Functional modeling of an industrial system
STEEL MELT SHOP "SMS"

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Abstract: In the steelworks, due to the complex nature of operations, systems, procedures and methods always involve a certain amount of risk. It is not possible to eliminate all hazards, so the goal is to eliminate and / or control high and critical potential hazards and reduce the rest of the hazards to the lowest reasonable risk level in order to protect workers and equipments against damage and to ensure the proper functioning of the production chain. Risk assessment involves identifying and analyzing the hazards, the sequences of events leading to the hazards and the risk of hazardous events. Objective of this work is the functional modeling of steelworks of the steel complex of EL-MILIA JIJEL (ALGERIAN QATARI STEEL) and the application of risk analysis methods (STPA, D-Higraph) to identify, analyze the dangers and recommend the necessary control measures for them.

Keywords: Modeling, Steel Melt Shop, Assessment of Risk and analysis, D-higraph, STPA, Hazard identification.

1. INTRODUCTION

Steel smelting workshop (SMS) receives CDRI, HDRI from DRI units or scrap and converts them to different grades of steel and billets, SMS is the first step in the chain of value of steelmaking where product differentiation and customization begins.

The entire steel making process is associated with various safety risks such as exposure to excessive heat, dust, noise, fire and explosion, falls from heights, confined spaces , electric shocks, gas leaks and radioactive leaks, etc. The objective of this document is to model the system and identify the hazards associated with the process of melting steel and have a safe system.

2. ABBREVIATIONS AND ACRONYMS

CDRI- Cold Direct Reduce Iron
DRI- Direct Reduce Iron
EAF- Electric Arc Furnace
EBT- Eccentric Bottom Tapping
HDRI- Hot Direct Reduce Iron
LRF- Ladle Refining Furnace
LVDT- Linear Variable Differential Transformer

3. PROCESS BRIEF:

Our system with its functional diagram is illustrated by the following figure:

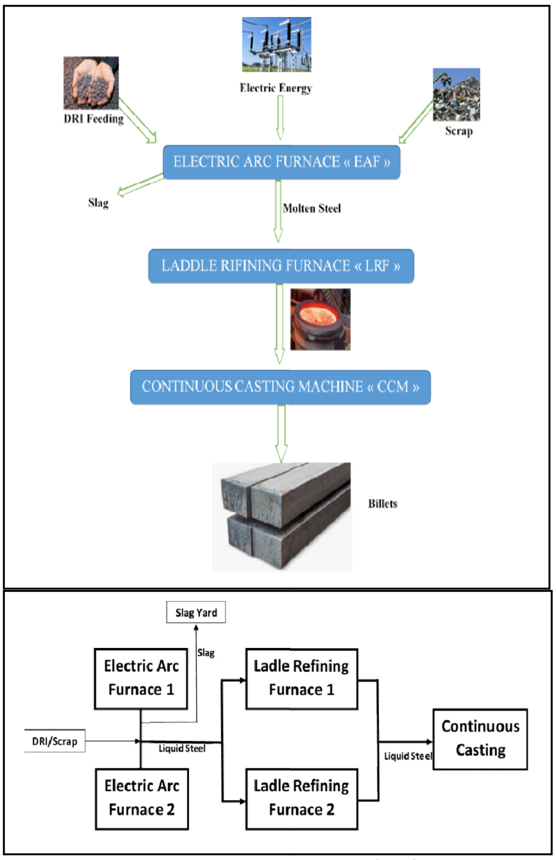

Fig. 1 Functional block diagram for Steel Melt Shop (SMS)

This system needs three sources (electricity, scrap and dri feeding) after the EAF step we obtain the Molten Steel and slag. The Molten Steel transferred to LRF and finely step the product transfer to continuous Casting Machine to obtained final product (Billets).

3.1. ELECTRIC ARC FURNACE (EAF):

Electric arc furnace (EAF) steelmaking uses heat supplied from the interaction of an arc of electricity between graphite electrodes and the metallic charge in the furnace to melt the solid iron feed materials [1].

