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A Respiratory Mask Fitting Test with Mask Leakage Detection by Digital Image Processing & Embedded System

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ABSTRACT: Respiratory masks are personal protective equipments that are worn on the face by those who have to work in vicinity of hazardous gases; it covers at least the nose and mouth, and used to reduce the wearer's risk of inhaling hazardous airborne particles (including dust particles, infectious agents, gases and vapors). Respirators are protective for the wearer in two basic ways. It removes contaminants from the air, thus called air-purifying respirators (APR). Such APRs include particulate respirators that filter out airborne particles and "gas masks," which helps in filter out chemicals and gasses. And some other respirators help by supplying clean and purified air from another source. The Air-supplying Respirators (ASR) comprise this category of respirators. They include airline respirators, which use compressed air from a remote source; and self-contained breathing apparatus (SCBA), which include their own air supply. Respirators should only be used as a "last line of defense" in the Hierarchy of controls when engineering measures and administrative controls are not feasible in place. When respiratory protective equipment (RPE) is used as a control measure under health and safety legislation, it is vital that the selected RPE is adequate and suitable. RPE must reduce exposure to as low as reasonably practicable, and in any case to an acceptable level. To ensure that the selected RPE has the potential to provide adequate protection for individual wearers, The ACoPs (Approved Code of Practice (UK)) supporting COSHH (Control of Substances Hazardous to Health (UK)) stipulate that tight-fitting RPE must be fit tested as part of the selection process. This will help to ensure that inadequately fitting face pieces are not selected for use. Selecting inadequate fitting face pieces can create inward leakages of airborne contaminants. The 'N95' respirators are used, but when subjected to careful testing; it blocks at least 95% of very small (0.3 micron) test particles. Even If properly fitted, the filtration capabilities of N95 respirators exceed those of face masks. However, a properly fitted N95 respirator does not completely eliminate the risk of inhalation illness or death. N95 respirators are not even designed for children or people with facial hair. Because of improper fitting on children and people with facial hair, the N95 respirator may not provide full protection against inhalation injuries. This paper throws some light on the innovative concept represented by our research fellows. The primary objective of our respiratory protection program is to prevent exposure to air contaminated with harmful elements and thus to prevent occupational illness. And secondary to determine which kind of face shape requires what type of respirator mask with no leakage, for the workers, working in the vicinity of hazardous gases.

KEYWORDS: Respiratory Mask; Mask Fitting; Respirator; APR; RPE; Leakage Detection; Hazardous gas prevention

I. INTRODUCTION

Inhalation injuries are the leading cause of worker's death, working in the vicinity of poisonous gases. A survey concluded that approximately 12,000 peoples die each year in the UK from long-term exposure to respiratory hazards at work. There are many different agents responsible for inhalation injuries. The types of such injuries are divided between, those caused by asphyxiates and local injury caused by toxins or steam. Common symptoms of inhalation injuries include burning throat, wheezing, muscle contraction, thickened or dry mucus, and in some extreme cases, failure of respiratory system. In many cases it has been observed that, injury acts or appeared soon after the agent is

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inhaled while in some other types such as asbestosis and benzene poisoning it may take years to develop after exposure. The human body airways and lungs receive continuous first-pass exposure to non-toxic and irritant (toxic) gases via inhalation. These Irritant gases, on inhalation, dissolve in the water of the respiratory tract mucosa and provoke an inflammatory response, usually from the release of acidic or alkaline radicals. Smoke, chlorine, phosgene, sulfur dioxide, hydrogen chloride, hydrogen sulfide, nitrogen dioxide, ozone, and ammonia are most common irritants. Given the gaseous nature of these elements, damage can be widespread. Inhalation injury can result in severe lung-induced morbidity and mortality. The National Institute for Occupational Safety and Health recommends that a person wear splash proof goggles, a face shield and a respirator mask when working in the vicinity of poisonous gases. Because a gas like chlorine is a gas which reacts on room temperature. Most exposure occurs via inhalation but sometimes exposure may also occur through skin or eye contact. Chlorine is considered as a strong oxidizing element causes the hydrogen to split from water in moist tissue, which resulting in nascent oxygen and hydrogen chloride that causes corrosive tissue damage. Additionally, oxidation of chlorine may form hypochlorous acid, which can Penetrate cells and react with cytoplasm proteins destroying cell structure. Chlorine's odor provides early warning signs of exposure but causes olfactory fatigue or adaptations, reducing awareness of exposure at low concentrations. With increased exposure, symptoms may progress to labored respirations, severe coughing, chest tightness, wheezing, dyspnea, and broncospasm associated with a decrease in oxygen saturation level while severe exposure may result in changes in upper and lower airways resulting in an acute lung injury. Employees working in environments with insufficient oxygen or where harmful dusts, fogs, smokes, mists, fumes, gases, vapors, or sprays like toxic substances are present and engineering controls measures are inadequate to prevent atmospheric contamination at the worksite, respiratory protective equipment is necessary. Nowadays, Respiratory protective equipment – more commonly referred to as respiratory masks –being used, that cover the nose and mouth or the entire face to guard the wearer against inhaling dangerous substances in hazardous atmospheres. Wearing a respiratory mask can stop developing the symptoms of respiratory illness caused by inhalation of hazardous substances at work. As human faces can be categorized in different style and shapes, respiratory masks also comes in many different styles and sizes to accommodate all types of face shapes.

