the hoods back to the pot at the end of anode setting operation. The rest of the steps are performed by PTM (Table 1, Procedure II).

To minimise manual work, Dupas introduced the concept of using PTM to handle the hoods in 2009 (Table 1, Procedure III) [1]. In 2011, Welch presented a fully automatic anode setting concept (no human involved in any step of anode change), which was suggested to be achievable with the 21st century technology. However, the cost of implementation of this 'no human' in operation concept could be high [2].

<u>Potential benefits from changing manual operation to automation</u>
One of the driving forces for reducing manual work is to increase operator safety. To examine the safety condition in Smelter A, a hazard assessment of the anode setting procedure was conducted. It identified that excessive heat, pot fume and the risk of tripping and falling into the cavity (as detailed in Table 2) are the major hazards for the floor operators when they perform manual tasks. In addition, personal protection equipment is not adequate (only wearing cloth masks, and lacking proper facial and eye protection). Being exposed to high temperature liquid bath and large amount of pot fume, the operators are not able to stay in front of the cavity for very long. Automation of steps 2, 4, 6, 7, 8 and 10 would be able to remove operators from these hazards.

Table 1: The summarised steps in "standard" procedures of anode setting

A standard anode setting procedure by steps		Procedure I: Low level automation with excessive human intervention – in smelter A		Procedure II: High level of automation with minimum human intervention – current practice in most smelters		Procedure III: Full automation – fully automated operation with no human intervention from the floor [Error! Reference source not found.]	
		Manual	Automatic	Manual	Automatic	Manual	Automatic
1	Remove hoods	√		√			√
2	Break crust	√*	√		√		√
3	Remove old anode		√		√		√
4	Reference old anode position	√			√		√
5	Place the old anode in a tray		√		√		√
6	Clean cathode by removing excess crust from the hole	√			√		√
7	Skim carbon dust from the hole and place in a separate container	√			√		√
8	Reference new anode position	√			√		√
9	Place new anode in the hole		√		√		√
10	Tighten the clamp	√*	√		√		√
11	Put the hoods back on the pot	√		√			√

Table 2: Potential hazard in the manual operation of anode setting in smelter A

	Procedure (Smelter A)	Manual	Automatic	Potential Hazards for the floor operators	Potential factors impact on the quality of anode setting
1	Remove hoods	√			
2	Break crust	√*	√	Exposure of heat, fluoride gas and dust	Excessive and large lumps of crust fall into the cavity
3	Remove old anode		√	Dripping of hot bath	
4	Reference old anode position	√		Exposure of heat and fume	Inaccuracy of position reference
5	Place the old anode in a tray		√		
6	Clean cathode by removing excess crust from the hole	√		Exposure of excessive heat, fume and risk of tripping and falling into the cavity	Unclean cathode surface which causes noise after anode setting
7	Skim carbon dust from the hole and place in a separate container	√		Exposure of excessive heat, fume and risk of tripping and falling into the cavity	Unclean bath surface which causes spikes and noise after anode setting
8	Reference new anode position	√			Inaccuracy of anode position
9	Place new anode in the hole		√		
10	Tighten the clamp	√*	√	Exposure of excessive heat, fume and risk of tripping and falling into the cavity	Incorrect clamp drop measurements
11	Put the hoods back on the pot	√			

Increasing the level of anode setting automation can also reduce the labour cost by reducing the number of operators. Smelter A uses Procedure I for anode setting, which requires at least 4 operators to perform the manual tasks on the floor and 1 operator to drive PTM. However, the high level automation anode setting procedure only requires 1 operator on the floor for hoods handling and house-keeping and 1 operator on PTM for performing the majority of the tasks (in Procedure II).

Furthermore, it is expected to improve the quality of operation by using PTM to complete the tasks (in steps 2, 4, 6, 7, 8 and 10) instead of human operators. The manual tasks are mostly completed in a rush because of the extremely high temperature and hazardous working condition as indicated in Table 2. The qualities of breaking the crust, cleaning cathode surface and skimming the bath surface have a lower priority than the completion of the tasks using as little time as possible (as observed in many smelters). The consequence of this rough manual work in anode setting operation is pot instability after setting due to one or a combination of the factors listed in Table 2. On the other hand, the higher level of anode setting automation should improve the quality of anode setting operation [1, 2, 3, 4].

