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IOT Based Smart Solution for Preventing Fall Injuries at Workplace

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Abstract: *In India fall injuries are increasing rapidly at workplace not only in the industrial sector even though construction and private sector too. Fall injury is the highest cause of death/ fatal/severe injuries. The severity of working at height incident depending upon the nature of job, height of application, uneven/cluttered surface etc.In this research paper a unique solution has been studied to bring revolutionary change in personal protective equipment which is used while working at height. There are many technologies are available, in chemical industry if any parameter deviate automatically machine will be shut-down and safe operating protocols will be activated but in conventional personal protective equipment it is hardly say there is still area of research where the technological improvement is needed to bring the robust safety system. Air bags are a very good example to correlate the smart PPE, if any passenger vehicle have air bag system collision with other vehicle automatically within milli second the airbag will be activated which saves the life of driver and passenger as well. Similarly Smart PPE has unique provision if PPE compliance is deviated at workplace immediately the violation shall be captured, and warning alert shall be given to user to remind them to compliance. This will help us to improve workplace safety. It is an error proof system that neither required manual surveillance nor manual recording of violations. In this research paper IOT internet of thing based smart safety harness has been studied and the workplace deviation were compared earlier with manual monitoring data to analyze the human error with respect to compliance of personal protective equipment*

Keywords: Internet of Things, Personal Protective Equipment, Fall Protection, Working at Height, Fall Injuries

I. INTRODUCTION

Working at height incident are really a foremost concern of every manufacturing industry not only affect the company safety performance it affects the morale of the company employees and contract workers and company's reputation as well. In Gujarat there are so many chemical industries and automobile industries are there. In Gujarat the industrial accidents are increasing year on year and there are so many surprising statistics which stated that casual attitude and lack of commitment from the management toward the safety resulting into the life-threatening risk to company employees and contract workers. In 2020 there were 212 nos. of fatalities, and 516 nos. of non-fatal accident were reported by the Director of Industrial Safety Health of Gujarat to DGGASLI Directorate General, Factory Advice and Labour Institutes. In 2021 there were 235 nos. of fatalities, and 621 nos. of non-fatal accidents were reported. Most causes behind this accident are working at height and fire and explosion. In 2020 working at height risk contributing 19 % causes to fatality whereas in 2021 it increases from 19 % to 20 % and increasing rapidly year on year. In 2020 working at height risk contributing 14 % causes to non-fatality accident whereas in 2021 it increases from 12 %. In nutshell it is clearly defined that injury due working at height is still ignored by the industry and there are many contributing causes behind that which required management attention and strict compliance enforcement through the regulatory agency.

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II. METHODOLOGY

In India anchoring of safety harness with anchoring point is being monitored through manually either deputing safety supervisor at workplace or walk the talk by the senior leadership team. Most of the industries are struggling for basic personal protective equipment compliance on their shop floor. Selection of advanced fall protection system while working at height involves many steps and required many inputs from engineering team and safety team and information technology team. The objective of this study is to provide the best solution for preventing fall injury from height. Working at height solution should be communicated to each contract worker those who engaged in working at height activity. Following below key steps have been involved for selection of advance fall protection system.

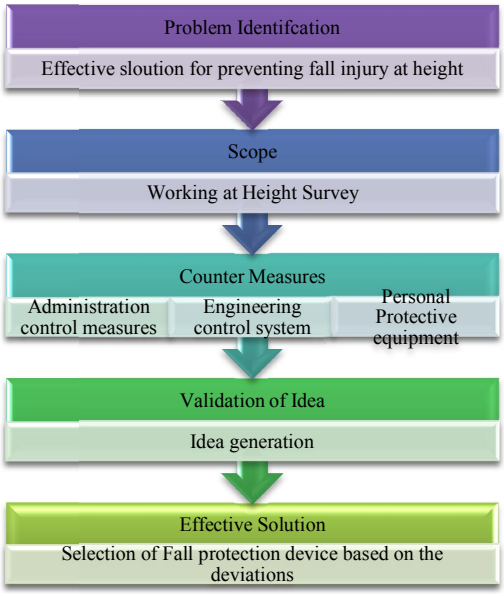

Figure 2.1: Flow of Selection of Smart Harness

Step No-1

Identification of Problem:

The first step is to identify the problem. In working at height 3P principle works called 3 points contact. At least 3 points of contact must be there while working at height. Either 2 legs and one hand or one leg and two hands must be engaged while working at height. This is the thumb rule while working at height whereas there are 3 basic requirements which should be standardized across the industry. The first one is access to height. Access to height means how access to working ate height either using of ladder, movable platform, platform with railing, monkey ladder, roper ladder or other means of access.

