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Original Article

# Risk Identification and Risk Assessment Using Failure Mode and Effect Analysis in a Textile Industry

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**ABSTRACT**

**Background:** Today with growth of industry, occupational hazards are increasing proportionally. One of the most important parts of these industries are human resources, which face with many various hazards. The aim of this study was to conduct an assessment of potential hazards in the textile industry using Failure Mode and Effect Analysis (FMEA).
**Methods:** This cross-sectional study was conducted in the spinning sector of textile industry. FMEA as one of the systematic risk assessment technique applied to each unit of the spinning sector to find out potential failure mods and its effects. Risk priority number (RPN) was determined based on severity, detectability and occurrence of hazards. Then PRN were categorized into low-risk (RPN ≤ 89), moderate risk (RPN = 90-199), and high risk level (RPN ≥ 200).
**Results:** A total of 58 risk were found in 6 units of the spinning sector. 38% were found to be at high level 45% at middle level and 17% at low level. The packing unit, had the highest risk compared to other units. Lifting heavy loud in the packing unit has the highest RPN (384) and bobbin falling down in the ring unit has the lowest RPN (24).
**Conclusion:** This study revealed that more than 80% of detected risk were unacceptable that showed hazardous condition for workers in textile industry. Lifting heavy louds followed by bobbing falling were the most hazardous task in this industry. The implementation of safety measures such as training programs, engineering and management controls were recommended.
**Keywords:** Failure Mode and Effect Analysis, Textile industry, Risk assessment
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## Introduction

Textile industries play an important role in the economy of the countries. Textile industries have different segments such as spinning, weaving, dying, wet processing and knitting (1). By the growth of technology in this industry hazard and accident increased proportionally. In the textile industry, as in other industries, there are many safety and health risks that can endanger worker health and create a potential condition for accident occurrence and eventually reduce economic efficiency. There are different types of hazards in this textile sector including Musculoskeletal disorders such as; awkward posture, repetitive movements, static work, inadequate space, pushing and pulling loads, working over shoulder height, exposure to chemical and physical agents such as; solvents, fibers, dusts, loud noise, vibration, and Psychosocial issues such as; work-related stress. Therefore, identification, assessment, and management of risks are very necessary for this industry to increase workplace safety and productivity.

Failure Mode and Effect Analysis (FMEA) is an inductive and proactive method for systematics evaluation of systems components failures and their possible effects (2). It was originally developed by NASA to improve and verify system reliability. FMEA reduces the risk of defects by identifying, analyzing and eliminating deficiencies and therefore decreases the costs of these defects and, consequently, increases system reliability and quality improvement (3). This method has been used in a number of occupation and industries including risk assessment of blast furnace as a vital part of integrated steel plant (4) engine piston casting (5) cement factory (6) risks of the onshore and offshore turbine (7) risk assessment of Yazd steel complex (8), can stock production (9), and blood transfusion failures in hospital (10). But there are limited research for evaluating failures in textile industry as a potential hazardous place for workers using FMEA method (11). Therefore, in this study we aimed to identify and assess possible risks in a textile industry and provide solutions to remove or minimize these risks using the FMEA method.

## Methods

This cross-sectional study was conducted in the spinning sector of textile industry in Esfahan, Iran. The spinning unit was selected for risk assessment because most workers work in this unit, as well as the working hours of this unit is 24 hours. In the Spinning sector, 130 employers were working in 3 shift. The average age of workers was 32 years and the working shift was 8 hours. All the participants were male. A team of interdisciplinary experts were gathered and the process and main tasks and subtasks were described and trained for them. The spinning process is composed of different process including cotton batting, cotton slashing, carding (cotton becomes wicker), tightening (wicker becomes multi-layer), flyer (the wicker is turned in to semi string), ring (main stage, semi string becomes string), Autoconer (preparing strings for packing) and packing, respectively. The main workstations were identified based on the interview and observation of unit. Then, for each operator, the potential hazards were identified through direct observation, interviewing and reviewing documentation of chemical and physical injuries. All details of duties and stages of the job were identified and operators were observed during the task by experts. Then the possible consequences of each hazard were identified.

The Priority risk number (PRN) was calculated by multiplying the three scoring parameters of severity, occurrence and detection (12). These parameters rate the failures by using a numerical scale from 1 to 10. The number 1 represents the best conditions for each mode and, as the situation worsens, the number increases, so that the number 10 represents the worst condition for each state (13). Table 1 shows the rating scale of PRN based on severity, occurrence and detectability.