Quality of illustrations in instruction

It was observed that the operational practice procedures were printed in A4 size papers and bound as booklets which are hung on the wall in the operators' office. The procedures present the step by step instructions in two columns, with one column containing description in words and the other one showing photo illustrations of the corresponding steps). The whole booklet was printed in black and white. Furthermore, the quality of the photos was poor and the visibility was low. In comparison to the same procedure, such as anode setting, the ones embedded in Gen3 potline control and management system (i.e. referred as Gen3 hereinafter) [5] have the following features:

- In terms of content:
    - Higher level of automation in terms of the content of the instructions (Procedure II vs. Procedure I)
- In terms of information display:
    - 20% - 40% fewer words used for the description in each step, but the instruction is clearer and simpler
    - High quality photos are used
    - Procedures are shown in colours

The design of the information display followed the principles suggested by Wickens et. al. [6].

Objectives

In the experiment, it was hypothesised that the highly automated anode setting procedure (Procedure II in Table 1) with improved illustrations replacing Procedure I can improve the safety, operation quality and reduce the workload for the operators in smelter A. However, Procedure II does not eliminate human intervention completely like the 'no human in operation' concept proposed by Welch [2]. Procedure II still requires one operator on the floor for hoods handling and house-keeping, and one operator for driving PTM to complete the tasks, which used to be manually performed by the floor operators. It is also hypothesised that with the improved visualisation of information and more automated procedure, the improvement might not be sustainable due to other human factors, such as resistance to change. In this case, the change refers to using Procedure II instead of Procedure I. The changes in some key decisions and decision makers due to the change from Procedure I to Procedure II could lead to resistance from the operators to the use of the new procedure. The understanding of the operators' response and behaviour towards the new procedure would be able to feedback to the management for continuous improvement of systems and work design and hence better implementation of new procedures.

Method

Training

The anode setting personnel including 8 floor operators, 4 PTM drivers, 2 shift supervisors, 3 vice shift supervisors and 4 engineers were given a training course which consisted of three steps.

Step one: providing detailed instructions

Two versions of Procedure II were written and embedded into Gen3. The detailed version describes the relevant background information, tools required, the procedure of the work and potential hazards and so on. The simplified version only presents the key steps of the work in simple and plain language with a typical illustration for each step (either a photo or drawing of the task). The experimenter explained the detailed version of the new standard Anode Setting Procedure (Table 1, Procedure II) with the participants in the operator's office in the potline. The purpose and potential benefits of Procedure II were also discussed.

Step two: providing simplified key instructions

The experimenter provided each participant a print-out of the simplified version of Procedure II from Gen3, which was designed to fit on one A4 page. The experimenter explained each step of the procedure in that page to the participants.

Step three: practising on the job

A "Practical training" session was conducted in the potroom after the "classroom training" in steps one and two. Two experimenters provided training to the operators. One experimenter trained the floor operators by supervising their actions and providing immediate feedback to the operators. The other experimenter trained the PTM operators by supervising their actions in the PTM cabin and providing immediate feedback to the operators. Both experimenters observed and recorded actions and comments from the operators.

Observations

The participants were informed by the managers that Procedure II would be used to replace Procedure I on a group of pots (16 pots), for the 4 trained crews. The experimenters observed the performance of the operators and the trial pots for a period of 6 months after the implementation. The key steps of the procedure (steps 2, 4, 6, 7, 8 and 10 in Table 1) were inspected by the experimenters and 3 trained vice shift supervisors for every anode setting operation.

Interview

The interview with the participants collected the feedback from all levels of operational staff about the impact from the implementation of this higher level of automation anode setting procedure to the trial pots. It also provides insight into the behavioural changes of the operators when the new procedure was implemented.

Results and discussions

Inspection results

During the experiment, the use of Procedure II (i.e. higher level of automation procedure for anode setting) improved the quality of anode setting operation. This is supported by the results collected from daily inspection of anode setting performance and noise level after anode setting observed from the real time traces of the 16 pots. The inspection of anode setting operation focused on crust breaking using jackhammer, and cathode surface cleaning and bath surface dust skimming using PTM pacman.