Step No-2

Scope of Work:

The second step is to conduct a survey in the plant and identify how many places where potential fall hazard can occur. Like process area where there is chances of fall hazard, roof sheeting activity. These activities either may be routine or non-routine activity. For routine activity in industry there is standard operating procedure is governed and accordingly work is carried out for example operating of process isolation valve at height so there is standard fixed mobile platform having toe guard, mid rail and top rail provision by which worker can work easily. The second one is the non-routine activity where a working at height permit is enforced to get the job done safely. So it is very important that the list out the area where there is possibility of fall while routine and non-routine job.

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Step No-3

Control Measures:

The third step is to identify the counter measure. There are multiple counter measures that can be adopted while working at height. However, it has been classified into three categories.

- Engineering control measures
- Administrative control measures
- Personal Protective equipment.

Engineering control measures- In engineering control measures there are lot of innovation and best practices have been adopted by the industry while working at height which totally eliminate the working at height risk example Thickness monitoring by using Drone Technology, painting through Drone technology, Scraping and NDT testing by using robotic solution crawler type robot, working at height using boom lifter and advance lifting mechanism. This advanced technology will not only reduce the time, cost, manpower but will bring down the high risk into medium and low risk category and having reliable system if it gets failed and there is not life-threatening risk to employee and contract worker so this type of technology will help to further strengthening of working at height control measures in terms of engineering controls.

Administrative Control measures- There are various administrative control measures used at industry for preventing fall injuries while working at height. All the administrative control measures are governed through the standard operating procedure for routine and non-routine activity.

- Work permit system
- Method statement
- Risk Analysis
- Training and toolbox talk
- Inspection of Lifting tool and tackles
- Vertigo test for height work
- Skill matrix for workers
- Safety display
- Deputation of supervisor.
- Monitoring through the camera or manual surveillance system etc.

Personal Protective Equipment- In working at height PPE is mandatory like safety helmet, safety shoes, safety goggle, safety hand gloves and most important double lanyard full body safety harness. FBSH is the most essential lift saving equipment by which the fall can be prevented. However, it is dependent upon the worker if he forgets to connect eh lanyard with the anchoring point which may be life-threating risk to workers. That needs to be ensured by deputing a safety supervisor or manager to comply with the PPE requirements. Apart from PPE, rescue equipment is also considered if fall occurs, and worker is hanging with the anchoring points. He must be rescued as soon as possible by using appropriate rescue equipment or method. If a person is hanging with the safety harness, he may be suffered with trauma suspension due to restriction of blood in his lower body part which again may be life-threatening risk to works so that's why rescue equipment must be considered while working at height.

Step No-4

Validation of Idea:

In above steps 1,2 &3 enable us to identify the problem and area where there is fall hazard and assess the risk and control measures in terms of engineering, administrative and personal protective equipment. Now step no. 4 enables us to select the effective fall protection system to prevent the fall injuries. For that all the control measures need to be validated whether they are reliable and having redundancy. In all the control measures need, be evaluated that if one layer of protection is failed then another layer of protection will overcome the situation or not. Identify the weakest control measures which is totally depending on the human behavior, knowledge, skill and try to fix it by adopting new technology or innovative solutions. There were multiple ideas that will be generated out of that the most reliable,

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trusted, authentication idea will be selected as advance fall protection system to prevent fall injuries while working at height.

Step No-5

Effective Solution:

After selection of Idea advance fall protection system, deviations shall be analyzed based on the basic trend. Earlier the working at height deviations were noticed either contractor supervisor or safety officer after that all the deviation were record into the system and the corrective action was taken based on the root cause like training need analysis, training effectiveness, skill development etc. Similar practice shall be followed for the advanced fall protection system and deviation will be logged in the system. Both the deviations will be analyzed, and comparison shall be made initially those have more deviations there will be more area of opportunity to work and again corrective action shall be taken accordingly.

