

Increase Casting Capacity of DC-5 Caster at EGA Jebel Ali

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Abstract

At EGA Jebel Ali site, the Direct Chilled (DC) casting complex “DC-5 caster” was installed at Casthouse 2 in 2003. The billet casting equipment was supplied by Wagstaff, and has a production capacity of 60 t per cast. Aligned with EGA's core values of continuous improvement, management aims to enhance productivity and manufacturing capacity by exploring opportunities to increase productivity and casting capacity. Each cast involves significant consumption of consumables and demands considerable preparation time and effort from operators. The goal was to boost productivity per cast from 60 t to 70 t, and reduce operational consumables.

Keywords: Productivity increase, Optimise operational consumables, Increase metal production per cast, Cost saving, Reduce scrap generation.

1. Introduction

EGA Jebel Ali Casthouse 2's direct chilled caster (air-slip DC casting), with a casting capacity of 60 t per cast and 12 casts per day, plays key role in organisations aluminium billet production. Air-slip casting technology produces the highest quality billets, known for their smooth surface finish, small shell zone, and uniform-grain structure.. The air-slip process uses an optimised mould length, faster casting speed, individual water jets and a unique air cushion to minimise heat extraction through the mould and enhance secondary cooling. The direct chill (DC) casting process extracts heat through two mechanisms: first through the mould wall as the molten metal contacts it, and secondly through direct contact (or “direct chill”) with a specifically designed water pattern as the semi-solidified billet exits the mould.

1.1 DC Caster Operation

Air-slip casting / DC casting process requires various raw materials and consumables with synchronised system parameters to achieve a high quality product. This process involves pouring molten aluminium into a water-cooled mould. As the aluminium cools and solidifies, a large cylindrical ingot, known as a billet, is formed. The DC casting table is shown in Figure 1.



Figure 1. Air-slip casting table with mould and billets.

Here is a general overview of the process:

1. **Melting:** Aluminium scrap or primary aluminium is melted in a furnace to form molten aluminium.
2. **Degassing and alloying:** The molten aluminium is treated to remove any impurities and gases, and alloying elements may be added to achieve the desired material properties.
3. **Casting:** The molten aluminium is then poured into a water-cooled mould. As the aluminium flows into the mould, it rapidly solidifies from the bottom up due to the cooling effect of the water-cooled surface. This process, known as Air-Slip Direct Chill (DC) casting, produces a solid cylindrical ingot called a billet. This rapid cooling helps to produce a fine-grained structure with desirable mechanical properties.
4. **Billet Removal:** Once the aluminium has solidified, the mould is opened, and the billet is removed. The billet is typically hot, so it may be allowed to cool slightly before further processing.
5. **Homogenisation:** After casting, the billet undergoes a homogenisation process to ensure uniformity in composition and microstructure. This involves heating the billet to a specific temperature for a certain duration, followed by controlled cooling.
6. **Sawing:** The billet is then cut into shorter lengths using saws. This step prepares the billets for subsequent processes such as extrusion or rolling.
7. **Quality Control:** Throughout the process, quality control measures are implemented to ensure the billets meet specified standards for dimensions, surface finish, and material properties.
8. **Further Processing:** The billets are further processed through extrusion, rolling, or other forming techniques to produce final products such as profiles, bars, rods, or sheets.

Aluminium billets generated via DC casting find extensive applications across diverse industries such as automotive, aerospace, construction, and consumer goods. Their popularity stems from their exceptional strength-to-weight ratio, resistance to corrosion, and recyclability.

1.2 DC Caster Maintenance

Some of the major components of DC Casters are:

1. **Hydraulic power unit** (Figure 2) – The hydraulic power unit serves as the fluid power source and oversees the operation of both the casting cylinder and mould table tilt system.

This hydraulic control mechanism ensures the consistently smooth and precise descent of the platen, essential for achieving successful casting.

2. **Internally guided hydraulic cylinder** (Figure 3) – The air-slip DC casting machine relies on an internally guided cylinder supported by a sturdy, dependable hydraulic system. Central to the machine's functionality, the casting cylinder facilitates smooth and gentle vertical movement, ensuring alignment accuracy during operation.



Figure 2. Hydraulic power unit.



Figure 3. Internally guided hydraulic cylinder.