For high quality anode setting operation, good crust breaking is the first step, but a good anode cavity cleaning (cathode surface cleaning and bath surface dust skimming) is crucial to pot stability. Anode cavity cleaning is performed immediately after the old anodes are removed. The inspection record shows that for 81% of a period of 31 days (immediately after training), crust breaking task was performed by PTM (jackhammer) according to the new procedure. However, 19% of the time, crust breaking was performed manually. For the same inspection period, there were 480 anode changes in total. In approximately 400 out of 480 anode changes, PTM pacman was used to clean the cathode surface. The operators manually cleaned the cathode surface for the rest of the 80 anode changes. The operators were also instructed to use PTM pacman to skim bath surface for carbon dust at least once per anode change. If excessive amount of dust was observed, skimming should be performed multiple times. However, the record shows for 384 out of 480 anode changes, one dust skimming using the PTM pacman was performed per anode change. About 100 counts of dust skimming were not performed. During the inspection period, those anode changes with manual crust breaking and cavity cleaning were effectively using Procedure I (in terms of the level of automation).

Crust breaking using Procedure I

The quality of crust breaking has a direct impact on the cavity condition and integrity of anode cover. Figure 1 (a) shows the rough job done by the PTM jackhammer. This required the floor operators to use a steel bar (approximately 1.6m long, 20mm diameter) to break certain spots before the PTM pulled out the pair of old anodes. The consequence of poor crust breaking using jackhammer and combination of manual work is poor cavity condition (eg. the edges are not straight which might cause poor position of new anodes) and large amount of crust lump could fall off and drop onto the adjacent anodes or deck plate as illustrated by the photo in Figure 1 (b).

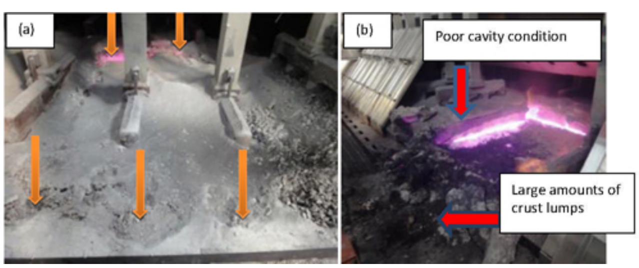

Figure 1: (a) The result of combination of PTM and operator manual work on crust breaking leading to (b) a poor cavity condition with large amount of big crust lumps on the deck plate.

Anode cavity cleaning using Procedure I

A series of snap shots in Figure 2 were taken when manual cleaning of the cavity was observed. Three operators stood in front of the hot cavity to scoop out the bath lumps for approximately 1.5 minutes, and then the fourth one came to replace one of the three operators on the job. The operators had to rush through the job, despite there being four operators on rotation scooping out the bath lumps for cleaning the cathode surface and skimming carbon dust on the bath surface. The result of the extreme hard work of the four operators is shown in Figure 3. This shows that carbon pieces with unacceptable amount of carbon dust were still floating on the bath surface.

Noise after set using Procedure I

As a consequence of poor cavity condition (due to poor crust breaking) and excessive amount of bath lumps and floating carbon pieces in the cavity (due to manual cleaning), the instability of a pot often can be directly observed from the real time traces on the supervisory screen. For example, the traces in the screenshot in Figure 4 show the noise level increased immediately after new anodes were set into the pot. The pot was unstable after this anode change for a sustain period of time (i.e. more than 8 hours).

