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Human Machine Interaction and Safety: Identification of Human Errors through Task Analysis

Skanda M.G[1], V. Ramesh[2] and D. Arunkumar[3]

[1,2,3]*Department of Industrial and Production Engineering, JSS S&T University, Mysuru, Karnataka, India*

Abstract—*In safety critical domains most of the industrial mishaps are attributed to human errors.Human operators will always be at the sharp end of the system and not many studies have given importance to study the causes of human error through psychological aspects of the operator. Human reliability literature classifies different types of errorsand its implications to safety. Based on the literature review current study was aimed at identifying the human errors in polymer processing industry in Bangalore city. Interview with the process operators revealed that the mixing, straining and milling sections of the processing plant are considered to be safety critical. Task analysis method was used to decompose the main task into sub-tasks to identify the critical task in these critical sections. Current study reveals that, human error needs to be studied from the point of view of cognitive mechanisms of operators in question. Identified errors in aforementioned sections were classified according to the James Reason's taxonomy. Study also asserts the importance interdisciplinary approach to analyze the human errors in industrial setups.*

Keywords*: Industrial accidents, human error, human reliability, Task analysis, human error taxonomy.*

1. INTRODUCTION

Workplace safety is becoming a paramount important aspect for organizations to prevent industrial accidents and incidents specifically in hazardous and critical sectors. Many safety training programs are being conducted by Government bodies as well as private consultancies to impart safety education to Industrial employees. It is a requirement under Factories Act, 1948 [1] that every organization shall ensure safety and welfare of all workers while they are at work in the factory which implies that factory authorities should take measures to establish identifying hazards and that are eliminated or reasonably controlled. Section 41A of the act deals with the site appraisal committee and rule made there undercalls for risk analysis report for which hazards are to be identified.

In most of the cases accidents and incidents are attributed to 'human error' for unsafe acts. Studies on industrial safety have put forth theories, policies and solutions to minimize human error by improving the design and environmental aspects of organizations.But, there is a need to study human errors systematically from the point of view of cognitive mechanisms of the operators working in critical industrial workplace settings.

2. HUMAN ERROR CLASSIFICATION SYSTEM

The field of human reliability analysis (HRA) aims to identify the causes and sources of human errors and provide a numeric estimate of the likelihood of such errors [2]. Many theories have been proposed to explain the human error in industrial environments and causes of accidents in industries [3]. This review will focus on major themes related to human error classification systems.

In his book on human error R.B Whittingham [3] defines general meaning of taxonomy and explains the purpose of doing the classification system, according to him 'Human error can occur in a wide variety of types and forms and be manifested in almost infinite number of ways. To introduce some order into what might otherwise become a veritable forest of errors; attempts have been made by experts in the field to formulate ways of organizing errors into taxonomies. The definition of taxonomy, according to Collins English Dictionary, is 'a grouping based on similarities of structure or origin'.

There exist various taxonomies of human error classification schemes used in complex safety critical domains. Human error classification systems are used both pro-actively by anticipating the errors and retrospectively during the post-accident/incident investigations.

The important most cited classification dominates human reliability literature are:, Reason's (1990) generic error modeling system[4,5]and Rasmussen's skill, rule and knowledge error classification (1986) [6] . A brief summary of these approaches is given below.

2.1 James Reason's Generic Error Modeling System (GEMS)

James Reason [4] developed error taxonomy incorporating lapses, mistakes and violations. Slips and lapses are characterized by attention failures and memory failures respectively. Slips and lapses are the examples of the unintended actions whereas mistakes are associated with intended action. A mistake occurs when an actor intentionally performs an action that is wrong. Therefore mistakes originate at the planning level, rather than the execution level, and can also be termed planning failures. Violations are more complex, and are categorized behaviors that deviate from accepted procedures, standards and rules. Violations can be either deliberate or unintentional [4].