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The classification of particulate respirators can be further subdivided into three categories:

1. *Particulate filtering respirators* – Sometimes referred to as disposable respirators because the entire respirator is discarded when it becomes unsuitable for further use due to considerations of hygiene, excessive resistance, or physical damage. These are also commonly referred to as "N95s."
2. *Elastomeric respirators* –Sometimes referred to as reusable respirators because the face piece is cleaned and reused but the filter cartridges are discarded and replaced when they become unsuitable for further use.
3. *Powered air-purifying respirators* (PAPRs) – A battery-powered blower moves the air flow through the filters.

II. RELATED RESEARCH WORK

Further researching in this area, our team concluded that proper fitting of respiratory mask on face is most important factor. Thus the respirator must fit properly and be maintained in a clean and serviceable condition. To support the cause of providing safer and non hazardous working conditions for workers, we are developing a simple respiratory mask fitting and mask leakage detection system with the help of digital image processing techniques and embedded systems. According to a reference data published on www.reliableplant.com approximately 5 % of U.S.A workers in about 20% of all work establishments wear respirator masks at least some of the time while working with their job functions. These workers employed at approximately 1.3 million establishments nationwide. Approximately 900,000 of these establishments have been determined to be "very small," i.e., having fewer than 20 employees. In India this picture is not very clear as small industries still does not stick to the rules and regulations in a strict manner.

III. GOVERNMENT REGULATIONS AND MANDATORY REQUIREMENTS

The Approved Codes of Practice supporting the Control of Substances Hazardous to Health Regulations 2002 (COSHH)3, the Control of Lead at Work Regulations 2002 (CLAW)4, the Control of Asbestos Regulations 2006 (CAR)5 and the Ionizing Radiation Regulations 1999 require that all reasonable steps be taken to prevent exposure to substances hazardous to health, or where prevention is not possible, to reduce exposure to the lowest level reasonably

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practicable. The employer must have documented evidence of the characteristics of the RPE to be used (CAR reg.7(4)(d)). Similar requirements are described in COSHH reg.6(4)(b), and CLAW reg.5(4)(b). These requirements are there to ensure that the RPE provided is suitable. The evidence to support the suitability will include fit test reports for face mask with tight-fitting face seals.

IV. RPE INSPECTION GUIDELINES

First of all the Inspectors should first ensure that suitable control measures including engineering controls are in use to minimize risk of exposure to hazardous substances. In context with using RPE Inspectors must be ensuring that:

1) A management system exists for correct selection, use, storage and maintenance;
2) For tight-fitting face masks the selection process must included an appropriate fit test. Where necessary, the results of the fit test report should be examined by the inspector for details, which should include the following:

- Name of the person fit tested.
- Face shape type of the person.
- Model and size of the face mask.
- Whether the wearer's own mask, company pool mask or a fit test service provider's test mask was used;
- The test exercises performed during the test.
- Fit test method employed;

Qualitative for filtering facepieces (FFPs, disposable masks) and half masks
Quantitative for FFPs (disposable masks), half and full face masks

- Measured fit factor values for each exercise (if applicable);
- Pass level used;
- date of the test;
- The details of the person carrying out the fit test.

3) The fit test certificate is valid and does relate to the correct RPE and the wearer. Checks should be carried out to establish the authenticity of the fit test certificate. This can be achieved by:

- Comparing the facepiece in use to the details recorded on the fit test certificate;
- cross-checking the details on the fit test certificate with those retained by the fit test provider;

Considering all above guidelines, we have decided to develop an innovative face mask fit test with leakage detection system. This new handy and portable system will be useful to all small or even large industries where on site fit tests and leakage tests will give 2nd opinion about safety standards of face mask.

V. PROPOSED SYSTEM

A. When it is necessary to conduct a RPE fit test:
It is good practice to have a system in place to ensure repeat fit testing of RPE is carried out regularly. This is important in case where RPE is used frequently as a primary means of exposure control, e.g. annual testing for workers involved in licensed asbestos removal (L143 paragraph 198).

B. An RPE fit test should be conducted in the following circumstances where the employer's health safety requires it.
When the wearer:

- Loses or gains weight;
- Undergoes any substantial dental work;
- Develops any facial changes (scars, moles, warts etc) around the face seal area;

C. Our concept for RPE fit test:

- A Digital Image Processing Analysis Test
- A Pressure Leakage Detection Test

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VI. A DIGITAL IMAGE PROCESSING ANALYSIS TEST

In this concept, the face shape type and face contour will be examined and the software will analyse and select the appropriate mask which is suitable for the wearer according to his/her face shape. The test will take in to consideration the original face structure of a person.

