Performance and reliability of human factor: case of a plasma welding workplace

Ivana Tureková & Constantine the Philosopher University in Nitra

Alena Hašková & Constantine the Philosopher University in Nitra
Introduction

• Human factors, which it defines as:
  “Human factors refer to environmental, organizational and job factors, and human and individual characteristics, which influence behavior at work in a way which can affect health and safety”.

• Human factor is statistically the most important factor in industrial systems, which encounters 60-90% of errors,

• It is necessary to assess the human factor reliability to avoid fatal system failure.
Definition includes three interrelated aspects that must be considered:

**INDIVIDUAL**
- Competence, skills, personality, attitudes, risk perception...

**ORGANIZATION**
- Culture, leadership, resources, work patterns, communications...

**JOB**
- Task, workload, environment, display & controls, procedures...
Introduction

- The incidents are, of course, the most obvious human errors in industrial systems.
- It is important to remember that human failures are not random; there are patterns to them. It is worth knowing about the different failure types because they have different causes and influencing factors and as a consequence the ways of preventing or reducing the failures are similarly different.

Types of human failures (unsafe acts) that may lead to accidents:

- Unintentional errors
- Intentional errors
Introduction

Unintentional errors:

• It Errors *(slips/lapses)* are “actions that were not as planned” (unintended actions). These can occur during a familiar task e.g. omissions like forgetting to do something, which are particularly relevant to repair, maintenance, calibration or testing. These are unlikely to be eliminated by training and need to be designed out.

• **Mistakes** are also errors, but errors of judgement or decision-making (“intended actions are wrong”) - where we do the wrong thing believing it to be right. These can appear in situations where behaviour is based on remembered rules or familiar procedures or unfamiliar situations where decisions are formed from first principles and lead to misdiagnoses or miscalculations. Training is the key to avoiding mistakes.
Introduction

Intentional errors:

• **Violations** differ from the above in that they are intentional (but usually well-meaning) failures, such as taking a short-cut or non-compliance with procedures e.g. deliberate deviations from the rules or procedures. They are rarely wilful (e.g. sabotage) and usually result from an intention to get the job done despite the consequences. Violations may be situational, routine, exceptional or acts of sabotage
Methodology

• Method of identification of failure causes (MIPS) was created on the basis of system model - Work Process Analysis Model.

• This model involves the elements of task analysis, ergonomic elements and last but not least also the work psychology elements.

• Owing to this wide approach, the MIPS method allows to analyze majority of factors acting upon the workers causing the failure of human factor
Methodology

• For system characteristic (environment and processes) the organisational reliability factors (SOF) are introduced.

• Factors represent indices, characterising the effect of a part of system upon the appropriate worker, which exerted and/or could exert certain effect upon the occurrence and/or course of undesirable event.

• The SOF factors are divided to groups, where each SOF group characterises a wider circle of effects and is therefore subdivided to partial ones (DPSOF).
Methodology

MIPS can be in simplified form illustrated via the flow chart:

```
Group SOF (k) → SOF(1) → DPSOF(1) → Set of questions (j)
               ↓                      ↓
               |                      |  identification of failure causes
               ↓                      ↓
               DPSOF(2)              (O_1*(V_p)_1)
               ↓                      ↓
               DPSOF(n)              ↓
               ↓                      ↓
               SOF(2)                ↓
               ↓                      ↓
               SOF(j)                ↓
               ↓                      ↓
               ...                  ↓
               ...                  ↓
               Set of causes and probabilities of their correct identification
               ↓                      ↓
               (F_p)_k               ↓
               ↓                      ↓
               Presentation of outputs
```
Methodology

• Quantitative analysis of MIPS methodology is based on a controlled interview with a selected worker of appropriate profession.

• Quantification was performed via the human failure factor – $F_p$, which allows to determine the probability of a correct determination of human failure causes $P_p$.

• Each negative answer from the check lists was penalized by one point and subsequently calculated with the weight coefficient (value 1 – 3). The factor of human element failure ($F_p$), to be determined for each SOF (k) group separately, is calculated by the formula (1).
Methodology

\[
(F_p)_k = \left[ \frac{\sum_i O_i \cdot (V_p)_i}{\sum_i ((V_p)_i \cdot j)} \right]_k
\]

where:

- \( F_p \) factor of human element failure,
- \( V_p \) appropriate weight coefficient \( z \),
- \( O_i \) penalization coefficient (sum of penalization points for negative assessment of appropriate DPSOF – each negative answer = 1 point),
- \( i \) question,
- \( j \) the number of investigative questions for appropriate SOF,
Methodology

• The resultant $P_p$ value expressed in per cents then shows what is the probability that there exists at least one from among the identified causes, which really caused the failure of a given person.

• The quantitative assessment shown in Table thus defines the measure of reliability of correct result determination.