Figure 2: A series of snap shots of manual anode cavity cleaning process (Procedure I)

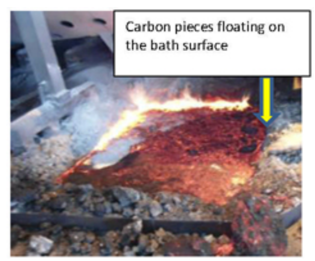

Figure 3: The result of manual anode cavity clean indicating the poor quality of the performance

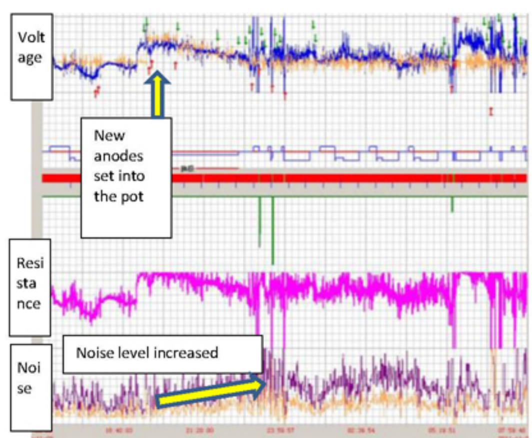

Figure 4: A screenshot of the supervisory screen showing the real time pot traces (voltage, resistance and noise) and high noise level after anode setting

Crust breaking using Procedure II

In Figure 5 (a) the positions of crust broken by jackhammer can be seen; the breaks were well spaced. This performance leads to good cavity condition (i.e. smooth and straight edges) and clean deck plate as shown Figure 5 (b). Good cavity condition will allow the new anodes to be set at the right position.

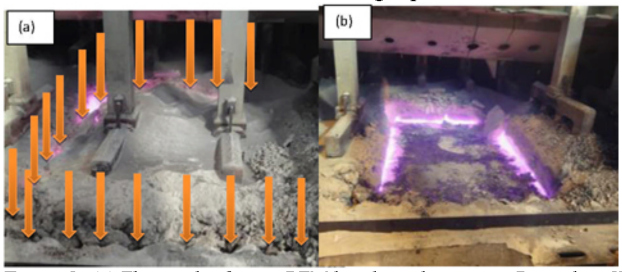

Figure 5: (a) The result of using PTM breaking the crust in Procedure II giving (b) a good cavity condition.

Anode cavity cleaning using Procedure II

When PTM pacman was used to replace manual work for anode cavity cleaning, the result was different. The photos in Figure 6 show the anode cavity being cleaned by the PTM pacman. The result of that action is shown in Figure 7. The pacman removed approximately 400kg of bath lump and alumina sludge from one cathode surface cleaning. About 200kg of carbon dust and carbon pieces were also removed from the bath surface cleaning. Clean cavity will allow the pot to be more stable and have less chance of forming spikes after anode setting [3].

Figure 6: Two snap shots of PTM (pacman) cleaning the anode cavity replacing manual work (Procedure II)

Figure 7: The result of the clean cavity using PTM pacman

Noise after set using Procedure II

The screenshot in Figure 8 shows that the noise of the pot remains at a minimum level after setting the new anodes, because of good crust breaking (as shown in Figure 5) and clean cavity (as shown in Figure 7) using PTM (i.e. by following Procedure II).

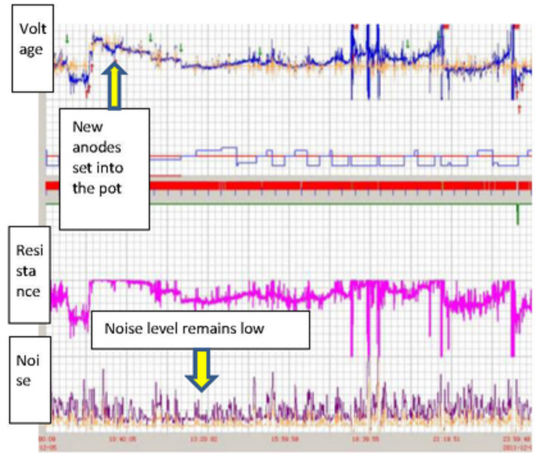

Figure 8: A screenshot of the supervisory screen showing the real time pot traces (voltage, resistance and noise) and minimum level of noise level after anode setting

Comparing the noise levels resulting from using two procedures

To further compare the quality of anode setting operation using two different procedures, noise data (i.e. the level of instability) after anode setting of the 16 pots was collected and is presented in Figure 9. This shows that on average, 43% of the pots (i.e. 6 out of 16) were noisy after anode setting for the period of observation when the old procedure was used, i.e. the anode cavity was manually cleaned. When the new procedure was implemented, on average, 13% of the pots (i.e. 2 out of 16) were noisy after anode setting was observed. This demonstrates that the pots are more stable after anode setting operation if the operators use PTM pacman to clean the cavity according to the new procedure. This is despite the fact that on some days, the operators reverted to manual actions.