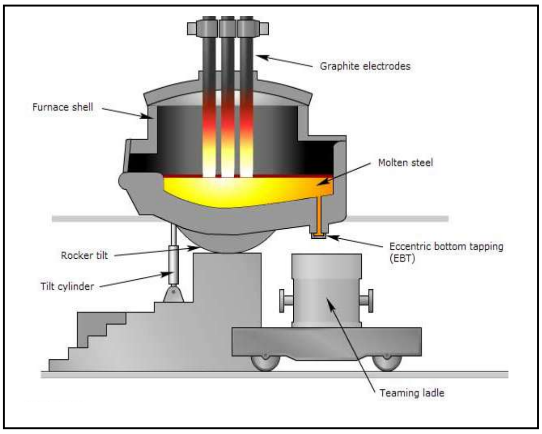

Fig. 2Electric Arc Furnace Diagram

3.2 LADLE REFINING FURNACE(LRF):

Ladle Refining Furnace (LRF) ensures reheating of Liquid Steel, coming from EAF Ladle Furnace utilizes electric energy& graphite electrode to raise & maintain Temperature. Homogenization of liquid steel temperature and chemistry of steel through inert gas stirring. Steel is refined & final composition is achieved[2].

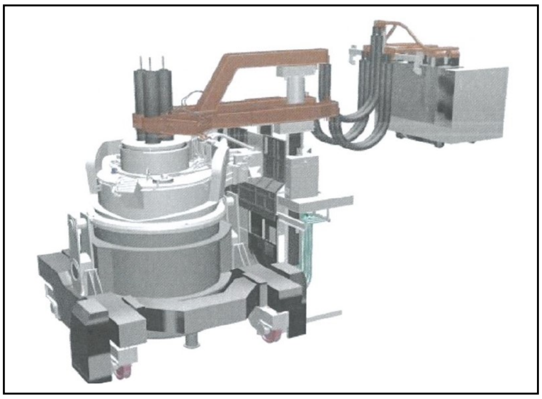

Fig. 3Ladle Refining Furnace Diagram

3.3 CONTINUOUS CASTING MACHINES:

Casting is the production of solid steel forms from molten steel. Casting begins when refined steel is poured from a ladle into a tundish, which is a small basin at the top of the caster. The falling steel passes through a mould and begins to take on its final shape. The strand of steel passes through the primary cooling zone, where it forms a solidified outer shell sufficiently strong enough to maintain the strand shape. The strand continues to be shaped and cooled as it curves into a horizontal orientation. After additional cooling, the strand is cut into long sections with a cutting torch or mechanical shears, the cut billets are dispatched to the rolling mill for further processing into saleable steel[3].

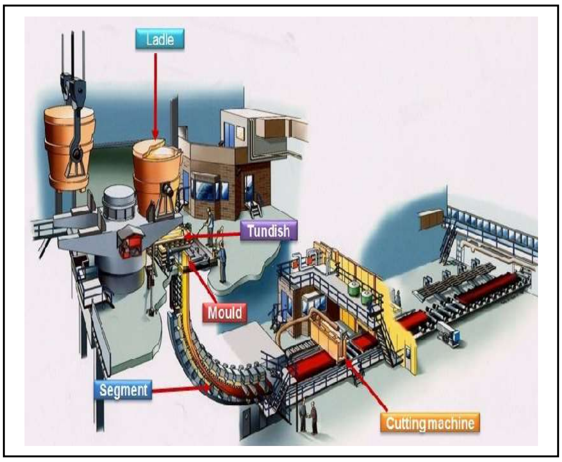

Fig.*4* Continuous Casting Machines Diagram

4. BACKGROUND:

4.1. STPA Hazard Analysis:

STAMP (Systems-Theoretic Accidents Model and Process) is a new accident model developed based on the system and control theory rather than the reliability theory. In STAMP, the system is viewed as a set of components, which interact to achieve the functions of a system. Furthermore, the reasons behind system accidents are not only single component failures, but also especially unsafe interaction among these components. Based on STAMP, a new hazard analysis technique called STPA (Systems-Theoretic Process Analysis) was developed. STPA is a powerful approach for hazard analysis.

The STPA safety analysis process involves that a hierarchical control structure diagram should visualize a system. Each level in this diagram contains a control process and control loop with actions and feedback. Before starting the STPA process, a safety analyst must establish the scope of the analysis, which includes defining the fundamentals of the analysis (e.g. accidents, system-level hazards and hierarchical control structure diagram). The STPA safety analysis process can be performed within two main steps: STPA Step 1: Identify unsafe control actions, this step aims at identifying the potentially hazardous control actions in the hierarchical control structure diagram; and STPA Step 2: Determine how the potentially unsafe control actions can occur. This step focuses on identifying the potential unsafe scenarios and causal factors for each unsafe control action [4].