**Table 1.** Hazard Scoring Matrix Based on Severity, Occurrence and Detectability

| Rating | Severity of hazard (S) | Occurrence of hazard (O) | Detectability of hazard (D) |
|---|---|---|---|
| **10** | Hazardous: It suspends operation of the system and/or involves noncompliance with government regulations, may cause death of worker or public. | Extremely high (Failure occurrence rate: ≥ 1 in 2 ) | Absolute Uncertainty: Design control cannot detect potential cause/mechanism and subsequent failure mode (Probability of detection is 0-5 %) |
| **9** | Serious: Failure involves hazardous outcomes and/or Noncompliance with government regulations or standards. May result in major injury or death of worker or major injury to public. | Very high (Failure occurrence rate: 1 in 3) | Very remote: Defect most likely remains undetected (Probability of detection is 6-15 %) |
| **8** | Extreme: Failure is hazardous and occurs without warning. May result in major injury to worker or moderate injury to public. | Repeated failures (Failure occurrence rate: 1 in 8) | Remote: Remote chance that the design/operation control will detect a potential failure mode (Probability of detection is 16-25 %) |
| **7** | Major: product performance is severely affected but functions. The system may not operate, moderate to major injury to worker or minor injury to public. | High (Failure occurrence rate: 1 in 20) | Very low: Very low chance that the design/operation control will detect a potential failure mode (Probability of detection is 26-35 %) |
| **6** | Significant: product performance is degraded. Comfort or convince functions may not operate, minor to moderate injury to worker. | Moderately high (Failure occurrence rate: 1 in 80) | Low: Low chance that the Design/operation control will detect a potential failure mode (Probability of detection is 36-45 %) |
| **5** | Moderate: Moderate effect on product performance. The product requires repair, minor injury to worker. | Moderate (Failure occurrence rate: 1 in 400) | Moderate: Moderate chance that the Design/operation control will detect a potential failure mode (Probability of detection is 46-55 %) |
| **4** | Low: Small effect on product performance. Minor or no injury to worker. | Relatively low (Failure occurrence rate: 1 in 2000) | Moderately high: Moderately high chance that the design/operation control will detect a potential failure mode. (Probability of detection is 56-65 %) |
| **3** | Minor: Minor effect on product or system performance, No injury to worker or people. | Low (Failure occurrence rate: 1 in 15000) | High: High chance that the design/operation control will almost certainly detect a potential failure mode. (Probability of detection is 66-75 %) |
| **2** | Very minor: Very minor effect on product or system performance, Slight danger- no injury to worker or public. | Remote (Failure occurrence rate: 1 in 150000) | Very high: Very high chance the design control will detect potential cause/mechanism and subsequent failure mode. (Probability of detection is 76-85 %) |
| **1** | None: No reason to expect failure. Slight annoyance- no injury to worker or public. | Nearly impossible (Failure occurrence rate: 1 in 1500000) | Almost certain: Design/operation control will almost certainly detect a potential failure mode. (Probability of detection is 86-100 %) |

The PRN were then classified into low-risk (RPN ≤ 89), moderate risk (RPN = 90-199), and high risk level (RPN ≥ 200). The first group was considered as acceptable and the two second groups as unacceptable risk.

## Results

Based on PRN calculation, a total of 58 risks were identified in 6 unit of spinning sector of textile industry. The associated PRN scores ranging from 24 to 384 (Table 2). For each unit some appropriate recommendations were proposed that are shown in table 2. The highest RPN (384) was related for heavy loud lifting in the packing unit and the lowest RPN (24) was related for bobbin falling down and insufficient space in the ring unit. Among six units under the study, packing unit has the highest and Carding and Ring unit have the lowest PRN. Figure 1 shows the percent of risk level in each unit of study. Of total, 38 % of risks were at a high level, 45% were in the middle level and 17 % were at low level.

