MALFUNCTIONS OF MACHINERY CONTROL SYSTEMS – RESULTS OF ACCIDENTS ANALYSIS

Dźwiarek M.
Centralny Instytut Ochrony Pracy, Warszawa, Poland

Abstract: The scope of this study covers events resulting from malfunctions of machinery control system. An analysis has proved that in the group of accidents caused by improper functioning of the machine control systems serious accidents happened much more frequently as compared to the group of accidents with no relation to the control system. The reasons for the majority of incidents caused by improper performance of safety functions consist in the errors made by designers.

1. Introduction

Accidents at work involve excessive costs, social and economic. The fact that improving the effectiveness of accident prevention should nowadays be intensified, for both moral and economic reasons, is commonly accepted. The effectiveness of accident prevention is stimulated by the quality of information about the causes and circumstances of accidents at work. They exert a decisive influence on the assessment of the risk posed by hazards causing accidents as well as ways of eliminating or reducing it. For that reason, information about incidents is very important, too, since after analyzing them it is possible to assess the effectiveness of preventive means. That is why research has been undertaken on accident causes as well as an analysis of phenomena leading to accidents.

Due to advanced computer techniques available on the market there is an increasing number of accidents at work which are caused by unpredictable functioning of machine control systems. Improper functioning of machine control systems results in an inappropriate behaviour of a machine, which may consist in; e.g., changing the parameters of working motion or improper signalling of the machine working state. As a result, the requirements of production quality will not be satisfied or defective elements will be produced, which will definitely involve addition production costs. Much more risky, however, are possible unpredictable movements of the machine as well as involuntary speed changes, unexpected starts or no stops when there should be one, ejection of mobile elements or machined parts, etc. Such phenomena emerge when improper functioning of machine control systems causes loss of safety function responsible for preventing effects like that. Such behaviour of the machine may cause an accident at work involving much
more serious results, leading to the loss of health or even life of the operator. Therefore, this study aims at determining typical phenomena causing accidents of this type.

2. Methodology of the study

So far there have been no detailed investigations into accidents caused by disturbances in machine control systems performing safety functions. In the literature only the results of investigations conducted on a very limited scale are available (Belisle & Laurin, 1999; Edwards, 2001; Malm, 2001). Some information can be found in papers devoted to a general analysis of accidents (Harms-Ringdahl, 1993). The information, however, consists only in the conclusion that such accidents happen and constitute a specified percentage of all accidents at work.

Malm’s (2001) report discusses several accidents caused by machine control systems being damaged or by improper implementation of safety functions. The analyses of accident causes, which were carried out, showed that machine control systems did function properly; the structural defects, however, were not indicated. The design solutions were not analysed either. The conclusions were limited to some recommendations concerning the need to avoid such events by means of applying proper work organisation schemes.

The scope of the study covers events resulting from improper functioning of machine control systems. To ensure proper extraction of data on such accidents from all the information on accidents that has been collected therefore becomes crucially important. Proper identification of the faults of control systems which may cause accidents requires a detailed analysis of the events that have taken place. Therefore, for the causes of accidents to be identified properly, it is necessary to establish co-operation between experts from research institutes and employees of industrial plants. The only way experts can assess an accident properly and identify its cause is to make the information about the accident available at an early stage. Therefore, a group of correspondents, consisting of employees of industrial plants, was organised to inform about events as soon as possible. The information was then forwarded to the relevant experts. In co-operation with the correspondents they analyse thoroughly the accident, even at the scene, if necessary. The available databases on accidents were created mainly for statistical purposes and to determine social and economic consequences of accidents. The research consisted of the following stages:

1. Organizing a network of co-operating employees of industrial plants, drawing up an inquiry sheet for initial assessment of the causes, circumstances and consequences of accidents or incidents.
2. Collecting from industrial co-operators information about events. Initial assessment of the events, after extracting those interesting in view of their causes, as well as their
thorough analysis.
3. Drawing conclusions and providing recommendations for an effective prevention of accidents.

A checklist was developed to facilitate the process of identifying accident causes properly. This checklist makes it possible to recognize and classify adequately an event as early as at the stage of its primary assessment.

3. Results

An important aspect of the study consisted in gathering as much information as possible about accidents and incidents related to improper functioning of machine control systems. To this end the following activities were undertaken:
1. A group of respondents was established in factories. They were appointed to collect information about events and to provide their preliminary classification.
2. A questionnaire was forwarded to factories together with a request to supply the authors of the study with information about accidents that were caused by the operation of a machine.
3. Co-operation with the National Labour Inspectorate was established.
4. Co-operation with staff dealing with occupational safety and health was established as well, in factories that register incidents to gather information about such events.

The questionnaire was designed to make preliminary classification of accidents according to their causes possible. There were about 100 questions in the questionnaire relating to those main features of a machine that might cause an accident. The questions were grouped in over 20 main groups. A negative answer to a main question meant that the accident causes did not belong to that group, there was therefore no need to answer more detailed questions. Only a positive answer to a main question required detailed information in terms of answering detailed questions. Thus the questionnaire was easy to fill in (see Dekker, 2003)).