3. **Platen and torque limiter** (Figure 4) – A steel platen, attached securely to the torque limiter, bears the weight of the cast load, the starting head base, and the starting heads. Its upper surface is precisely machined to ensure a flat mounting surface for the starting head base, guaranteeing precise alignment of the starting heads with moulds in terms of both elevation and position. To withstand the rigors of service with molten aluminium, the platen is coated with a protective layer.
4. **Casting table and hydraulic cylinders** (Figure 5) – The reverse tilt system employs hydraulic tilt arms in conjunction with an integrated rail system to elevate and rotate the mould table, moving it upward and away from the open pit. This action positions the mould side of the table away from pit stripping operations. This innovative design facilitates concurrent table maintenance and billet removal, thereby improving personnel safety.
5. **Sensor and proximity switches** – A series of platen proximity sensors are mounted in the pit wall to provide platen location information and cast length correction. The upper limit switch locks out the platen fast up control. The lower limit switch is set at the end of cast length and activates an alarm. The middle limit switch, if applicable, is used for various signals and interlocks depending on the equipment configuration.



Figure 4. Platen and torque limiter for DC caster.



Figure 5. Casting table and hydraulic cylinders for DC caster.

2. Current Casting Unit Performance and Opportunities for Improvement

2.1 Current Practice

2.1.1 Operations Requirement

Before implementation of this project, the DC caster had a capacity of 60 t of billet per cast. To maximise production efficiency and improve homogeniser performance, there was a strategic need to increase the casting capacity to 70 t per cast. This enhancement not only addressed the surplus metal in the furnace, which exceeded the casting capacity, but also aimed to elevate overall productivity. The proposed solution entailed implementing a higher capacity casting table outfitted with a greater number of casting moulds.

2.1.2 Maintenance Limitations

The specifications and parameters did not support the handling of 70 t billets per cast. It was suggested to upgrade the entire hydraulic system to increase the capacity of the DC caster by 10 t, a solution associated with significant expenses. Figure 6 shows schematic for casting table with platen cylinder.

Following the conclusion of each casting cycle, the platen had to be raised by approximately 1 m to facilitate the handling of billets using a chain hook beam for transfer from the DC table to the laydown area.

To lift the platen cylinder with an additional 10 t of billet cast weight required more hydraulic energy. However, the existing hydraulic power unit functions with a pressure of 3.1 MPa (31 bar), which was constrained to lifting a maximum of 60 t of billets.

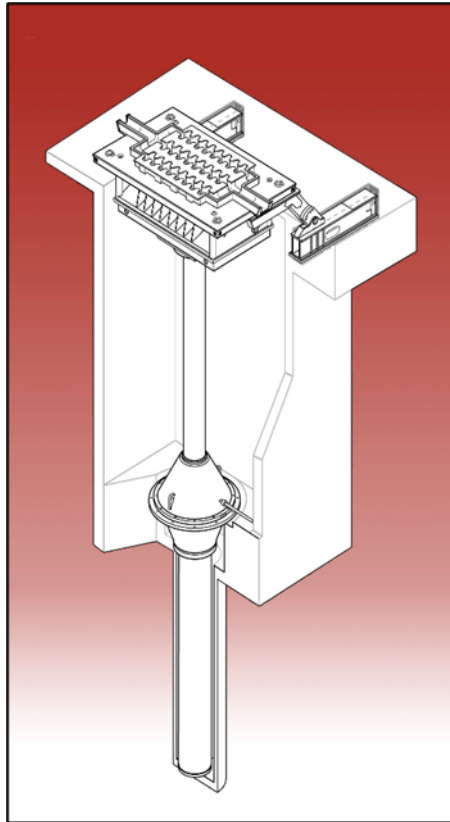


Figure 6. Casting table with platen cylinder.

The casting process necessitates the downward movement of the casting cylinder, which does not demand additional energy. The existing system can effectively manoeuvre the casting cylinder in the downward direction during casting operations involving 70 t.

Although casting with 70 t of billet was feasible using the existing system by utilising gravity for downward movement of the cylinder and platen, the system lacked the capability to lift the platen with 70 t using the casting cylinder. Lifting of platen by casting cylinder with 70 t billets was not feasible.

The recommendation for a comprehensive hydraulic system upgrade project entailed a lengthy process, which required a shutdown of the entire DC caster for a few weeks, impacting production.

2.2 Identification and Analysis of Potential Avenues for Improvement

As continuous improvement was essential, in this instance, a thorough root cause analysis was necessary to explore alternative methods for enhancing caster capacity. Utilising a fishbone diagram, a visual tool for examining cause and effect relationships, offered a structured approach superior to some other brainstorming tools for identifying the causes of a problem.