**Table 2.** Characteristics of Failures and Risk Priority Number in Six Units of Study

| Unit | Failure mode | Potential effect | (O) ×(D) ×(S) = RPN | Risk level | Action |
|---|---|---|---|---|---|
| Flyer | Roll over with excessive pressure | Hand damage, damage to device and stop working | 6×2×7 = 84 | Low | use appropriate tools instead of workers hands and RPM control |
| | Loud noise | Hearing loss | 6×5×8 = 240 | High | Use Air plug and air muff |
| | Weeding and rubbing of needles, nip points and Inappropriate function due to disability | Amputation and damage to devices | 6×2×8 = 60 | Low | Use brushes instead of hands to cleaning, Turn off the devices when cleaning and periodic visits. |
| | Lack of Illumination | Vision weakness | 6×3×6 = 108 | Middle | Modify the Illumination intensity |
| | Exposure to dust | Respiratory discomfort | 6×6×5 = 180 | Middle | Appropriate ventilation, using appropriate breathing masks. |
| | In- running nip point | Death, Amputation and severe injuries | 6×2×9 = 108 | Middle | Machine appropriate guarding and worker training. |
| | Moving and changing the distance between the rollers | Hand crushing | 6×4×7 = 168 | Middle | Hand tools using |
| Tightening | Nip-points | Amputation and hand crush | 6×4×10 = 240 | High | Precaution in work |
| | Inappropriate stairs | Severe injuries and temporary disability | 6×8×5 = 240 | High | Machine regular inspection |
| | Cables erosion | Death and fire | 6×4×10 = 240 | High | Machine regular inspection |
| | Falling tools and materials | Severe injuries and working time lost | 6×6×5 = 180 | Middle | Good arrangement of tools and materials |
| | Exposure to loud noise | Hearing loss | 6×8×7 = 336 | High | Using air plug and air muff |
| | Exposure to dusts | Respiratory discomfort | 6×4×4 = 96 | Middle | Using respiratory masks |
| | Lack of illumination | Vision weakness | 6×4×4 = 96 | Middle | Redesigning illumination system |
| | Polling and awkward postures | Musculoskeletal Disorders | 6×7×5 = 240 | High | Redesigning work station |
| | Shift work | Digestive disorders-stomach upset | 6×8×5 = 240 | High | Avoid recruiting people with a stomach trouble |
| | Long time standing | Musculoskeletal disorders | 6×4×7 = 168 | Middle | Redesigning work station |
| Packing | Long time standing | Musculoskeletal disorders | 6×4×7 = 68 | Low | Redesigning work station |
| | Back rotation and bending | Musculoskeletal disorders | 6×6×8 = 288 | High | Load holding training |
| | Heavy load carrying | Waist disk | 6×8×8 = 384 | High | Using load carrying tools |
| | Accident with lift truck | Body injuries | 6×4×7 = 168 | Middle | Safety training, |
| | Inappropriate hand tools | Musculoskeletal disorders, wrist injury | 6×8×5 = 240 | High | Ergonomic design |
| | Repetitive tasks | Musculoskeletal disorders | 6×6×7 = 252 | High | Training ergonomics principles |
| | Lack of Illumination | Vision weakness | 6×4×4 = 96 | Middle | Redesigning illumination system |
| | Sharp edge | Body injuries | 3×2×5 = 30 | Low | Appropriate arrangement |
| | Slider level | Body injuries | 3×2×5 = 30 | Low | Suitable flooring, safety shoes, and soaking the floor of the work area |
| | Exposure to dust | Breathing discomfort | 6 ×4×4 = 96 | Middle | Using breathing mask |
| | Exposure to load noise | Hearing loss | 6×8×7 = 336 | High | Using Ear muff and ear plug |
| Autoconer | Electricity | Electrical shock | 3×8×10 = 240 | High | Regular monitoring , earth connecting |
| | Rotational parts | Hand and finger injury | 6×8×4 = 190 | Middle | Using guard and shield |
| | Dust exposure | Respiratory damage | 6×4×4 = 96 | Middle | Using appropriate respiratory protecting equipment, redesigning Industrial ventilation system |