III. PLANT DESCRIPTION

Coromandel International is India's pioneers and leading Agri-solutions provider, offering diverse products and services across the farming value chain. Starting our operations from India's first fertiliser plant at Ranipet, Tamil Nadu in 1906, we have been evolving for over a century by offering customized farm solutions and advisory services. Our 'Farmer First' approach, quality focus and consumer connect initiatives have helped in gaining farmer's trust and has established 'Gromor' amongst the most trusted brands in the country.

This dissertation has been prepared for CIL Dahej Plant. CIL Dahej plant has one molecule pesticide agrochemical. CIL Dahej plan has 13 acres of land has one manufacturing facility and utility facility associated with warehouse fire pump hose and adequate management staff.

CIL Dahej plant has three management systems.

- Process Safety Management System
- Occupational Health and safety Management system
- Environmental Management System

CIL has its own working at height standard and procedures in place and everyone's has undergone this training including contract workers. CIL working at height standard covers all the aspects and strong administrative control measure to avoid any untoward accident at site.

- The following control measures are available at CIL Dahej site to prevent fall injury while working at Height.
- Fall Control Measures
- Fall Protection Measures
- Fall Arrest Measures

IV. ANALYSIS AND DISCUSSION

For selection of IOT based smart solution for working at height for preventing fall injuries at height following below steps has been adopted.

Step No-1

Identification of Problem:

CIL Dahej plant has many working at height applications where every day working at height permits are obtained by the engineering team. This working at height job is safely executed by implementing robust administrative control like working at height permit system, Job safety analysis, Vertigo test while working at height. Toolbox talk, safety inspection for safety harness, PPE compliance, Training and other control measures based on applications.

The following majority of tasks are generally required for working at height and observed risk category.

Table 4.1: High Risk Area

Sr. No.	Task	Height of the Job	Risk Category
1	Roof Sheet Fixing Job	30 Mtr.	High Risk
2	Preventive Maintenance for Chimney or Stack	30 Mtr.	High Risk
	Scaffold erection work for civil work for manufacturing building	30 Mtr.	High Risk

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3	Lightening arrestor installation job	30 Mtr.	High Risk
4	Pipeline erection job	20 Mtr.	High Risk
5	Painting Job	20 Mtr.	High Risk
6	Maintenance of Isolation valve and assembly	20 Mtr.	High Risk
7	Leakage attending job inside the plant	10 Mtr.	Medium Risk
8	Project execution job inside the plant	10 Mtr.	Medium Risk

Step No-2

Scope of Work:

The second step is to conduct a survey in the plant and identify how many places where potential fall hazard can occur. This data can be obtained from the record of the work permit system. How many high-risk permits have been issued and what are the control measures associated with that. The scope of work involves the area where height work shall be carried out and the number of past working at height deviations. Once all the deviations are captured in one place then based on highest number of deviation where worker deviated the PPE compliance that area will be the area of opportunity where smart solution for working at height can be explored. Please find below the tabulate form for step 2.

Table 4.2: High Risk Area with Safety Violations

Task	Height of the Job	Risk Category	Area	Number of Violation/ 2023-24
Roof Sheet Fixing Job	30 Mtr.	High Risk	Production- Process Area	45
Preventive Maintenance for Chimney or Stack	30 Mtr.	High Risk	Utility DG and Boiler	10
Scaffold erection work for civil work for manufacturing building	30 Mtr.	High Risk	Production- Process Area	5
Lightening arrestor installation job	30 Mtr.	High Risk	Admin Building	7
Pipeline erection job	20 Mtr.	High Risk	Production- Process Area	15

The Highest deviation or violations have been recorded while roof sheet fixing job where there is inadequate supervision was observed most of the time and majority of time supervisor won't be able to supervise the worker's activities whether he has anchored his safety harness with anchoring point or not.

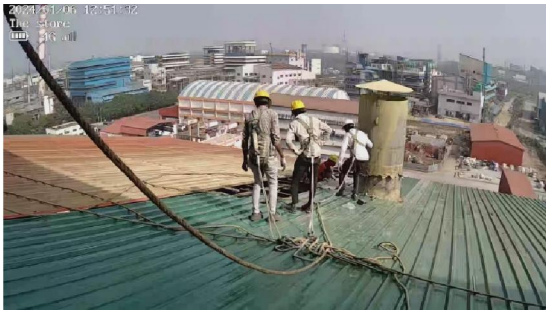

Figure 4.1: Working on Rooftop

Step No-3

Control Measures:

The third step is to identify the counter measure. There are multiple counter measures that can be adopted while working at height. The highest number of observations was observed while roof sheet fixing job at Manufacturing plant in process area. There were 45 nos. of PPE deviations were recorded where all the observations belonging to full body safety harness where worker did not connect the safety harness while roof sheet fixing activity. However, the following control measures were adopted while roof sheeting fixing job.

