Safety issues of mechanical parking systems in the light of directive 98/37/EC

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Abstract

In this paper the authors report some interesting implications of the EU’s directive 98/37/EC, concerning safety of machinery, that derive from identifying the reasonably expected uses of machinery. Such aspects emerged during a forensic study that was carried out after a fatal accident occurred by means of a device named a “mechanical parking system”. Although the machine is subjected to the cited directive, it is not regulated by a specific standard. After a brief description of the accident course, the circumstances that made it possible are carefully analysed in order to verify a possible unpremeditated omission of the necessary safety measures. Particular attention is given to the characterization of the normal use and of the reasonably expected uses of the machinery: such issues are widely analysed and discussed. The authors conclude that the institution of a prohibition for a specific type of usage is not sufficient to exclude that type as a reasonably expected use.

Keywords: mechanical parking systems, machinery safety, forensic studies.

1 Introduction

The chronic parking shortage, which affects the urban centres, has lead to a generalised tendency to concentrate the increasing car numbers on the few available areas, according to intensive solutions characterized by the spasmodic research for the manoeuvre spaces reduction and by the distribution on different levels that can be reached with dedicated ramps.

Recently, this solution evolved to further radically intensive forms, in which the necessity to reduce the manoeuvre spaces on behalf of the parking places, lead to the total elimination of the access ramp, dedicated lift systems allowing
the movement of vehicles [1]. Through these lift systems it is possible to make good use of the areas otherwise useless, such as basements, underground depots, garrets, etc. [2]. This solution was also extended; even with a different goal; to the urban solid waste collection; especially in historical centres; through the use of the ecological platforms with total withdrawal under the ground level [3].

To demonstrate the fact that the market for such machineries is growing, the significant number of companies which have recently chosen this kind of activity is invoked, as easily can be deduced starting an internet search with the key words “mechanical parking systems”. Nevertheless, such a significant market increase, was not accompanied, in the normative field, by an adequate standardisation activity capable to guarantee the necessary emphasis on the safety related thematic of such systems, even and especially considering the fact that their operation is not exclusively carried out by qualified personnel but, on the contrary, by the end user, as in the case of any lift. In fact, these systems, even presenting similar operational characteristics to the industrial lifts or to the automotive workshop elevators, are not included in their specific standard application field and, consequently, are not even subjected to the law requirements to guarantee the correct operation in safety conditions.

In this context, it was considered useful to present some explanatory remarks on the directive 98/37/EC [4]. These remarks resulted from a forensic study following a lethal incident occurred with this kind of system, but they are generally valid and deserve to be considered during the risk evaluation procedure and on the consequent choice of the necessary and proper safety measures. We have to mention that, because the examined case actually happened, a penal procedure for manslaughter is undertaken by the place of jurisdiction. All the references regarding places, persons and others were omitted in order to respect the privacy and to avoid the interference with the present and future judicial phases.

2 Description of the device involved in the accident

The considered device consists in a mechanical parking system used to lift up and lower the cars, consenting to minimize the overall parking space. In the examined case that system works on an underground garage, as shown in figure 1, not equipped with a car ramp, the access being realized with a mechanical lift. The machine components are:

- lifting table with the approximate dimensions of 3.0 x 5.5 m sustained and guided by an hydraulic pantograph (which, for simplicity, was omitted in figure 1);
- electric system including the control front panel, the command buttons and other components (micro-switches, limit-switches, actuators, etc.);
- hydraulic system for oil collection, pressurization and transportation to the hydraulic jacks;
- two safety doors on the car parking pit entrance.
3 Analysis of the most significant safety problems

The safety analysis carried out in this report, has no ambitions to be exhaustive and it is briefly conducted regarding only the most significant hazardous situations, which may occur during the system operation, aiming only to analyze the details that are necessary for a clearer presentation of the work main arguments. Methodological issues related to accident analysis, useful for a study directed to a preventive testing of hazards related to the machinery, may be found in Wagenaar and van der Schrier [5] and Goossens and Cooke [6].

3.1 System operation

The considered device is used for the car vertical displacement in a garage, between two floors. The elevation is 2.7 m.

3.2 Hazards

The hazardous situations that can be outlined, relatively to the operating conditions, may be classified according to the possible position of the exposed subject. Therefore, it seems suitable to divide the enclosing space of the system in two different zones. A first zone, which could be defined as the *manoeuvre*
volume, includes the prismatic volume defined by the mobile platform vertical translation between the two limits (upper and lower bound). A second zone, which could be defined as the surrounding volume, is external and contiguous to the previous one and it is delimited by a surface adequately positioned apart from the surface delimiting the previously mentioned volume.