A comprehensive root cause analysis revealed several causes and contributing factors, as outlined in Figure 7.

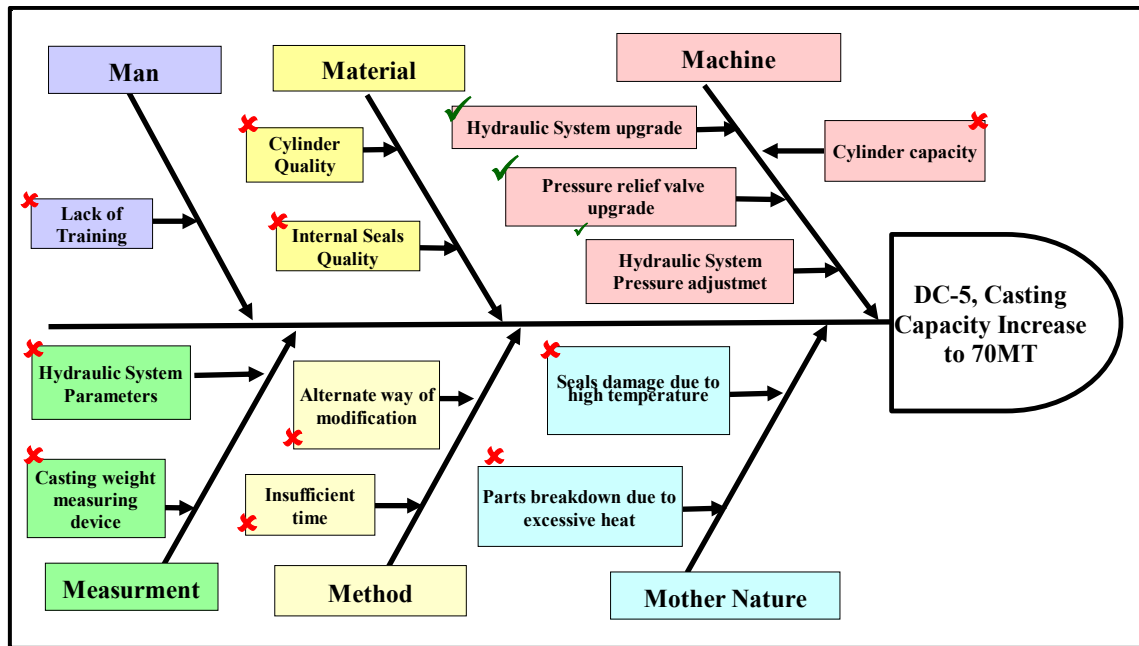


Figure 7. Fish bone diagram for comprehensive root cause analysis.

The prioritisation of contributing factors was crucial for achieving milestones with optimal resource utilization. Among the various causes identified, three options were singled out for action:

- (a) Entire hydraulic system upgrade,
- (b) Hydraulic pressure adjustment, and
- (c) Pressure relief valve upgrade.

While hydraulic system upgrade (a) was previously recommended to enhance caster capacity, it was deemed costly. Among the remaining two options, manual adjustment of pressure (option b) allows machine operation on a single pressure parameter (unchanged during operation), utilising the existing manually operated pressure relief valve.

3. Enabling Caster to Handle Higher Capacity Billets

Following the results of the root cause analysis, the second-prioritised factor, action (b) was chosen for initial execution. A trial was conducted to assess the condition of the casting cylinder while gradually increasing hydraulic pressure to accommodate a 70 t load. It was crucial to ensure that the hydraulic pressure did not exceed the maximum operating pressure of the entire system. The existing operating pressure was 3.1 MPa (31 bar) with a 60 t load, and during the trial, it was observed that 3.8 MPa (38 bar) was the breakeven point for lifting a 70 t load. This pressure remained below the maximum system operating pressure of 4.1 MPa (41 bar). However, achieving the desired capacity increase posed challenges with manual operation of the pressure relief valve at higher pressures continuously. This highlighted the need to address the hurdles in handling the existing hydraulic system and its functions with higher pressure ratings. Increasing the overall system pressure would mean operating all hydraulic components and end-user equipment at elevated pressures, whereas the requirement was solely focused on lifting the casting cylinder with higher pressure.



Figure 8. Aluminium billets.