## Methodology

**Assessment of probability of determination of human failure cause $P_p$ by the values of factor of human element failure $F_p$**

<table>
<thead>
<tr>
<th>$F_p$</th>
<th>$P_p$</th>
<th>Probability of correct determination</th>
<th>Qualitative assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 0.20</td>
<td>&lt; 10 %</td>
<td>very low</td>
<td>Neither human failure, nor effect on other causes is supposed.</td>
</tr>
<tr>
<td>0.21 – 0.30</td>
<td>10 – 30 %</td>
<td>low</td>
<td>Human failure is not supposed, however the identified cause might affect the acting of other causes belonging to another group.</td>
</tr>
<tr>
<td>0.31 – 0.40</td>
<td>30 – 50 %</td>
<td>moderate</td>
<td>Cause acting might result in human failure at participation of causes belonging to another group</td>
</tr>
<tr>
<td>0.41 – 0.54</td>
<td>50 – 80 %</td>
<td>high</td>
<td>Acting of cause in appropriate group might result in human failure and/or significantly participate in it.</td>
</tr>
<tr>
<td>0.55 – 1.00</td>
<td>&gt; 80 %</td>
<td>very high</td>
<td>Acting of cause in appropriate group caused the human failure and/or its effect on occurrence was decisive.</td>
</tr>
</tbody>
</table>
Methodology

• For practical applications it was selected workplace of engineering production. An overview and arrangement of the attended equipment is shown in Figure:

![Diagram of workplace](image)

Methodology

The most risky activities for employees is cutting material plasma. The main health risks with plasma devices are:

- ultraviolet and infrared radiation,
- burns from splashing metal,
- fumes, aerosols and gases from the workpiece evaporation,
- noise, moving up to about 110 dB,
- high arc temperature,
- high voltage.
Methodology

Types of equipment in operation:

a) power brake type LOD 315
b) table shears type NTE 3150
c) plasma-cutting equipment
d) plasma cutting
Methodology

The workers of following professions were selected for analysis:

• two workers attending the machine (a fitter and a shift foreman) – were subjected to 227 relevant questions,

• operating manager – responded to 234 relevant questions.

Differentiation of questions is essential; these must be formulated with regard to work position. Method also supposes that the managing workers should know the answers to all questions. Each negative answer allows to define the cause that might lead to failure of the appropriate worker.
Results

• The results from analysis by MIPS method have shown that the human failure factor on the workplace for plasma cutting of materials $F_p$ varies in average from 0.17 to 0.30.

• In quantitative assessment it means that though human failure is not supposed, the identified cause might affect the behaviour of worker.

• In spite of the fact that the risk of human factor failure is rather low, the analysis has revealed several weak points actually in each of analysed fields.
## Results

### Comparison of estimation probability for the effect of human factor \((P_p)_k\)

<table>
<thead>
<tr>
<th>k</th>
<th>Group name</th>
<th>Equipment operator</th>
<th>Shift foreman</th>
<th>Head of organisational unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Training</td>
<td>&lt; 10 %</td>
<td>&lt; 10 %</td>
<td>&lt; 10 %</td>
</tr>
<tr>
<td>2</td>
<td>Tasks and duties</td>
<td>&gt; 80 %</td>
<td>50 – 80 %</td>
<td>50 – 80 %</td>
</tr>
<tr>
<td>3</td>
<td>Decision making and control of processes</td>
<td>10 – 30 %</td>
<td>30 – 50 %</td>
<td>&lt; 10 %</td>
</tr>
<tr>
<td>4</td>
<td>Operations and manipulation</td>
<td>10 – 30 %</td>
<td>&lt; 10 %</td>
<td>&lt; 10 %</td>
</tr>
<tr>
<td>5</td>
<td>Work group</td>
<td>10 – 30 %</td>
<td>&lt; 10 %</td>
<td>&lt; 10 %</td>
</tr>
<tr>
<td>6</td>
<td>Attendance and supervision</td>
<td>&lt; 10 %</td>
<td>10 – 30 %</td>
<td>&lt; 10 %</td>
</tr>
<tr>
<td>7</td>
<td>Control and management</td>
<td>30 – 50 %</td>
<td>10 – 30 %</td>
<td>10 – 30 %</td>
</tr>
<tr>
<td>8</td>
<td>Personal features</td>
<td>30 – 50 %</td>
<td>30 – 50 %</td>
<td>&lt; 10 %</td>
</tr>
<tr>
<td>9</td>
<td>Risk factors of work environment</td>
<td>&lt; 10 %</td>
<td>&lt; 10 %</td>
<td>&lt; 10 %</td>
</tr>
<tr>
<td>10</td>
<td>Workplace</td>
<td>&lt; 10 %</td>
<td>&lt; 10 %</td>
<td>&lt; 10 %</td>
</tr>
<tr>
<td>11</td>
<td>Stress factors</td>
<td>&lt; 10 %</td>
<td>&lt; 10 %</td>
<td>&lt; 10 %</td>
</tr>
</tbody>
</table>
Results