Neglecting the transportation and system mounting hazards for the sake of brevity, and referring to the two zones in which the possibly exposed subject could be, the hazards connected to the operator activity can be classified as follows:

- subject placed in the “manoeuvre volume”:
  - direct or indirect electric contact related to the complex power and command electric system;
  - lifted car fire;
  - platform collapse from the upper position;
  - shearing;
  - crushing under the pantograph platform;
  - damages due to the objects ejection following a platform structural collapse;
  - damages following a fall down caused by a platform structural collapse;

- subject placed in the “surrounding volume”:
  - direct or indirect electric contact related to the complex power and command electric system;
  - fall down into the parking pit;
  - shearing;
  - damages due to the objects ejection following a platform structural collapse.

As shown in the previous list, the outlined hazards lead to extremely high damages, considering also that, for each of them, the operator lethal accident cannot be excluded. It results the need for adequate safety measures in order to keep the risk under a minimum level, according to the present legislation. Some of the outlined safety measures are easy to take and economically convenient, while others are absolutely difficult to be considered. In particular, we considered the death risk to which the subject is exposed on the lifting table during a car fire occurrence. In fact, taking into account this hypothesis, the escape is mainly precluded by the necessary travel time of the lifting table (about 45 s), which is considerably greater than the characteristic time for such fires, that show mainly an explosive kinetics.

Considering the previous aspects and the fact that the prohibition of transportation of human or animal is not prejudicial for the operation of the analyzed system, many producers force this kind of restricted use. In this way it is possible to contain the costs of safety measures. At the same time it is possible to significantly reduce the owner periodically duty forced by the law in the case of transportation of persons and goods.

The institution of an operation restriction dedicated to the car transport only leads, basically, to the exclusion of the hazards related to the presence of persons
on the lifting table. In this way it is possible to exclude all the hazards considered in the first group previously mentioned even if it is necessary to take into account the possible presence of system maintenance personnel inside the garage pit. In these cases it is a must to force some further restrictions on device operation, which nevertheless are not considered in this work, as they are normally well established in other category of lifters (lifts, goods lift, platforms, etc.).

3.3 Safety measures

On the basis of the system operation and the related risks analyzed in the previous paragraph, it is possible to set the necessary boundary conditions to define the safety measures. In particular these conditions restrict the presence of the exposed subject to the area contiguous to the manoeuvre volume. The different safety measures that can be taken are:

- measures to be taken in the device designing and set up phase;
- system operation guidance (including operation and maintenance procedures, possible prohibitions and limitations, etc.);
- specific safeguardings for not eliminable hazards.

Excluding in this study the measures of first group, as they are not directly related to the aim of the present work, we will consider only those related to the remaining groups. The latter are normally finalized to exclude the presence of potentially exposed subjects from the surrounding volume. These subjects are the system operator and other persons that for the most different reasons can stay or transit in the vicinity of the system.

3.3.1 Operating instructions and directions

The operation guidance has to mention the hazards related to the system operation and the system usage limitations (i.e. prohibition for transport of persons or animals). Moreover it is important to make possible the system operation only by in advance trained personnel, for this purpose key operated switches have to be used.

3.3.2 Commands

Commands have to be placed outside the surrounding volume and in such a position in order to assure the full visibility in all the operation phases. Moreover it is advisable to adopt a hold-to-run control that allows subordinating the system operation to the presence of the operator. Eventually they have to be implemented in order to avoid an unexpected start-up. With these safety measures it is possible to eliminate the risks related to shearing, falling and ejection of objects to which the operator can be exposed during the system operation, and it is possible to achieve a significant risk reduction for the subjects previously listed.

3.3.3 Shutter doors

In correspondence to the platform entrances two automatic shutter doors have to be placed in order to prevent the falling in the underlying pit. Their opening
be possible only when the platform has reached the entry/exit position. Therefore, micro-switches adoption must lead to the platform halt, in case of untimely opening. For all subjects, these measures are effective either for the significant reduction of the falling risks or for the reduction of the risks related to shearing.

4 Accident dynamics

The accident regarded a person sheared, in the chest zone, between the lifting table and the garage ceiling. The reconstruction of the accident dynamics established that this was possible because of the omission of two of the previously mentioned safety measures during the system set up, contrary to the specifications on the system handbook and in detail:
- lack of hold-to-run control;
- lack of the shutter door in the lower platform position.

5 Consideration on accident dynamics

If the relation of cause and effect between the lack of the safety devices, previously mentioned and the accident is evident, it is important to clarify if the presence of the injured on the lifting table, in manifest contrast with the system operation instructions, could be prejudicial for the definition of possibly third responsibilities. For this purpose it is necessary a careful analysis of the safety legislation in force, on which the following considerations can be made.