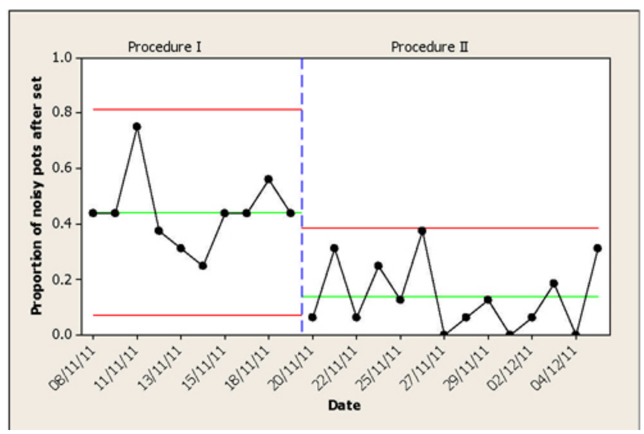

Figure 9: An assessment of noise situation of the trial pots before and after implementation of the new procedure

In addition to pot stability, the new procedure improved operator safety. The photos in Figure 2 show that the operators were exposed to high level of heat, excessive amount of pot fume and tripping and falling hazards during the manual work. In contrast, when the operators followed the new procedure and used PTM pacman to clean the cavity, no manual work was required as shown in the photos in Figure 6. The new procedure removes the operators away from the identified hazards, hence improving the safety level.

Changes in decisions and decision makers

As Taylor et. al. pointed out "many key decisions lay embedded behind the operating procedures themselves" [7]. The implementation of new operating procedure has led to the changes of some key decisions. During the implementation of Procedure II, the changes of the tasks from 'manual and completed by floor operators' to 'automatic and completed by PTM and its operators' are the explicit changes. These explicit changes in the operating procedure have brought the implicit changes in the decisions arising in the anode setting operation and the change of the decision makers. Table 3 describes the decisions and the corresponding decision makers for the steps of Procedure I and II where the changes occur. It shows the changes in the decision questions and most of the decision making responsibility has been shifted from the floor operators to the PTM operators.

Table 3: The changes of the decisions and the decision makers when Procedure II was used to replace Procedure I

A standard anode setting procedure by steps		**Procedure I: Low level automation with excessive human intervention – in smelter A**		**Procedure II: High level of automation with minimum human intervention – current practice in most smelters**	
		Decisions	By	Decisions	By
1	Remove hoods				
2*	Break crust	1. Which position on the crust do I have to break using the steel bar? 2. How long do I have to spend on this task?	Floor operators and PTM operator	1. Am I able to see the centre channel from PTM cabin above the pot superstructure? 2. How long do I have to spend on this task?	PTM operator
3	Remove old anode				
4*	Reference old anode position	1. Which spot of the anode top can I stand on so that I will not get burnt? 2. What is the reading of the anode position?	Floor operators		
5	Place the old anode in a tray				
6*	Clean cathode by removing excess crust from the hole	1. Which position shall I stand so that it is not too hot and I will not fall into the pot? 2. How much crust material do I have to fish out? 3. How long can I stand the heat and pot fume?	Floor operators	1. Do I have to scoop once or twice? 2. How much time do I have to spend on this task?	PTM operator
7*	Skim carbon dust from the hole and place in a separate container	1. Which position shall I stand so that it is not too hot and I will not fall into the pot? 2. How much carbon dust can I skim? 3. How long can I stand the heat and pot fume?	Floor operators	1. Do I have to skim carbon dust? If yes, once or twice? 2. How much time do I have available to spend on this task?	PTM operator
8	Reference new anode position	1. What was the reading of the spent anode position? 2. Where should be the position for the new anode?	Floor operators		
9	Place new anode in the hole				
10*	Tighten the clamp	1. Is the hood placed on superstructure so that I can stand on it? 2. How tight the clamp needs to be?	Floor operators	1. Is it tight enough?	PTM operator
11	Put the hoods back on the pot				