• Analysed worker judged the entire system and work team by his answers.
• Since he follows mainly from his own experience and subjective feelings, then he has revealed also the facts concerning himself.
• If contradiction in answers of several persons was observed, it is obvious that one side did not respond in accordance with real state.
• There were minimum subjective questions, mainly owing to the fact that such statements are not always trustworthy in practice.
Implications for policy/Practice

• Final step of analysis consisted in elaboration of protocol on investigation.

• This protocol contained the calculated values \((F_p)_k\) and \((P_p)_k\) and possible reasons of effect of human factor on the analysed work activity.

• In case of software processing of this method the protocol is generated automatically by computer.
Implications for policy/Practice

Predicted imperfections that could exert the most significant effect upon the failure of human factor within the given SOF group are given in table:

<table>
<thead>
<tr>
<th>SOF Number</th>
<th>Found out imperfections</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>There is not elaborated organisation order with clearly defined tasks and duties for duly performance of functions.</td>
</tr>
<tr>
<td>2</td>
<td>There were not issued organizational and management regulations in the plant. The occurred undesirable event is not always duly investigated.</td>
</tr>
<tr>
<td>3</td>
<td>There are not specified procedures for elimination of operational anomalies.</td>
</tr>
<tr>
<td>4</td>
<td>The workers are not sufficiently attentive sometimes and they also neglect the importance of safety regulations.</td>
</tr>
<tr>
<td>5</td>
<td>A system fault are possible.</td>
</tr>
<tr>
<td>6</td>
<td>Employees are not subjected to any psychological analyses prior to entry. The work risks are not regularly and continuously identified and assessed. This fact is caused by a low system pressure.</td>
</tr>
<tr>
<td>7</td>
<td>Regarding absence of some work procedures, there occur improper work habits of some workers. The employees have not opportunity to utilize the medical care beyond the compulsory that would be organised by the employer.</td>
</tr>
<tr>
<td>8</td>
<td>Risk factors are not regularly measured on the workplace, since the character of works does not suppose their increased values.</td>
</tr>
<tr>
<td>9</td>
<td>There does not exist any systematic search for dangerous points on the workplace. Their revealing is thus rather incidental and non-systematic.</td>
</tr>
<tr>
<td>10</td>
<td>The employees themselves do not realise the existence of all risks, connected with performance of technology they work on.</td>
</tr>
</tbody>
</table>
Implications for policy/Practice

• Despite the fact the overall risk of human factor failure was very low for most of the evaluated areas.

• The analysis revealed the weaknesses in the management of work, working procedures and the determination of clear responsibilities.

• Software evaluation of MIPS methodology allowed to propose the measures for lowering the influence of human factor errors on the occurrence of adverse event when plasma cutting equipment is used.

• Applied method was assessed as appropriate and effective method.
Conclusion

The SOF field Tasks and duties was identified as the weakest link from the viewpoint of human error in analysed plant.

It was found out that the tasks and duties for performance of functions were not clearly defined on all stages of management.

Therefore the following corrective measures were suggested:

• to elaborate the organisation order for performance of necessary functions with clearly defined tasks and duties,
• to appoint unambiguous right powers and responsibilities on all stages of management.
Conclusion

• Not only quantitative assessment of actual risk level brings about the greatest merit of this method, but also qualitative assessment in the form of verbal description of imperfections on the analysed workplace as well.

• It is just this qualitative assessment, based on which the corrective action can be then suggested.

• It can be concluded, that the studied method is a suitable instrument at application of reliability assessment for the human factor in case of cutting by use of plasma equipment.
Conclusion

• The MIPS method is relatively new technique in the field of assessment of human factor failure.

• Therefore it would be inevitable for next development and application of this method to perform a statistical assessment of significant samples of mutually comparable plants.

• Unfortunately, only few data attained by application of this method were published up to now and therefore the expert’s appraisals play an irreplaceable role in present practice.
Conclusion

• MIPS method is a suitable analysis method also for unexperienced evaluator because of its simplicity and intuitiveness.

• It can be used as a software application which facilitates the calculations and the software automatically generates the report of investigation.

• The designers of the methods reported the accuracy of results at the level of 80 – 90 %. This analysis will most likely reveal majority of real causes which could possibly lead to unexpected event caused by human factor errors.
Performance and reliability of human factor: case of a plasma welding workplace

Ivana Tureková & Constantine the Philosopher
University in Nitra

Alena Hašková & Constantine the Philosopher
University in Nitra

icCSBs 2016