- Engineering control measures- Proper platform was provided while access to height apart from that safety net was provided to prevent the fall injuries. Generally, all the working at height is executed through the proper

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scaffold having access to height, toe board, mid rail and had rail and working platform which assure the working at job.

- Administrative control measures- Administrative control measures are the most important control measure while working at height. The following below list of administrative control measures is adopted while roof sheet fixing activity.
  - Job Safety Analysis- for all the non-routine activity job safety analysis is done before carrying out the working at height job. It is very essential step for preparing the working at height job.
  - Working at Height Permit System- This is the second most important legal document which requires while working at height. The height permit is filled out by the issuer and executor department, and they fill all the details for the person who will be working at height. It is a legal document, and a copy of the permit must be displayed at the location while carrying out the job. The work permit is signed by the all the authorized person and safety personnel also.
  - Tool Box Talk- Training is given before starting the height work job to all the contract workers who engaged in the working at height activity.
  - Height Pass Test- Vertigo test is performed for all the contract workers for checking their fitness while working at height. All contract workers must be qualified to work at height pass the test. This is mandatory test for working at height.
  - Safety Inspection- There are multiple inspections carried out like PPE inspection, Safety harness inspection, Work permit audit inspection etc.
  - Personal Protective equipment. - For working at height there are specific personal protective equipment are used like.
    - Safety Helmet
    - Safety Shoes
    - Safety Goggle
    - Safety Hand Gloves
    - Double Lanyard Full Body Safety Harness,

Figure 4.2: PPE for Working at Height

Step No-4

Validation of Idea:

In above steps 1,2 &3 enable us to identify the problem and area where there is fall hazard and assess the risk and control measures in terms of engineering, administrative and personal protective equipment. Now step no. 4 enables us

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to select the effective fall protection system to prevent fall injuries. For that all the control measures need to be validated whether they are reliable and having redundancy. Based on the above problem working at height for oof sheet fixing work is more challenging and has many deviations and having limited control measures and mainly depended upon the administrative control measures not engineering control measures. Please find below the risk matrix.

Table 4.3: High Risk Area with Safety Violations& Control Measures

Task	Height of the Job	Risk Category	Area	Number of Violation2023-24	Control Measures
Roof Sheet Fixing Job	30 Mtr.	High Risk	Production-Process Area	45	Administrative control measures

To overcome this problem IOT based safety harness has been introduced to prevent fall injury while working at height. This full body harness will bring a unique solution to avoid fall from height. If operator or worker who is working on the roof at 30-meter height missed to attached safety harness hook to anchoring point the alert will be released to the supervisor who is standing at ground floor. All the deviations shall be recorded in the system so that analyses can be done, and appropriate action can be taken accordingly. Please find below the process of smart safety harness system and its associated assembly.

Figure 4.3: Smart Safety Harness

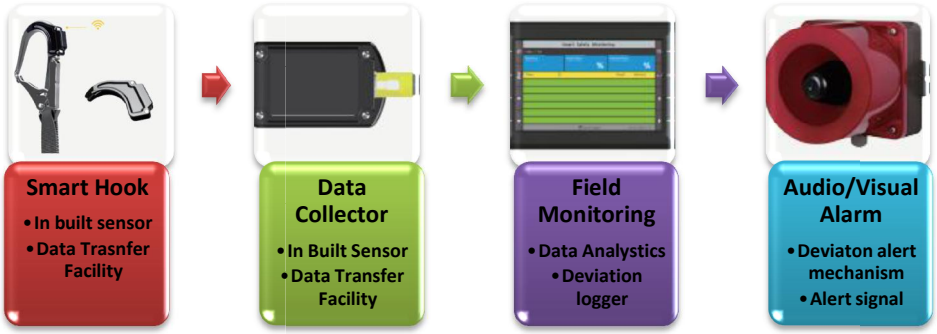

Figure 4.4: Assembly of Smart Safety Harness

Smart Hook- This is the major and important component of smart safety harness system. It is totally based on an IMU based sensor built with hook assembly. This IMU Inertial Measurement Sensor 9- Axis is calibrated for accelerometer, gyroscope, and magnetometer readings. The data is acquired from the IMU sensor and sent through the BLE Bluetooth low energy sensor. Following below are the functions of smart hook assembly.