**Table 2.** Characteristics of Failures and Risk Priority Number in Six Units of Study (continue)

| Unit | Failure mode | Potential effect | (O) ×(D) ×(S) = RPN | Risk level | Action |
|---|---|---|---|---|---|
| | Insufficient lighting | Reducing visibility | 6×4×4 = 96 | Middle | Redesigning lighting system, modifying lighting intensity |
| | Excessive noise exposure | Hearing damage, Job stress, concentration disturbance | 6×8×7 = 336 | High | Using Earmuff and earplug |
| | Inappropriate manual handling | Musculoskeletal disorders | 6×8×7 = 336 | High | Training on ergonomic principles, use of automatic load carrying devices |
| | Bobbin falling down | Foot injury | 6×8×4 = 192 | Middle | Regular maintenance, using the right distance between the device and the operator |
| | Awkward posture | Musculoskeletal disorders | 6×8×5 = 240 | High | Redesigning work station, training |
| | clash the cart with the workers body | Body injury | 6×6×4 = 144 | Middle | Using personal protective equipment, training |
| | Pulling and pushing | Musculoskeletal disorders | 6×8×7 = 336 | High | Training on ergonomic principles |
| Carding | Falling the clamp on the hand | Hand crush | 6×4×8 = 192 | Middle | Training, regular maintenance |
| | Excessive noise exposure | Hearing damage | 6×8×7 = 336 | High | Using Earmuff and earplug |
| | Awkward posture | Musculoskeletal disorders | 6×6×7 = 252 | High | Training on ergonomic principles |
| | Insufficient lighting | Reducing visibility | 6×4×4 = 96 | Middle | Redesigning lighting system, modifying lighting intensity |
| | Work above shoulder high | Neck and shoulder damage | 6×6×5 = 180 | Middle | Training on ergonomic principles |
| | Objects falling down | Foot injuries | 3×2×4 = 24 | low | Instrument monitoring, Regular maintenance |
| | Slipping | Body injuries | 3×2×5 = 30 | Low | Regular cleaning, proper safety shoes |
| | Back bending | Back and neck damage | 6×4×7 = 168 | Middle | Training on ergonomic principles, Perform periodic examinations |
| | Shift work | Gastrointestinal disorders, sleep disorders | 6×8×5 = 240 | High | Choosing suitable workers, conducting periodic examinations |
| | Dust exposure | Respiratory damage | 6×4×4 = 96 | Middle | Using appropriate respiratory protecting equipment, redesign ventilation system |
| Ring | Work above shoulder high | Neck and shoulder damage | 6×6×5 = 180 | Middle | Care in working, training |
| | Bobbin falling down | Head and body damage | 3×2×4 = 24 | low | Instrument monitoring, Regular maintenance |
| | Awkward posture | Musculoskeletal disorders | 6×8×5 = 240 | High | Redesigning work station, training |
| | Nip points | Hand crush | 6×6×5 = 180 | Middle | Appropriate guard |
| | Electricity | Electrical shock | 3×4×9 = 108 | Middle | Regular monitoring , earth connecting |
| | Sharp edges and wins | Hand injury | 3×4×4 = 48 | Low | Appropriate guard , training |
| | Excessive noise exposure | Hearing damage, Job stress | 6×8×7 = 336 | High | Using Earmuff and earplug |
| | Dust exposure | Respiratory damage | 6×4×4 = 96 | Middle | Using appropriate respiratory protecting equipment, redesign ventilation system |
| | Insufficient work space | Musculoskeletal disorders | 3×2×4 = 24 | Low | Redesigning work station |
| | Long standing | Musculoskeletal disorders | 6×3×6 = 108 | Middle | Redesigning work station, provide work and rest schedule |

## Discussion

In recent years, organization and industries are gradually increasing their concern with safety issues related to the environment. FMEA is a useful systematic approach for tracking failures that has been extensively used in organization and industries (14-17). In this study, risk assessment of spinning sector as one of the most important part of textile industry was carried out using FMEA method. The results showed 58 different risk types in 6 units under the study. The highest PRN was related to ergonomic factors such as heavy load carrying in the packing unit. In accordance with this finding, Kazemi et al in their study using relative stress index found that awkward posture and manual work were the most effective factors on occupational disorders in textile industry (18). FMEA has also been used to detect failures in the production process (3).

Ahmad et al, investigated workplace environment in terms of indoor air quality, lighting, furniture and tools, acoustic and building general environment in four textile industries in Pakistan. They found that the finding of their study showed that Acoustic, indoor air quality and building general environment have a significant effect on employee health compliance (19).
In current study Health, Safety and Musculoskeletal Disorders risks such as loud noise, rotating parts, bobbin distance change, electric shock, electrical wires erosion, heavy load lifting, awkward posture, tools falling had the highest RPN. Biswas et al found that poor working postures and subsequent musculoskeletal disorders are prevalent among the dyeing workers in textile industry (1). In contrast, some studies found environmental factors such as a high temperature in the work and bad ventilation as the main complaints in the textile industry (11).
In this study more than half of identified risk were unacceptable requiring urgent safety control and modification to reduce risk. The high prevalence of unacceptable risk within factories were also identified in other research (20).
Considering that the highest risk priority number is related to ergonomic factors and exposure to loud noise, there are some recommendations to remove defects originating including Apply automatic system for lifting heavy load, Redesign work station with ergonomic problem, Electrical wiring replacement and using earth system, Applying sound absorber, Designing appropriate barrier for sharp, Winning and rotating part, Designing ventilation system based on dust collectors, Modifying lighting system, Personal protective equipment, Safety training programs, applied controls and work environment Regular monitoring, Ergonomic training programs, Job rotation program for worker in units with high noise.
This study used traditional approach for calculating PRN that may suffer from some limitation such as not precisely estimating and not taking into consideration the relative importance of three factors of severity, occurrences and detectability. Some recent studies proposed new method for calculating PRN based on fuzzy logic (21, 22).

## Conclusion

This study found potential risk in the textile industry using FMEA method and priorities them according to PRN score. Applying appropriate control such as engineering controls, management controls, safety training programs were recommended.

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## Ethical consideration

The current study was approved by the Research Committee of Isfahan University of Medical Sciences.

## Conflicts of interests

Authors declared no conflict of interest.

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