It will also consider following factors related to the facing structure of wearer:

- Warts on face
- Cleft chins
- Scars on the face sealing area
- Depressions around the temple/cheekbones
- Unusual chin profiles (chisel feature)
- Unusual nose shapes
- Very large/small or angular faces

VII. A PRESSURE LEAKAGE DETECTION TEST

This test is only for full covered pressurized face masks. A pressure sensor gadget will be placed inside the mask and rate of drop in pressure inside mask and leakage area will be detected using testing equipment.

VIII. THE WORKING PLAN FOR PROPOSED SYSTEM

A. Take the following steps to perform the test:

- Store pictures of all workers as they look in normal conditions.
- Develop software which will analyse all facial parameters as given above and suggest the proper face mask type best suited for the wearer.
- Before wearing a mask, every time, the wearer should again submit his / her face photo to system.
- The system will find any changes in face structure and suggest new type of mask for the person, if required.
- The wearer when placing the mask on face must go through a leakage detection test.
- If leakage test is cleared, the person can use the mask.

B. Flow Control for working plan of proposed system:

Step 1: Submit face photographs of employees to the system.
Step 2: System software will now analyse facial parameters.
Step 3: Software would display a suggestion message on screen which will suggest face mask according to the analysed facial parameters in previous step.
Step 4: Now the employee will have to go through the leakage detection test for checking if the leakage exist.
Step 5: If the leakage is detected in the test, step 2 will be repeated.
Step 6: If the leakage is not detected, the test will be completed successfully.

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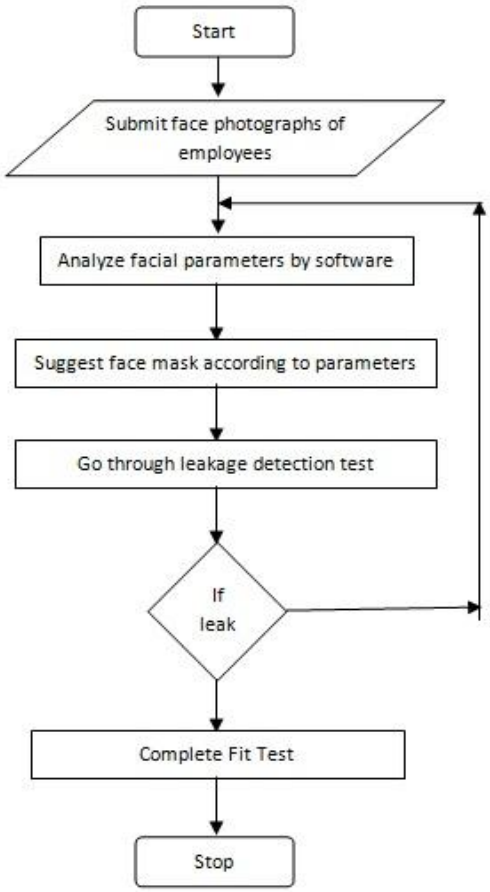
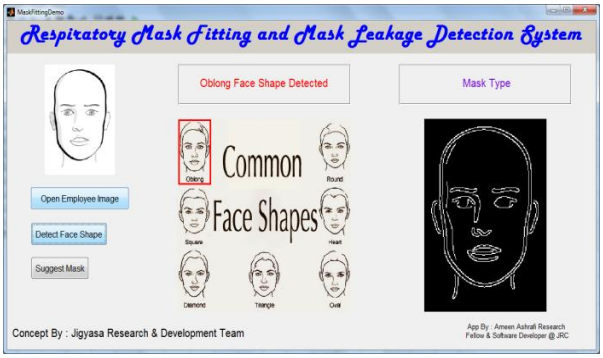


Fig.1. Flow Control of Proposed System

IX. PROTOTYPE TESTING RESULTS

The prototype testing results showed that the proposed system performs better with the RPE test. The proposed technologies provides efficient path for minimize the risk of inhalation injuries while working in vicinity of hazardous gases.



.Fig.2. Face Type Classification by software

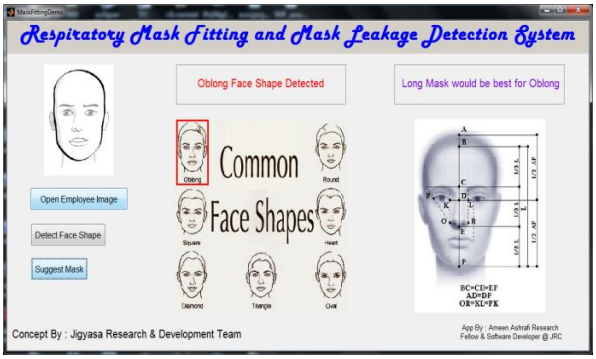


Fig.3. Mask Suggestion on facial parameters analysis

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Result Sheet (Mask Fit Test)

Parameter	Processing Result (Max 10)	Grade
Position of the mask on the nose	8	A
Room for eye protection	6	B
Room to talk	6	B
Position of mask on face and cheeks	7	B
Chin properly placed	5	C
Adequate strap tension, not overly tightened	9	A
Fit across nose bridge	8	A
Respirator of proper size to span distance from nose to chin	5	C
Tendency of respirator to slip	4	F
Note	Any F in grade suggests rejection	

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BIOGRAPHY

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