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Commissioning and Start-Up of Ingot Casting Machines in the Biggest Integrated Aluminum Complex in the World

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Abstract

This paper describes the current Maaden/Alcoa joint venture in the Kingdom of Saudi Arabia (KSA) with particular focus on the commissioning and start-up of the standard ingot casting machines. These are installed in the first standard ingot cast house in KSA built during 2012. This is part of the largest fully integrated aluminum complex in the world which starts at the mine and follows an aluminum processing chain that runs through to final products being shipped from the Cast House and Rolling Mill operations. The paper will describe Ma'aden experience in ingot casting machines: commissioning and start-up, the challenges faced particularly with de-molding machines, robots and strapping machines and the latest equipment's and technology being implemented. The Ma'aden cast house include a TAC facility which gives the advantages of less dross and more pure metal leading to a high quality product. Ma'aden also implemented ingot height laser control which makes ingots and bundles weight control well managed, also implemented latest version of MES (Manufacturing Execution System) which is doing multiple functions including: management life-cycle, resource scheduling, order execution and dispatch, production analysis for (OEE), and materials track and trace.

Introduction

Ma'aden's $10.8 billion joint venture with Alcoa will be the largest and most efficient vertically integrated aluminium complex in the world. It will use Saudi Arabia's bauxite resources to profitably produce aluminum for domestic and international markets as well as to facilitate the development of domestic downstream industries in the Kingdom.

The aluminium project involves the development, design, construction and subsequent operation of two integrated sites:

Al Ba'itha

Al Ba'itha, near Quiba in north-eastern Saudi Arabia and around 600km north west of Ras Al Khair, is the site of the project's bauxite mine and ore crushing and handling facilities which are due to begin production in 2014.The mine plan has been prepared based upon the estimated capacities of the project's refinery and smelter and envisages production at an annual mining rate of 4.0 million mtpy of bauxite.

Ras Al Khair

The project's alumina refinery, aluminium smelter and rolling mill are under construction at Ras Al Khair, 90 km North of Jubail. Bauxite ore transported by rail to Ras Al Khair will be refined in the GCC's first alumina refinery to produce 1.8 million mtpy of alumina, which will in turn be processed in the smelter to produce 740,000 mtpy of aluminium. The rolling mill with initial hot-mill capacity of 380,000 mtpy will focus initially on the production of sheet, end and tab stock for the manufacture of cans and other products including auto, construction and foil applications. The rolling mill will be one of the worlds most technically advanced and will have the capacity to re-cycle aluminium scrap.

The smelter and rolling mill will begin operations in 2013 while the alumina refinery will come on stream in 2014. Alumina will be imported to supply the smelter for the intervening period.

A key infrastructure item for the aluminium operations at Ras Al Khair is a power, steam and water facility. In October 2009 Ma'aden signed an energy conversion agreement with the Saline Water Conversion Corporation (SWCC) and Saudi Electricity Company (SEC) to develop a joint power and desalination plant which will generate 2400 MW of electricity and 1.025 million cubic meters of water per day. Of that, the aluminium complex will use 1,350 MW of electricity and 25,000 cubic meters per day of water. The remaining electricity and water will be supplied to national grid.

Ma'aden-Alcoa Joint Venture:

The Ma'aden Alcoa project will be the lowest-cost aluminum production complex within the world-wide Alcoa system. It will help lower Alcoa's overall production cost base and capitalize on growth opportunities in the Middle East region.
The project is being developed by a joint venture formed in 2009 between the Saudi Arabian Mining Company, (Ma'aden) and Alcoa. Ma'aden currently holds 74.9% of this joint venture; Alcoa currently 25.1%. The project is a platform for growth: Alcoa's commitment and capability is demonstrating alignment with the Kingdom's development goal of adding minerals and metals as the third pillar of the country's economy alongside hydrocarbons and petrochemicals. Alcoa's capacity to participate in and support the development of this third pillar is earning opportunities for Alcoa to participate in future growth initiatives within the Kingdom.

Safety Culture of Ma'aden-Alcoa Joint Venture

The safety culture in the company is built around the core concept that achieving zero work-related injuries is possible. The safety systems are built on a foundation of values and principles. They are anchored in place with committed people who are actively engaged and effectively supporting a safe work environment, safe work methods, and overall production system stability.