3.1 Experiment for Action (b)

Upon analysing the root cause and conducting an in-depth study, it was determined that option (b) was partially accepted. During the study of option (b), starting from the existing system pressure of 3.1 MPa (31 bar), the pressure was incrementally increased by 0.05 MPa (0.5 bar) each time, while evaluating the casting cylinder with a platen load of 70 t. No movement was observed until the pressure gradually increased to 3.4 MPa (34 bar). At this point, the system was verified for all parameters and safety conditions.

After ensuring the system's health and verifying its condition, the pressure was increased again by 0.05 MPa (0.5 bar) increments until reaching 3.6 MPa (36 bar). Once more, no movement was observed in the casting cylinder. Repeating the previous step, all parameters of the system were checked and verified for system healthiness.

Upon the commencement of system pressure escalation for further evaluation and analysis, a similar incremental approach was adopted, with pressure gradually increasing in 0.05 MPa (0.5 bar) intervals until reaching 36 bar. Interestingly, at this juncture, the casting cylinder exhibited some momentum but lacked the necessary energy to smoothly elevate the platen with a 70 t load. Undeterred, pressure continued to rise until the casting cylinder successfully lifted the platen with the 70 t load which is 3.8 MPa (38 bar). Throughout these tests, comprehensive monitoring and verification of all system parameters and equipment, involving the engineering team, were conducted. At the determined breakeven point of hydraulic pressure, which was 3.8 MPa (38 bar), safety checks were thoroughly executed to ensure the system's integrity. Following the initiation of multiple tests, it was confirmed that the platen, loaded with 70 t of billets, could indeed be lifted with a system pressure of 3.8 MPa (38 bar) applied to the casting cylinder. However, a consequential side effect emerged: all other hydraulic components would operate at 3.8 MPa (38 bar), which was unnecessary. Consequently, option (b) was only partially approved as per engineering team evaluation. Further deliberation is required to identify alternative solutions to operate at the existing system pressure of 3.1 MPa (31 bar). In summary, two conditions must be met: an operating pressure of 3.8 MPa (38 bar) for the casting cylinder and 3.1 MPa (31 bar) for all other hydraulic components.

3.2 Action (c) – Work Description

Concluding option (b) as partially approved derived that pressure is enough but manual adjustment will not work for healthy system. It was required to get more other options which can accommodate multiple pressure automatically as per system requirement.

After evaluating option (a) as deemed costly and option (b) partially approved with multiple tests of pressure rising; option (c) started being execution. Pressure relief valve needs to be upgraded in order to accommodate multi pressure for different hydraulic components. Hence looking towards all above parameters and keep system healthy operation in mind, a new “Proportional Pressure Relief Valve” introduced in place of manual operated pressure relief valve as the important concern was to lift casting cylinder platen with 70 t load to reach the level of removing billet, which is approximately 1 m. Proportional pressure relief valve installed and pressure setting required as 3.8 MPa (38 bar) for casting cylinder with 70 t and 3.1 MPa (31 bar) for all other operations even for casting cylinder until 60 t of billet as well. Figure 9 refers schematic of proportional relief valve to get introduced.

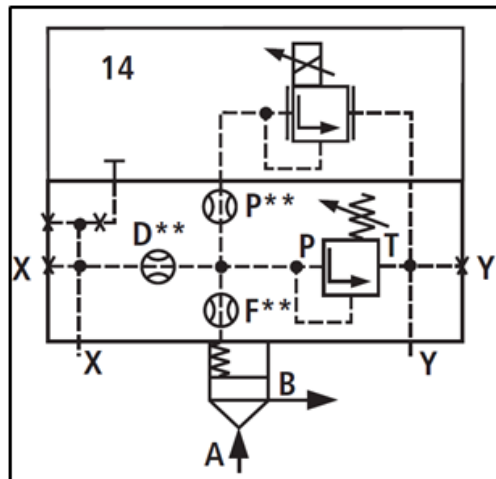


Figure 9. Proportional relief valve schematic.

The synchronisation of a new proportional valve with the existing system's Human-Machine Interface (HMI) has been successfully executed. Beginning at 4 A and gradually increasing to 20 A, the current was meticulously increased to initiate the opening of the proportional valve through the control panel. This adjustment was crucial in accommodating a pressure of 3.8 MPa (38 bar) necessary for the casting process, specifically tailored for handling a substantial load of 70 t of billet.

