CAUSE AND PREVENTION OF EXPLOSIONS INVOLVING DC CASTING OF ALUMINUM SHEET INGOT

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Keywords: Molten Metal Safety, Aluminum DC Casting, Molten Aluminum Explosions

Abstract

The casting of aluminum alloy sheet ingot and T-bar presents the potential for some of the most volatile situations that can occur in DC (direct chill) and EMC (Electromagnetic) casting processes. Aluminum Association explosion incident data from over 300 explosions spanning a twenty-year period were reviewed and analyzed looking for common factors and repetitive reasons for explosions. Analysis of explosions occurring during the three stages of sheet ingot casting, ‘start of cast’, ‘steady state’ and ‘end of cast’, were examined and prioritized. Case studies illustrate the need for understanding both technical and non-technical factors contributing to explosions involving molten metal. This paper identifies the major causes of explosions involving DC casting of aluminum alloy sheet ingot and makes recommendations for how to prevent the recurrence of such events and minimize the risk of injury.

Introduction

Molten substances such as aluminum and alloys of aluminum for wrought ingot applications pose potential hazards for worker safety, especially if these hazards are not properly understood or if safe job practices are not strictly followed. Of greatest concern are the hazards that can result in metal and water explosions.

Educating the workforce has been an ongoing effort in the aluminum industry for many years. Through the Aluminum Association, the combined efforts of many companies has fostered a more consolidated approach to safety related research, molten metal incident reporting and information sharing. Through the Aluminum Association’s incident (explosion) reporting program, valuable information has been gathered that has helped identify major areas of safety concern in aluminum cast shops. The three major areas are: (1) Melting furnaces, particularly involving scrap charging, (2) Casting, particularly the start-up phase of DC casting and (3) Metal Transfer. Safety guidelines for these three areas are generally addressed in The Aluminum Association publication: “Guidelines for Handling Molten Metal.”\cite{1}

DC casting may be divided into two major sectors: (1) open mold technologies, and (2) hot-top technologies. A paper discussing safety concerns involving hot-top technology was presented at TMS in 2003\cite{2}. The present paper focuses on the safety concerns of open mold technology, specifically sheet ingot casting and T-bar casting. Please note that references made to sheet ingot casting in this paper usually apply to T-bar casting as well. For reference, Figure 1 shows typical components of an open mold set-up for producing sheet ingot by the DC casting process.

Aluminum Association Data

The Aluminum Association has been collecting data on molten metal explosions for over 20 years. Companies submit reports on a volunteer basis, and all names are withheld to preserve confidentiality. In the period 1980 to 2002, a total of 1,877 reports were received. There were 614 reports pertaining to casting, of which 494 involved DC, HDC and EMC\cite{3}.

With the cooperation of the Aluminum Association, the authors were privileged to access the complete data base, including incident descriptions as written by submitters of the reports. Incident data also includes other information related to the explosion including a rating of the force of the explosion\cite{4} (Force 1, Force 2 and Force 3), the number and extent of injuries, the amount of metal involved, the alloy, metal temperature, type of plant (Recycling, Reduction, Rolling or R&D) and month and year. This more complete information enabled us to determine that of the 494 DC/HDC/EMC incidents, 309 involved the production of sheet ingot, including EMC and T-bar (i.e. open mold technology).

From a health and safety perspective, the Aluminum Association data\cite{5} indicates a significantly higher injury rate and number of injuries for all types of casting incidents compared to melting and transferring incidents. Figure 2 shows that between 1980 and 2002 there were 417 injuries reported in casting related incidents, including 17 fatalities. This highlights the importance of understanding the nature of the hazards associated with the casting process before proposing solutions.

![Figure 1. DC Open mold set-up: (a) launder, (b) down-spool, (c) mold wall, (d) bottom block](image-url)
Analysis of the Data

Using the written descriptions of the incidents, root cause or primary and secondary causes were assigned for each incident. Based upon this incident analysis, the data was analyzed through various Pareto and statistical methods including mosaic plots, contingency tables and contingency analysis, which are shown in Figures 3 through 8.

Figure 2. Injuries by Molten Metal Operation

Figure 3. Reasons for Explosions – All Cast Stages

Figure 4. Reasons for Explosions – Cast Start-up

Figure 5. Reasons for Explosions – Steady-State

Figure 6. Reasons for Explosions – Termination

Figure 7. Injury Level vs. Force of Explosion