Cast-House Capabilities:

The Ma'aden Cast-house is divided in to three sections which produce three different types of products: a).Standard ingot typically 23.7 kg produced through three ingot casting machines. b) Rolling Slab for the hot mill produced by two VDC casting pits using EMC technology, the cathouse is the first plant in Middle East to use this technology. c) Extrusion billets produced by one VDC casting pit using Air-Slip technology. This paper covers in

detail the ramp up of the three ingot casting machines as the first part of plant being commissioned.

Ingot Casting Machine:

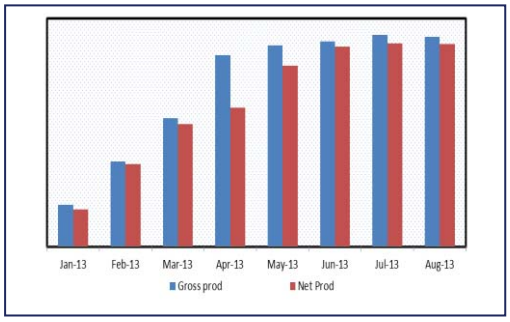
The first 23.7 kg ingot was made in the cast house was on 12/12/2012 as the first ingot casting machine was commissioned. The cast house has three identical ingot casting machines with design capacities of 33 tph. These machines were fully commissioned during the first half of 2013 in conjunction with the ramp-up of reduction pots.

Each casting unit includes a casting wheel, ingot cooling system, de-molding system, robotic layer stacker, double bundle conveyer, reject conveyer, automatic stacking, weighing, marking and strapping stations and automatic loading facility.

These machines are connected to five 100MT capacity furnaces and use open mould casting technology with water as cooling medium. In addition there is an dedicated water cooling plant with its own chemical treatment system. The Ingot casting plant design capacity is 520,000 mtpy.

Commissioning and Start-up:

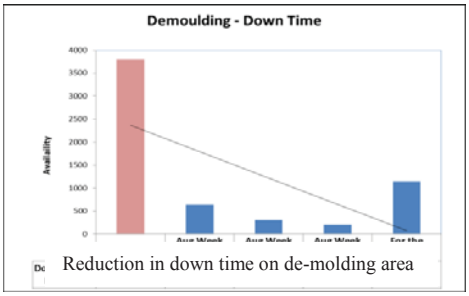
The first ICM-1 was commissioned during Dec-12 and reached full production by the end of Jan-13. ICM-2 was commissioned during Jan-13 and reached full production by end of Feb-13 while, ICM-3 was commissioned during Mar-13 and reached full production capability by end of April-13.



Production ramp-up during 2013

Equipment's Stabilization and Reliability Enhancement:

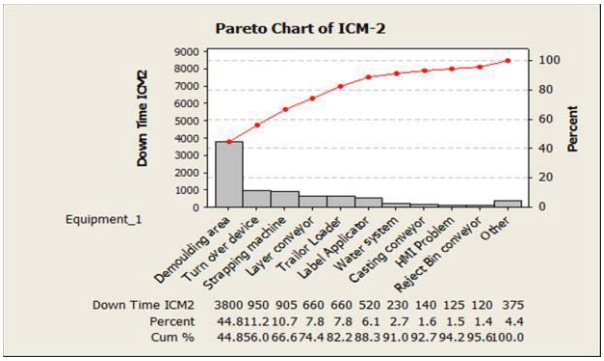
In the beginning of the 2nd quarter of 2013 the challenges of stabilizing the equipment's are started. The most critical areas were the de-molding area, strapping machine and stacking robot. Extensive efforts were made during this period utilizing experience of Alcoa experts and a dedicated team from all disciplines to overcome the issues associated with the machines and reduce the down time for significantly. The approach was to assign a reliability focus team to each area from different departments and by using different problem solving techniques those teams achieved excellent results.



Reduction in down time on de-molding area

Applying Pareto analysis and other problem solving techniques, lead to the identification of most critical equipment's and the next step was to identify the root causes and apply corrective actions which significantly improved the equipment reliability.