Resistance to change

The operators were interviewed at the beginning of the implementation and also 6 months after the implementation. In the first interview, the floor operators were very positive about this new procedure. All of them agreed that this new procedure was much easier for them and they supported this change. 6 months after the implementation, the floor operators were observed to have gone back to skimming the dust manually and occasionally manually scooping out the crust lumps. In the second interview, the floor operators explained to the interviewer that after the use of PTM dust skimming, they have lost a portion of their income in the last 6 months which was usually generated from manual dust skimming (i.e. manual dust skimming was recognised as hard work and rewarded with money in the potline management system. A monetary reward and punishment system, which was adopted in this smelter, is necessary and effective in some smelters in Asia. However it might be difficult to be used in Western smelters where the Union plays an important role in the management of the employees [8, 9]).

During the interview, most of the PTM operators commented that the anode crust was very thick and hard to break using the Jackhammer. Anode cavity cleaning was difficult because the limitation of the PTM travel speed and it was impossible to separate dust from bath. The feedback from the shift supervisors confirmed the comments from the operators. Most of the supervisors commented that most of the operators did not like this new procedure. They often had to be supervised to encourage the use of PTM pacman to clean anode cavity. When the manual tasks in Procedure I are instead done using Procedure II methods, it results in an increase in the workload for the PTM operators using the Pacman. These PTM operators were not happy with the increase in workload. For the floor operators, despite the fact they had a reduced workload, they also were not any happier because they gradually felt 'lost' and unhappy about the decrease in the salary due to no manual dust skimming.

The results of implementation of Procedure II as well as the interviews were presented to the managers and engineers. They agreed the new procedure is safer for the operators and better for operation quality. However, it might take some time to implement the procedure fully on the whole potline, because the resistance to implementation of Procedure II from the operators seems to be strong. The resistance to the implementation of the new anode setting procedure comes from both the floor operators and PTM operators regardless of the recognised benefits to the pot performance and operational quality from the new procedure. The interviews indicate that the floor operators are more concerned about the loss in income and their routine jobs (i.e. manual tasks), while the PTM operators had no incentives to accept the increase in their workload. This was also confirmed from the observations of their behaviour and decisions made during anode setting operation.

The explicit changes in the operating procedure and the implicit changes in decision making could be perceived as losses by the floor operators. The losses refer to not only the actual loss of the tasks which they considered as their daily routine job before the implementation, and hence the loss of the portion of salary that comes from manual dust skimming, but also the loss of decision making responsibility. This perception of loss could directly lead to the resistance of the implementation of new procedure, regardless of the potential benefits to the pot stability that could be gained. This explains the behaviour of the PTM operators. Doing the tasks in Procedure I was enough for the PTM drivers to fulfil their duties and earn their salary. The PTM operators could perceive all their tasks in Procedure II as exceeding what they are currently doing to achieve higher quality of operation. Furthermore, this 'extra' work provides them with neither the recognition nor any increase in their salary. Therefore, time consuming issues and all kind of difficulties such as visibility of anode cavity and dust bath separation in the implementation of procedure II often reported by the operators, regardless that additional training sessions were provided during the 6 months of implementation.

Work design modification

From the feedback model as illustrated in Figure 10, presented by the author in the 9th AASTC, 2011 in Tasmania, Australia, once the performance (of human operators or process) is assessed, feedback can assist people to learn and improve [10]. In the situation of implementing the new anode setting procedure in Smelter A, to remove the resistance to implementation from the operators, once the behaviour of the operators was understood, work design modification (i.e. Tasks in the feedback model) was recommended. For the floor operators, it was recommended that there be two operators on the floor to carry out the tasks specified in Procedure II instead of four. The other two operators could be given the responsibility of re-dressing anode covers, which is not yet part of standard work practice in Smelter A. Furthermore, the reward system could be modified. Monetary reward should be given to both floor and PTM operators on the basis of anode setting quality but not manual dust skimming. The floor operators can provide immediate feedback to PTM operators to work as a team and assist them to make better decisions, especially on the anode cavity cleaning tasks.