Before delving into the intricacies of synchronization, it is pertinent to mention a significant update to the Human-Machine Interface (HMI). As mentioned in Figure 10; Two new options, "below 60 t" and "above 60 t," have been incorporated into the HMI interface. This addition allows operators to swiftly toggle between settings, facilitating a seamless transition from 3.1 MPa (31 bar) to 3.8 MPa (38 bar), depending on the load conditions. This selection switch, conveniently situated in the operator's cabin, enhances operational efficiency and flexibility within the system.

Sequence of operation has been revised and set to new pressure as well. Existing operation at 3.1 MPa (31 bar) pressure kept as it is and only platen fast up process has been raised till 3.8 MPa (38 bar).

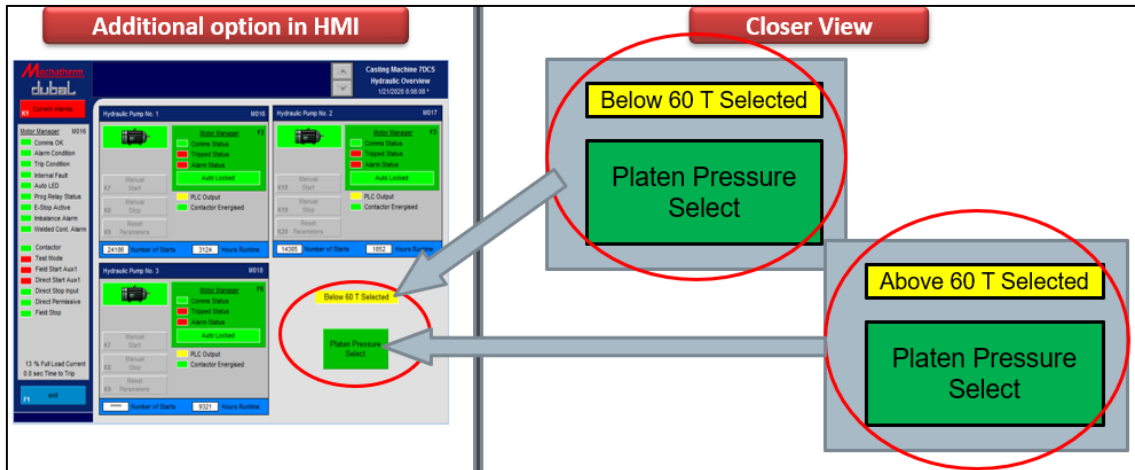


Figure 10. New Selection mode switch in HMI.

The proportional pressure valve functions at 3.1 MPa (31 bar) for standard operations but transitions to 3.8 MPa (38 bar) exclusively when lifting 70 t cast for stripping purposes. To facilitate this transition, a special option button has been integrated into the Human-Machine Interface (HMI). This button activates the relief valve, ensuring the system operates at 3.8 MPa (38 bar) when needed.

The "above 60 t" selection activates a stand mode for precisely 2 minutes. Following this duration, the system automatically reverts to normal parameters. This feature is crucial for enhancing safety measures for the platen cylinder. The 2-minute timeframe has been carefully determined, as it allows the platen to lift approximately 1 meter high, facilitating the billet stripping process. This highlights the sophistication and practicality of the new system's design. The billet strapping process encompasses both lifting and shifting of billets once the casting process is completed.

4. Results and Conclusions

The implementation of a meticulously crafted action plan, informed by extensive tests derived through root cause analysis, has yielded remarkable benefits across various facets. Notably, these benefits include cost reduction, heightened productivity, and enhanced efficiency, both within the DC caster and in the subsequent continuous homogeniser furnace process.

Some of the highly effective benefits are:

- a. Achieving a cast weight of 70 t instead of the previous 60 t per cast marks a notable advancement. With this enhancement, an average of 250 casts can be processed each month.
- b. The reduced number of casts is a direct result of the increased casting capacity to 70 t. This reduction translates into significant cost savings across various aspects of the casting process, including expenses related to energy, operational consumables, spares, manpower, and time.
- c. The efficiency of homogeniser furnaces has been significantly enhanced through the increase in cast length, a direct result of the expanded capacity of the caster. This development marks a pivotal advancement in metal processing operations, offering a range of benefits that ripple across the production landscape.
- d. The recent increase in caster capacity has sparked a significant reduction in scrap generation within metal processing operations. This notable shift can be attributed to the ability to accommodate longer lengths of billets, a direct consequence of the expanded caster capacity.

- e. A noteworthy cost-saving achievement has been realised through the combination of increased productivity and cost avoidance strategies implemented in-house rather than resorting to third-party solutions. This approach reflects a proactive stance toward optimising operational efficiency while minimising expenditure.