- Detection hook fastening- within 55 mm of scaffold pipe, 15 mm of lifeline rope.
- Switch to sleep mode when unused in 10 minutes.
- 8 hours per day battery 3 V.
- Wireless frequency 2402-2840 MHz
- Light weight 30 gm

Operating Criteria for Smart Hook Assembly

- The hook sensor activated when an impact is applied or when the hook lever is operated for anchoring this time alert will be released.

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- When anchoring the hook, the front and rear angle of hook must be in the range of -10 to + 30 degree for hooking detection to work.

Figure 4.5: Images of Smart Hook

Data Collector – It is one type of data collector it can scan the smart safety harness within 100-meter radius and connect the RS422 and having BLE sensor Bluetooth low energy sensor. It can collect data up to 50 smart safety harnessand also having LTE provision.

Figure 4.6: Images of Smart Safety Harness Data Collector

Field Monitoring Device- It is one kind of table to monitor all the deviations. All the events are logged into this. It shows the deviations log user wise, location wise and safety harness tagging wise.

- Display number of workers having smart safety harness
- Display status of hook anchoring or not
- Battery Status will be shown.
- Communication status will also be displayed.
- Location of the area.

This field monitoring device is also available in the flame proof type enclosure because in the chemical industry all the electrical and instrument must be FLP type to avoid fire and explosion risk at site.

Figure 4.7: Images of Smart Safety Harness Field Monitoring Device

Audio/ Visual Alarm- This will be utilized if any deviation is recorded, if will give the alarm and will be blinking during the night shift if any deviation is observed this will be helpful for work and supervisor to acknowledge the deviations. This audio and visual device is also available in the flame proof type enclosure because in chemical industry all the electrical and instrument must be FLP type to avoid fire and explosion risk at site.

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Figure 4.8: Images of Smart Safety Harness Audio Visual Device

Step No-5

Effective Solution:

After implementing this smart solution at work place it is important to have analyze the data, based on accuracy it will be decide whether it can be used for further application or not. For that is very important how the data is communicated from one device to another, if is there any communication breech then what will be the consequence associated with that. The IMU sensor is provided in the hook assembly. The data is acquired from the IMU sensor and sent through the BLE Bluetooth low energy sensor to the data collector. Data collector collects all the data and transfers all the data through BLE to Field monitoring device. It is a total cloud-based data storage facility which collects all the data and archives the same. All the deviations are logged into the system and a data analytics facility is also available where the area is seeking attention to avoid accidents based on the numbers of serious deviations. This filed monitoring device can be replaced with a smart phone or laptop to record all the deviations. Initially the more deviations are recorded the more attention will be given to addressing the same.

V. CONCLUSION

In this research study it has been concluded that the IOT based smart solution called smart safety harness is very effective for fall injuries while working at height. It gives real time violation/ deviation by which contract worker will enable to know their mistake and reconnect his safety harness with the anchoring point. This is a full proof or error proof solution in workplace safety which will not only improve the safety performance of the company. It will improve the productivity and morale of the employees and contract employees. The conventional monitoring system in which the contract supervisor or safety personnel were used to stand to supervise the high-risk job whether contract worker is complying with the personal protective equipment (Anchoring of safety harness) if it deviates the supervisor counselling them to strict adherence with PPE while working at height. Sometimes supervise or contract workers ignore the safety regulation which can lead to sever health injury or sometime 100% surveillance was very difficult task or most of the time Hight work activities used to carry out on roof where there is no adequate solution however now there are many technologies are available like Drone surveillance, Fixed camera surveillance but it has not yet improved to detect safety harness anchoring compliances. The program needs to be configured on the latest technology however they are not much cost effective as compared to smart safety harness. This smart harness can be used by any contract workers and anywhere it can be used even including remote location also. In the result section it has been found that the near miss pertaining to safety harness has dropped drastically which can contribute to save the life while working at height

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