Table 1: Basic error types with examples

Error Type	Example
Slip (attention failure)	• Misperception • Action intrusion • Omission of action • Reversal of action • Misordering of action • Mistiming of action
Lapse (memory failure)	• Omitting of planned actions • Losing place in action sequence • Forgetting intended actions
Mistake (intention failure)	• Misapplication of good procedure • Application of a bad procedure • Poor decision making • Failure to consider alternatives • Overconfidence

Reason makes the point that slips and lapses are likely to result from either inattention (e.g., failing to monitor performance at critical moments in the task, especially when the person intends to do something out of the ordinary – such as deviating from the normal procedure of operation) or over attention (e.g., monitoring performance at the wrong moments in the task). Whereas, Reason argues, mistakes are likely to result from either the misapplication of a good procedure (e.g., a method of performing a task that has been successful before in a particular context) or the application of a bad procedure (e.g., a method of performing a task that is ‘‘unsuitable, inelegant or inadvisable” at the most basic level [4, 5].

2.2 Skill, Ruled, Knowledge based behavioral model for error classification

According to Rasmussen [6, 7] errors are also affected by skill, experience and familiarity with the situation. Fig. 1 shows three levels of cognitive control, denoted as skill-based, rule-based, and knowledge-based, behavior.

Human action can be highly automatic (i.e. skill based), associative (i.e. rule-based), and analogous or exploratory (knowledge-based). Aspects of the task that are very familiar and routine will be largely automatic (i.e. skill-based behavior). Aspects of the task that are unfamiliar and rarely encountered will require effort and conscious attention (i.e. knowledge-based behavior). In between these extremes are aspects of the task that require identification and recall of the appropriate response which is stored in memory (i.e. rule-based behavior).

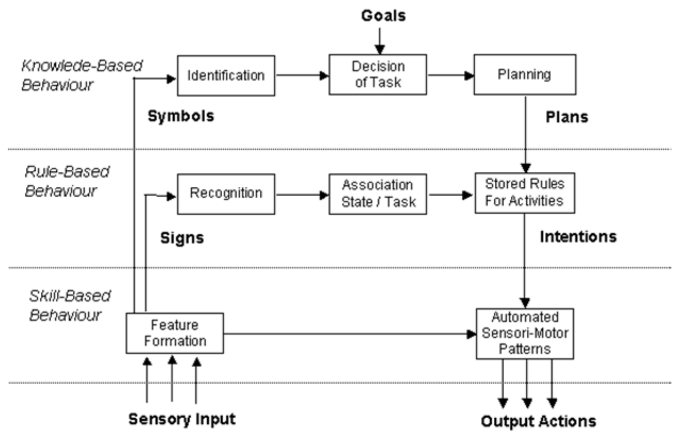

Fig. 1: Three levels of performance of human operators (Adapted from J. Rasmussen’s SRK model)

3. METHOD

The primary data was collected through interview with shop floor supervisors and operators. Interview with the operators revealed that, mixing, straining and milling sections were considered to be critical sections as incidents such as injuries to the hand were frequently reported in these sections. All the three sections mentioned are highly procedure driven and require safety precautionary measures in doing the each step of task. Also, past record showed that in straining section a worker lost his hand while replacing a mesh in a strainer.

A task analysis [8] was carried out for mixing, straining and milling sections were carried out and types of errors and causes of errors were identified. Classification of errors was done based on James Reason’s generic error modeling system to identify and classify the error types.

In the current study, after performing the task analysis in mixing, straining and milling sections we classified the errors in each process using James reason’s error modeling system. We also observed that there was a lack of safety features in each department. Classification of errors by this methodology would enhance productivity and to enhance safety features.

4. PROCESS DESCRIPTION AND CRITICAL SECTION

4.1 Mixing process

1. Raw materials from the outsource are brought to the inventory
2. One of the labor’s loads the raw materials near the machine from the inventory
3. the material is fed into the machine

4. The fed material is drawn into a form of thin sheets/tapes. These tapes are conveyed to the strainer using a conveyor

Critical steps: Manual feeding of raw materials in mixing section.