The enterprises, where the questionnaire was administered, were chosen from a random sample developed by the Central Statistical Office (GUS). They were factories representative of Polish industry sampled from a group examined by GUS on the national level taking into consideration both the fields of activity and a number of employees. The factories which answered the questionnaire (20%) revealed practically the same structure as the whole sampled group of factories. As a result 837 factories were examined. Mainly large and medium factories filled in the questionnaires. Information collected in co-operation with the National Labour Inspectorate concerned mainly accidents that happened in small factories.

As a result data about 700 accidents—with different causes—that took place in 1996–2002 were collected. Information was gathered from both the questionnaires and
respondents. The accident reports were grouped according to the causes indicated in questionnaires and then forwarded to the experts in various (appropriate) fields for further detailed analysis. Thus experts checked if the questionnaires had been filled in correctly. As a result, 144 accidents caused by the operation of a machine were identified, with 54 of them caused by improper functioning of machine control systems.

Those accidents constituted 36% of all accidents that took place when a machine was operated (see Figure 1). In the analysis, the following classification of the severity of accidents was introduced in accordance with Standard No. ISO 13849-1:1996:

- slight (normally reversible) injuries: this group comprises all types of brushing, lacerations without complications, contusions, etc.;
- severe (normally irreversible) injuries: this group comprises all kinds of amputations and death.

![Fig. 1. Accidents caused by improper functioning of the control system in relation to all accidents at machines](image)

Figure 2 illustrates the results of accident analysis in view of their severity: accidents caused by improper functioning of machine control systems serious accidents happened much more frequently (41%) as compared to the group of accidents with no relation to the control system (7%). Those results proved that machine control systems are very important.

![Fig. 2. Severity of accidents](image)

It should be emphasized that in all the analysed accidents the events were connected with incorrect behaviour of the workers. The accidents caused by sudden events independent of the human activity were definitely of secondary importance. On the basis of the analysis
carried out, these authors could determine the following main incorrect activities undertaken by the operator that lead to the accident:

- inadequate response to a sudden event,
- employment of working procedures that do not satisfy safety requirements,
- attempts at defeating of safety systems.

Those activities may be undertaken spontaneously, but sometimes also on purpose. However, in a substantial majority of cases the operator’s incorrect behaviour results from a sudden unpredictable situation caused by improper machine operation.

According to the basic safety principles a machine should be designed in a way that there are no hazards in the course of its normal operation as well as during predictable incorrect operation. That means that the designer should use structures that prevent purposeful incorrect operation of the machine. Therefore, if the operator employs improper working procedures intentionally causing an accident, the event should be considered as a result of errors in machine design.

Accidents caused by the control system were then analysed from the viewpoint of their causes. The results are shown in Figure 3. It is clear that lack of safety functions is the most common cause (58%). That means the accident might have been prevented if the designer used a proper safety function. Lack of functions like guard position control and presence sensing in a dangerous zone is most frequent (this type of causes should be considered as a special kind of an incorrect definition of a safety function). Another group comprises accidents caused by random failure of a safety-related element of the control system due to either an improper choice of the category of control system or inadequate fulfilling of the category requirements. Accidents of this type account for 26% of all accidents. Other accident causes, i.e., errors made in defining safety functions (the definition of safety function does not predict all possible events, 4%), errors made in the course of design (errors in the control system software, 6%), and inadequate resistance to environmental impacts (climate factors, interferences in power supply, of both electric and pneumatic type, 6%) constituted a considerably smaller percentage of all accidents. Therefore, the analyses carried out proved that the reasons for the majority of incidents caused by improper performance of safety functions consist in designers’ errors.

![Fig. 3. Frequency of different causes of accidents caused by improper functioning of the control system](image-url)
4. Conclusions

This study has proved that accidents caused by improper functioning of machine control systems pose a serious problem. The in-depth analyses that have been carried allow one to conclude that they constitute a percentage of all accidents caused by the operation of a machine that cannot be neglected. Additionally, it should be emphasized that the results of such accidents are usually much more serious as compared to accidents from other causes. Therefore, a thorough analysis of such accidents is crucially important so that planning adequate protective measures is possible. One should have in mind, however, that not only a direct accident cause should be indicated and removed but the main indirect cause should also be identified since such accidents can be avoided in future only when this cause is removed as well. The analyses carried out have proved that a machine operator’s incorrect behaviour is a very important factor in a series of events that cause an accident.

Workers’ incorrect behaviour can be avoided by means of intensifying supervision and training courses. It is, however, obvious that this approach cannot be a fully reliable means since it is impossible to totally eliminate human errors that are an element in an event sequence that leads to an accident. One should therefore concentrate on technical measures that could neutralize workers’ errors. The analyses carried out have proved that the main causes of all the accidents consist in machine designers’ errors. The control system designed in a proper way should be resistant to operators’ errors. Thus, a worker’s incorrect behaviour should be treated as a normal event instead of a deviation causing an accident. A machine operator’s incorrect behaviour results from disturbances in the performance of the system; it is not their cause. This is the only way in which the operator’s errors should be treated in the course of accident analysis. It makes it possible to properly identify the true accident causes and to plan adequate preventive measures.

References