Analysis of equipment's failure



The development of human resources:

The area where this massive project built is still to be considered a remote area as the plant is located 120 km from the nearest city which is Al-Jubail Industrial city. This adds a challenge to hire and develop people who are willing to work in this area. In addition to this, the aluminium business is new to the Kingdom and it does not have a local experienced work force immediately familiar with operating a Smelter. There is also a strong country drive to recruit and develop a local work force in KSA companies. The management accepted the challenge and developed a multicultural work force with a significant number of local employees. To achieve the above the cast-house management along with the smelter training department developed a training program for different levels of employees. Managers & engineers were sent to partner locations in USA to improve their understanding of aluminum manufacturing. The Cast House management developed a program for the operation team for a smooth start-up and operation. Four teams were formed with a mix of 8 experienced and 8 new operators. To acquaint them with the aluminium process the new operators initially completed three months on-job training programs at nearby smelters. After the formation of the teams, one month intensive training was provided by the company utilising experienced in-house trainers on molten metal hazards, forklift operations, LTV procedures, confined space entry and working at height. Then all trainees were tested and certified.

After the employees were tested and certified the teams were assigned for commissioning the furnaces and Ingot casting machines. Two teams were assigned for commissioning and start-up of the furnaces and two teams were assigned for commissioning and start-up of the ingot casting machines.

These teams were involved from the Pre-commissioning stage. It gave lot of exposure for the new operators and also helps them to understand the process. The commissioning was done in two stages. The first stage was cold commissioning. During this period trials were undertaken with cold ingots and the downstream equipment tested and adjusted. The line speed was gradually increased. During the cold commissioning period the new

operators were trained on the panel operations also. After cold commissioning the teams were engaged for Lockout Tag out Verification (LTV) procedure validation process. The SWI's procedure were verified and approved.

The second stage of commissioning was the hot commissioning. During this stage the total area was barricaded with single exit entry to avoid un-authorized persons entry. The hot commissioning Zone was clearly marked and displayed a safety communication board to create awareness at the site. Mandatory PPE's Standards for entering the Hot and cold commissioning zone were also displayed. During this period there was also erection work going parallel in the cast house and there was a huge risk of contractor movement inside the hot commissioning zone. To avoid unauthorized entry in the high risk zone, the hazards associated with the hot commissioning were frequently discussed in the daily contractor tool box meetings.

In the first phase of furnace commissioning the furnaces were carefully dried out utilizing an external burner system. Once the required temperature and time were achieved some purchased ingot was charged into the first furnace to seal the hearth with molten metal. After this process the molten metal inside the furnace was solidified and again 30 tons cold metal charged and melted. Once the molten metal was ready the furnace titling and emergency handling test were conducted. Also the teams were trained on the furnace operations during this period.

In the second phase, hot trials were conducted on the ingot casting lines. This was done in two stages. In the first stages the ingots were taken up to Bundle conveyor during this stage the water system, demoulding system and Robots were fine tuned. After four days of continuous effort the first bundle of ingot was formed. In the second stage the double bundle conveyor, manipulator and Trailer loader systems were commissioned and the operation of all the equipment tuned and optimised.

Salient Features of Ma'aden Ingot casting line:

The Ma'aden Ingot casting lines are equipped with a number of the latest technical developments which includes a laser control system designed to tightly control the ingot height and weights so, the bundles produced by Ma'aden machines are more stable and can be transported for longer distance without damage. Each machine also incorporates a bundle compactor which makes the bundles more compact before inline strapping so that these strapped bundles will not be affected by multiple handling. Each line also includes an in-line label applicator which is connected to the Manufacturing Execution System (MES). MES system sends all the information including grade, batch number, weight of the bundle, date of production and machine number to the printer of the label applicator and it is applied to each bundle.
The manipulator system identifies defective bundles and places these on the rejected bundle conveyor and the good bundles on double bundle conveyor. The trailer loader system loads the bundles onto a pallet and once full this is transported to another area where it is prepared for shipment. Apart from this the each machine has lot of safety features. All the equipment is protected by fences which have access gates so if anyone enters inside the gate the power supply to the machine will be disconnected and the equipment will be stopped.