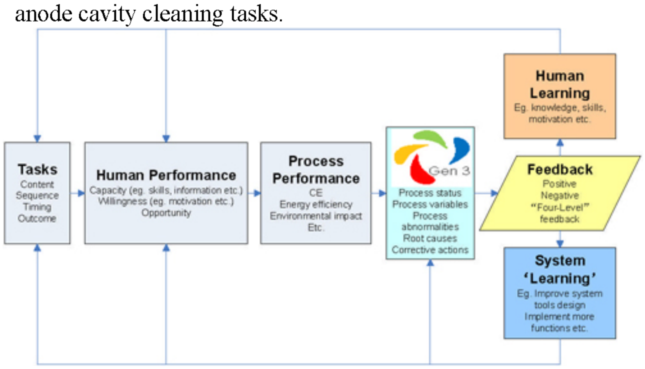

Figure 10: An illustration of the feedback and learning model for improvement of both human and process performance [10]

Each decision of the PTM operators has direct contribution to their performance and the quality of anode setting. However, the one in step 7 (cleaning anode cavity bath surface) is crucial to the stability of the pot. To assist the PTM operators in making decisions, guidelines are embedded in the one page clear and simple visual instruction. For step 7, "Do I have to skim carbon dust?" was the guiding question for the PTM operators. The inspection and observation outcomes indicate that the PTM operators often decided the answer to that question was "NO". However, when the guiding question was later modified to "Do I have to skim ONE scoop of dust or TWO scoops?", the outcome was different. The PTM operators often decided ONE scoop dust skimming was needed. This modification of the guiding question ensures at least one scoop of carbon dust skimming will be performed.

Further learning from Smelter B

The same experiment was carried out in another smelter, which is referred as Smelter B. In this experiment, Gen3 was used to provide feedback to the operational staff within an 8-hour shift. Figure 11 shows an example of Gen3 detecting a noise pot condition after anode setting (refer to [5] for detailed description of Gen3 detection tools and other functions). Highlighting the pot in yellow and stating the pot status as 'High frequency noise' is meaningful feedback to the operators as an indication of potential poor anode setting quality. The noise after set data was only calculated and used to indicate the quality of anode setting in Smelter A. It was only used by the manager to assess the operators' performance monthly. But in Smelter B, it was also used as a feedback to the operators within 8 hours after anode set. This approach effectively sped up the information flow in the feedback model [10]. The investigation in Smelter B will be continued and the findings will be reported in a future publication.

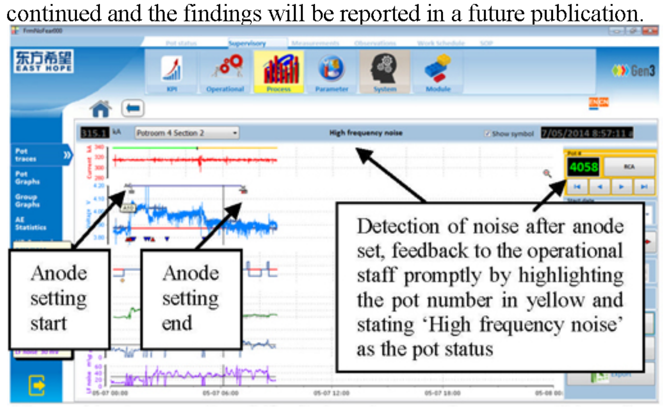

Figure 11: An example of Gen3 detecting a noise pot condition after anode setting and providing feedback to the operators promptly.

Summary

The experimentation of using the high level of automation and better quality of visualisation procedure for anode setting shows the positive outcome in improving safety factors for the operators and improving pot stability. However, simply replacing the old procedure with the new procedure has brought resistance from the operators to the implementation. It is recommended to review and modify the work design for the operators, the management systems such as reward policy and task contents such as guidelines for making operational and control decisions. Implementing the modification in work design and management system as recommended is an opportunity for future research. The findings could be used to optimise the feedback model [10]) as well as improve operational decision quality.

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