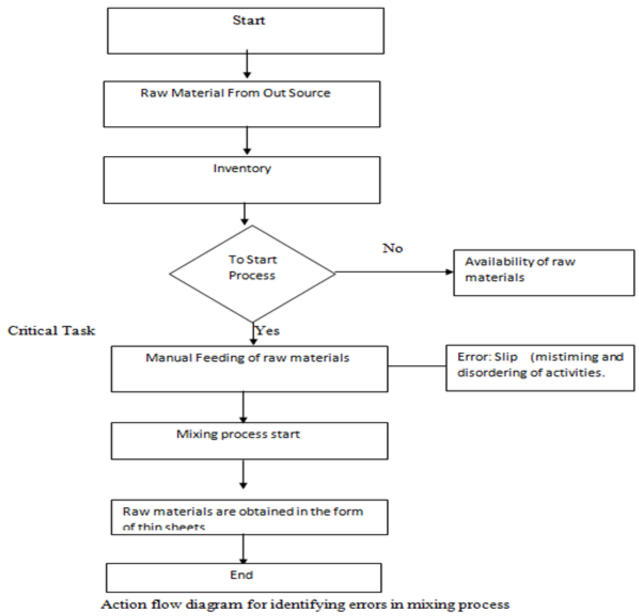

Fig. 2: Task analysis action flow diaram

4.2 Straining process:

1. The strainer machine begins to give pure components/shining components as output
2. The mesh used inside the machine filters the dust particles, foreign materials
3. Mesh used will be replaced for every four batches where, 1 batch= 4 bundles.
4. Finally the shining components are weighed approximately to 25kgs

Critical steps/defects

1. During the change of mesh, threaded ring of diameter approximately 8 inches may damage the foot due to its heavy weight and its hotness and if the mesh is not replaced at regular intervals, the obtained rubber will be in impure form which contains foreign particles
2. Improper placing of mesh 3. In this section, manual feeding of raw materials should be considered as critical task because while feeding of raw materials, accidents may occur and cause damage to workers and it may also lead to machine breakdown.

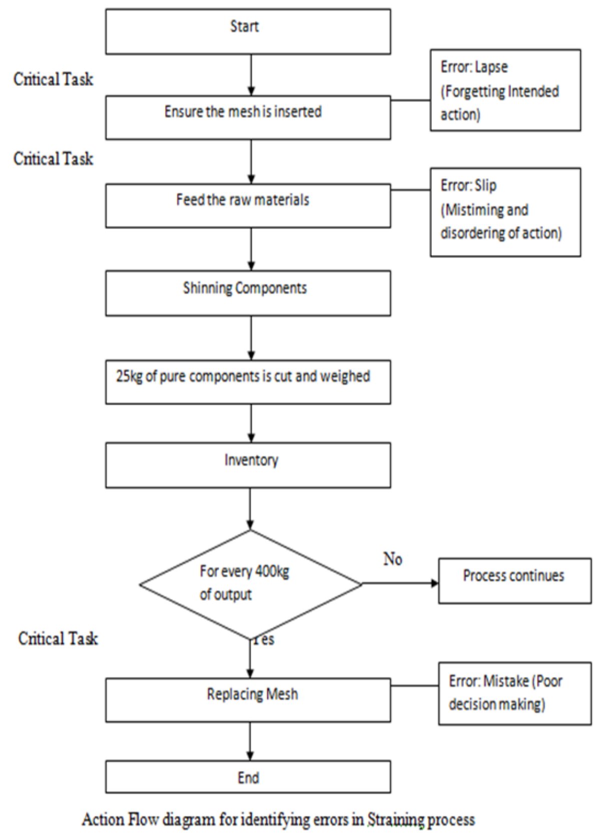

Fig. 3: Task analysis action flow diagram

4.3 Milling process:

1. Shining components weighing 75kgs along with 25kgs of work way and three types of chemicals are fed into the twin mill machine where it is processed for few minutes until the mixtures are completely mixed.
2. Mixed components are cut manually into tapes and cooled using soap solution.
3. Cooled components are then placed to the inventory by laborers