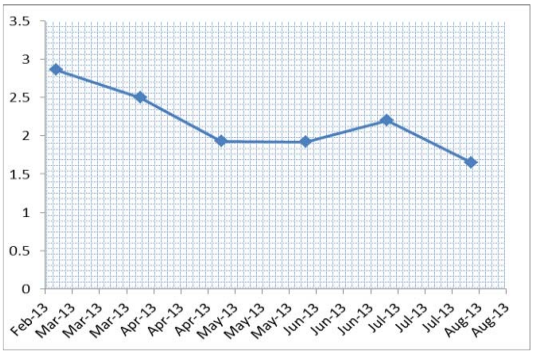
TAC Make Molten Metal Cleaner:

Metal cleanness is a major factor of aluminum casting success which enhancing purity of the products and increases the equipment's reliability. The TAC system (treatment of aluminum crucibles) is equipped with four stations capable of treating up to 120 crucibles per day. These remove the dross in the crucibles and also reduces the alkaline metals (Sodium, Lithium, etc.,) from the molten metal. By this high purity metal will be received in the holding furnaces.

Skimmer at TAC station

Ingot Height Measure & Control:

The Ingot casting machines are equipped with lasers measuring the molten metal height at the exit of the furnace and casting wheels which then feed back to the automation system to keep the final ingot height under tight control. In addition to getting the ingots and bundles within the desired weight, this will also help on reducing the scrap rate on the lines. Also, it will help the production continuity and the equipment's reliability. Further ongoing tuning of this control loop is further assisting to reduce scrap levels and achieve better reliability and productivity.



Scrap percentage reduction

Back-to-Back Casting Increases the Productivity:

At beginning of Aug-13 Ma'aden commissioned a back to back casting capability on ingot casting lines 2 and 3.
The benefit of Back - to - Back casting is the ability to run the Ingot Casting Machines continuously by switching seamlessly from holding one furnace to another. This generates both productivity and recovery benefits, the former associated with eliminating changeover times and the latter due to the reduced rejection levels normally associated when starting and finishing casts.

ISO 9001 is Another Achievement:

On 27th of Aug 2013 Ma'aden Smelter received ISO 9001 Certification by "BSI Group - British Standards Institution" an independent third party certification body. Certification was awarded in recognition of Ma'aden compliance with effective quality in the manufacture of molten aluminium. Conformance to ISO 9001 standards required the implementation of a procedural system, extensive training, increased documentation, improved reporting, detailed objectives, targets and plans; and adjustments to systems on every level of the company. "Our success in achieving this goal is due to the marvelous dedication and teamwork of everyone in the company," said Silvio Porto, Smelter General Manager. "ISO registration reflects our commitment to achieving and maintaining excellence in our business and operations; and to continuous improvement and an on-going commitment to provide our customers with product quality" he noted.

The Certification Audit was conducted from 30th of June to 8th of July covering all the areas of the smelter, the BSI auditor mentioned at the closing meeting of the audit that the quality management systems is robust and the smelter is recommended to receive the ISO 9001 certification without any non-conformances.

BSI Auditor with Silvio Porto, Smelter General Manager

Conclusion:

So far it has been a unique and challenging experience with many problems faced and overcome during the commissioning of the ingot casting lines. The first challenge was the lack of experience for the new local workforce joined the company months ago before start-up but by meticulous planning and proper training the challenge was successfully passed. The second challenge was frequent breakdowns in de-moulding, Robot and Strapping machines. This was significantly improved by assigning dedicated focus team on each machine by the Cast house management. These teams consist of a cross functional team members from operation, technical and maintenance. The teams used Ma'aden Business System which implies using different techniques of problem solving tools and by that the down time reduced by 85 % within two months on de-molding area. Apart from that, and to improve the equipment availability a first line maintenance care program was introduced and the operational members were trained on this. By giving 10 minutes dedicated inspection before each machine start-up, the major breakdowns were reduced the availability of the lines increased.

Commissioning of Green field aluminium cast house has lot of challenges. By Systematic planning and dedicated approach the Ma'aden-Alcoa team overcomes the challenges and successfully commissioned and stabilized three open mould casting machines within four months. The experience and challenges faced during commissioning and start-up gave a lot of confidence to the management and operation team.