4.2. D-HIGRAPH:

The Higraphs are a general kind of diagramming objects well suited to the behavioral specification of complex concurrent system. They were first presented by Harel (1987, 1988) and they can be considered as an extension and combination of conventional graphs and Venn diagrams. Higraphs consist two elements, Blobs(states) and edges (transitions) connecting the blobs. However, higraphs are not suitable for process systems specifications.

Rodrîguez&Sanz(2009) first presented D-higraphs as a functional modeling technique that merges functional and structural information of system modeled.

They came from the dualization of D-Higraphs: blobs represent transitions and edges represent states. Disjoint blobs imply and AND relation, i.e., both transitions between states take place. Orthogonal blobs represent and OR relation, i.e., only one of the transitions takes place[5-6]. It has to be noticed that a D-higraph is not a dual higraph (like dual graphs), obtained from changing blobs by edges and edges by blobs. The duality lies in the interpretation of blobs, edges and their properties [7-8].

5. PROCESS HAZARD ANALYSIS AND NECESSARY RISK CONTROL MEASURES:

The following table illustrates the application of the process hazard analysis in our system and the different risk control measures take account to approve the safety of our system:

Table 1. process hazard analysis and necessary risk control measures:

Area / Section / Activity	Hazards	Risk Control Measures
Movement of the ladle car and align the ladle properly underneath the EBT of furnace	- Hot Metal spillage. - Fire	Level sensors for free board measurement system to be in place (Laser/Radar/Camera based) to avoid overfilling.
Hot Metal ladle is lifted by charging crane	Free fall of HM/Steel ladle from Crane	- Auto/Manual emergency breaks Shall be made available in cranes and operators to be trained. - Hooter shall be provided to alert persons. - Hazard Sign Board Display.
Tapping	- Spillage slag/metal from the mouth - Fire - Blast	- De-slagging to be ensured before tapping. - Dog house doors to be kept closed before tapping.
Heating by Electric Arc	- Electrode breakage - Metal spillage - Fire	- Roof balance to be ensured (automatic LVDT control system can adopted) - Ceramic ring to be provided for non-contact of electrode and steel hood
Trickling/Puncture of ladle on transfer ladle car	- Fire hazard - Explosion	- Visual inspection of ladle refractory and life monitoring / Thermography of refractories.
Blowing of oxygen	explosion	- Lance positioning and facilitating converter till to be defined as standard procedures - Arrest the water leakage ensure that water is not entrapped in hot metal.
	Oxygen Lance free fall	- Digital encoder for lance movement. - Provision of emergency push button
Turret Operation	- Metal spillage during ladle placement - Fire& explosion	- Interlocks to be in place for turret rotation while placement of ladles on loading arm. - Slide gate attachment of hydraulic hose to be ensured - Trained operator for crane with proper guidance system (Laser/marker) should be installed for vertical placement of ladle. - Overfilled ladle with liquid steel should not be placed on turret - Any ladle having red spot on shell should be not placed on turret
Casting operation related abnormalities and emergency situations	- Metal spillage - Fire hazard - Explosion - Radioactive hazard	- During start of continuous casting operations, Ladle Turret emergency rotation must be checked to ensure proper rotation and

		safety measures during casting ladle troughs / slide gate failure led slag / metal splashing. - Proper safety clothing& precautions to be taken by mould operators for preventing fire related hazards during mould overflow, tundish stopper running, mould boil, radioactive hazards when using radiometric type automatic mould level control system
Collision of two crane	Hot metal spilling	Anti collision device is mandatory for all crane if 2 or more cranes operating in same bay.
Free Fall of ladle due to wire rope cut /rope drum failure/ Brake failure	- Hot metal splillage - Fire - Explosion - Equipment damage	- 4 fall wire rope system in all hot metal crane should be followed. - Speed Encoder to be installed with interlock. - PLC based cranes is safe for usage. - Emergency brake system should be available in all cranes

6. CONCLUSION:

In this paper, we deals with the Functional modeling, Hazards identification risk assessment and control measures in Steel Melt Shop plant "ALGERIAN QATARI STEEL" by using risk analysis methods (STPA Hazard analysis, D-Higraph). These methods will help to identify the various hazards in plant and assessment of risk to control hazards takes place in a steel melt shop plant. Assessment of risk analysis and control measures will be prepare to reduce the worksite accidents takes place in steel melt shop plant. Risk analysis and control measures implemented. After that comparison of risk rating before implementing control measures and after implementing control measures mentioned

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