Critical steps/defects

1. Chemicals ratio may vary

2. Irritation of eyes, hands and legs may occur while cooling pure components by fan in soap solution

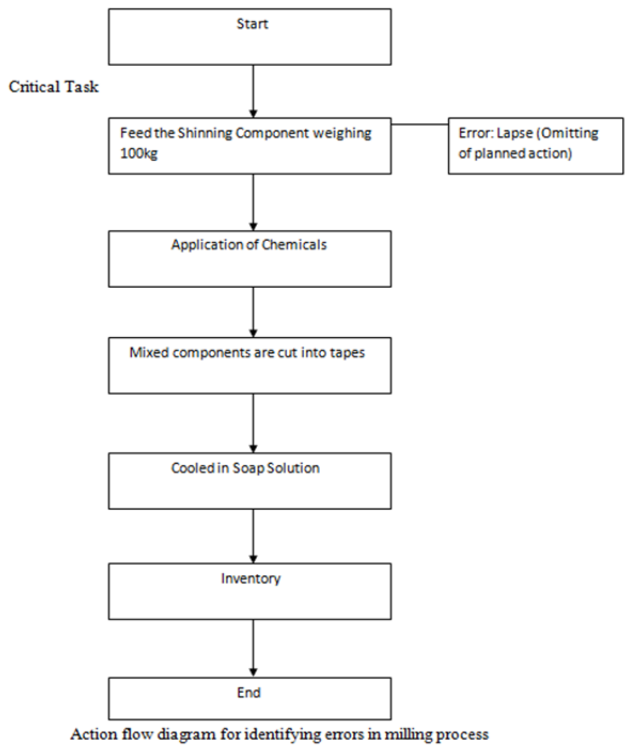

Fig. 4: Task analysis action flow diagram

5. DISCUSSION

The action flow diagram shows the critical steps and type of human error committed in carrying out the task. The summary of type of error and its characteristics and causes are summarized in the following table and table respectively.

Table 3: Types of error identified in tyre tube polymer processing organization

	Process	Critical task description	Type of error identified
1.	Mixing	Manual feeding of raw material	Slip
2.	Straining	• Insertion of mesh • Feeding of raw materials • Mesh replacement	Lapse Slip Rule based mistake
3	Milling	Milling of stock compound	Lapse

The summary of type of error and its characteristics and causes are summarized in the following table

Table 4: Cause and Characteristics of errors

Error type	Cause	Typical characteristics of error mechanism
Slip	Mismatching and Misordering of procedure	• Frequently performed action goes wrong
Lapse	Forgetting intended action	• Error of omission due to memory lapse. Action in a procedure is not intended
Mistake	Poor decision making	• Decision-making failures; errors of judgment. • Misapplication of a good rule or application of a bad rule

From the table major types of errors which occur in three different sections of the plant and their typical characteristics of error mechanism have been listed. Study revealed that there is lack of safety measures and training to the employees in dealing with the critical operations in the sections considered. We assert that these types of error identification and documenting errors will further help the organizations to mitigate errors committed by the worker.

In mixing process manual feeding of raw materials leads physical damage of workers and decreases the production rate. So by using James Reason's error modeling system critical task was classified as slip.

In straining process ensuring that raw material is inserted, Feeding of raw materials and replacing mesh were found as critical steps. According to James Reason's error modeling system ensuring that mesh is inserted was classified as lapse, feeding of raw materials is classified as slip and replacing of mesh considered as mistake.

In milling process feeding of shining components weighing 100kgs was found as critical step and this critical task was classified as lapse. In milling section, improper proportion of chemicals leads improper mixing of pure components with chemicals. In tube extrusion section, improper ratio of chalk powder leads sticking of pure rubber. From this mistake in curing section temperature and pressure will vary, so that in inspection section bulge, body blister and other types of scrap will comes as output.

Based on the review of human reliability literature and exploratory case study - The need for taxonomic approach to human error has been discussed in the paper. Industry specific taxonomy will help the professionals to have a ready reckoner checklist when conducting a safety audit.

6. CONCLUSIONS:

The current paper asserted the importance of taxonomic approach in the identification of human errors in industrial setups through task analysis. The literature review showed that human operators are always at the sharp end of the system and are prone to errors, which leads to accidents and incidents.

Further, this paper argued on a premise that human fallibility is not avoidable but it can be prevented or its effect can be mitigated by proper understanding of the job and behavior of the operator in performing the task.

Research shows that there is a need to define the detailed nature of errors and develop the database comprising of industry specific accidents and incidents. A robust database of predictive errors based on previous case studies (retrospective analysis) and task analysis will help the safety professionals to identify and categorize the errors and will lead to a better management of errors through this database.

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