5.1 Reasonable expected operation of the machinery

Directive 98/37/EC [4], annexe I, paragraph 1.2.2 “Principles of safety integration”, sub-paragraph “c”, establishes which are the situations that the manufacturers must consider during the design and the construction of the machinery:

“c) When designing and constructing machinery, and when drafting the instructions, the manufacturer must envisage not only the normal use of the machinery but also uses which could reasonably be expected.

The machinery must be designed to prevent abnormal use if such use would engender a risk. In other cases the instructions must draw the user’s attention to ways — which experience has shown might occur — in which the machinery should not be used.”

The concepts of normal use and use reasonably expected have still to be clarified. Considering the examined case, the machinery normal use is the one inferable from the Instruction manual, previously mentioned together with the prohibition to transport persons and animals. As for the meaning of use reasonably expected, it can be useful to consider the Standard EN 292/1 [7], which, on paragraph 3.12, reports on machinery expected use and on incorrect use that is reasonable to expect, establishing how both type of use must be considered during the risk analysis. Regarding the incorrect use that is
reasonable to expect, the mentioned Standard explicitly refers to the incorrect expected behaviour that results from a normal negligence and not from a deliberate intention of using incorrectly the machinery.

5.2 The normal negligence and the deliberate intention of using incorrectly the machinery

Aiming to clarify the meaning of normal negligence and deliberate intention of using incorrectly the machinery the following example can be useful. It is well known the risk related to the intervention on live electric systems, because of the high risk of electrocution with almost always fatal consequences. For this reason manufactures expressly forbid in their instruction manuals such kind of interventions and, at the same time, they prescribe to apply on the machineries clear and unequivocal indications in this respect, action that is readily carried out according to a redundancy criterion: it follows that the machinery are completely covered with adhesive labels. The operating restrictions mentioned in the instruction manual and the safety signals placed on the machineries are adopted to decrease the risk related to the incorrect use, but are not the only ones that are taken.

In presence of the prohibition alone and in absence of further preventions, it could happen that the operator, not concentrating or having the attention diverted, for normal negligence, opens the electric system front panel, without unplugging the main, exposing himself to an high electrocution risk. The manufacturers of electric systems use opportune devices such that when the door is opened, automatically unplug the system or, alternatively, locking systems that can be opened only with special tools or keys, given only to authorized personnel. It is clear that, once the door is open, the incautious operator can arm again the system bypassing the safety device but, in this case, this action implies the deliberate intention of using incorrectly the machinery.

Therefore what is the difference between normal negligence and deliberate intention of using incorrectly the machinery? On the basis of what written above, it can be stated that the difference could substantially relate to the sequence of actions that the operator has to carry out to expose himself to the particular hazard.

5.3 Definition of possible responsibilities for the observed incorrect use

The above considerations related to the studied incident allow drawing the following remarks. The presence of a person on the lifting table was and is a foreseeable event, in fact considering the related possible hazards, it was rightly decided to prevent the transport of persons and animals, choosing to report this limitation, either on the instruction manual, or directly on the machinery using proper safety signals.

Even if the risk analysis had demonstrated the necessity to equip the considered machinery with a shutter door with an interlock switch and with the hold-to-run control, when the machinery was put into service these safety devices were not installed. This intervention has never been carried out. It is
worth underlining that the adoption of these safety devices, even if carried out with the aim to protect, from the above mentioned hazards, the subjects in the surrounding volume, would be effective in preventing the machinery incorrect use.

According only to the prohibition to transport persons included in the instruction manual, the possible presence of a person on the lifting table can be classified as an incorrect expected behaviour that results from a normal negligence and therefore it must be taken in due account. The above written reasoning is schematized in flowchart reported in figure 2.

![Flowchart](image)

Figure 2: Responsibilities for hazards of machinery.

### 6 Conclusions

The detailed analysis of the event, the object of the present work and the relation of cause and effect, allow the highlighting of some interesting aspects whose validity can be generally extended. First of all it emerges the opportunity to
evaluate, when drafting the technical construction file, not only the normal use but also the possible identified restrictions, for which the necessary safety solutions have to be defined with the same conscientiousness and precision that rightly is reserved to the definition of the safeguardings for the incorrect use. In absence of these, even facing a precise prohibition, in case of accident, the manufacturer cannot elude the possible culpable responsibilities.

In the second place, if the machinery requires relatively complex and economically important operations of assembling or setup, as in the examined case, it might be necessary to individualize a single judicial figure, to which the complete machinery project management must be entrusted. In this way it is possible to deliver equipment complete and efficient in each part, from the construction to the set up. Following this principle it would be possible to determine unambiguously responsibilities in case of accident, and to reach a higher warrantee level for the correct implementation of the designed safety measures. At last, on the basis of the relevant diffusion of this kind of lifting systems, it must be emphasized the immediate necessity to develop a harmonized standard for the examined machine category.

References