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Ergonomics in designing process: dialogue between designers, executors and users in the maintenance activity of radars in an oil refinery

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Abstract. This paper aims to discuss the role of ergonomics in design process using the dialogue developed by designers, implementers and users in an oil refinery. It was possible to identify the need of minimizing the postural constraints, risk of accidents, mechanical shocks and to enlarge safety perception in the access and permanency of the users at the workspace. It has been determined and validated by workers and managers to implement different deadlines depending on programming, viability and execution time for the improvements proposed. In a long-term: it was proposed the substitution of the ladders with time planning according to the maintenance program of the tanks; in a short-time: it was suggested the expansion of the existing platforms, implementation of a walkway connection provided with guardrails between the upper access of the side ladder and the repositioning of radar set and aerial aiming at the usage by workers at the workstation of the new platform. It was also elaborated eight typologies of intervention, according to the request, type of tank, material stored, and its setting place. The design process arises from ergonomics workplace analysis that presents concepts for solutions which was a mediator tool to be settled between users and implementers.

Keywords: ergonomics workplace analysis, work activity, social process of design, design and use, process industry

1. Introduction

The oil refining industry has a historical resistance to the incorporation of ergonomics in the design processes of production units. Such resistance has led to participation of ergonomists in some isolated projects [7, 9] and has provided barriers to the spread of a culture in ergonomics in the work context of the refineries.

The role of the ergonomist in the design process is (or should be) to change the representation on the work of designers and the actual design activity [5]. This perspective can be achieved through participatory design methods which include the worker's knowledge about the work activity [11].

The partial results of projects to adapt workspaces facilities in oil refineries in Brazil, involving teams of ergonomists, have been presented in previous study [4].

The purpose of this article was to explain the application process of Ergonomics Workplace Analysis and propose improvements in the transformation of a work situation in an oil refinery.

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2. Methods

It was used as reference the ergonomics program of an oil refinery occurred between 2008 and 2010. The refinery has organized an ergonomics subcommittee whose goal was to develop a survey of ergonomic demands in the several areas of the company. The demands were presented to a multidisciplinary consultancy in ergonomics that developed a social process, coordinating a group of people who had the role of analyzing the problems and solutions, acting collectively. The group was formed by consultants (researchers from a public university), by members of the company (subcommittee and technicians) and by the company executor.

From the prioritization of ergonomic demands, the consulting organized the ergonomics workplace analysis [6] making the selection of the main work activities involved. Then the group was responsible for diagnosing and suggesting improvements for the prioritized demands.

The case selected to this article was originated by demands related to level radar sets positioned at the top of stocking tanks. Forty four working cases were considered and distributed in different areas of the oil refinery. The analysis aimed at identifying the main risks to which workers were submitted and suggest improvements in work spaces.

In order to evaluate some risk factors presented in the demands of the radar, it was used the Ergonomics Workplace Analysis (EWA) [1] translated under license for academic purposes [3]. As a second step, it was developed the design requirements and improvements concepts were proposed.

The methodology of action (Table 1) was presented in previous publication [4]. It was based on the study of the work activities of the operator of technical instrumentation and interaction of the group members, especially between ergonomists, designers, implementers and users. This method intended to understand the workers labor routine, approaching the context of the analysis to a complex view from the actual work, bringing ergonomics, design and use to the investigation process. The study of the activity was developed as follows:

Table 1
Phases of the ergonomics intervention process

Phases	Procedures
Analysis of demand and general characterization of the area	-Study of work activities and context; - Characterization of demand with the understanding of the routine work to install, calibrate, check and perform maintenance on the radars of stocking of the refinery; - Analysis of prescribed work, of the working groups, of the environment in production, product developed and the organization of work in the units; - Interviews with operators for the understanding of operational and specific aspects of the unit and the documents detailing the tasks.
Characterization of the task	- Filmed visits to all 44 tanks with the workers for assessing working conditions on radar; - Preparation of job descriptions, seeking the understanding of the constraints for each of the workers' demands.
Use of EWA	- Application of a qualitative instrument for assessment of the constraints, considering: the workspace, postures and movements, physical effort, risk of accidents, cognitive and organizational demands.
Diagnosis of present situation	- Preparation of diagnosis; -Determination of desirable features for each improvement (project requirements).
Design concept	-Elaboration of design concepts together with users and supervisors (design of schematic drawings, legal and/or technical specifications, for each solution developed); - Dispatch of the validated concepts to the assembler company (interaction with the implementation phase).
Specification	- Evaluation of the technical drawing sent by the assembler company (adapted to their constructive methods and materials); -Validation and release of details for the construction and deployment in the areas.
Implantation	- Participation in meetings for forward deployment actions during periods of maintenance stop for tanks; -Monitoring of the deployment of each demand for possible on field modifications.
Final validation	-Validation of technical and functional aspects with users by perception questionnaires and drawing up a comparative table between the existing situation and the new one; -Final evaluation of the improvement.

3. Results

3.1. Task description and demand identification

The task of periodically maintenance of instrumentation equipment in conventional tanks at stocking in an oil refinery was assigned to an operational continuity team. This team worked under a fixed schedule (7:30 am to 4:30 pm), formed by eight technical workers. It was composed by one team coordinator and one supervisor (manager or superintendent). Their main functions were to perform administrative work tasks. The six remaining technical workers were responsible for the maintenance tasks of various instruments distributed in the operational areas.

The work of the technicians followed a schedule that was planned by the management sector. They were responsible to adjust the performance and the faults in the safety-critical loops and to ensure their functionality. That was tested periodically and/or during the shutdown maintenance.

It was identified three distinct types of maintenance: (a) corrective maintenance performed when there were failures or when the instrument operated improperly; (b) detective maintenance performed periodically, outside periods of shutdown maintenance; (c) preventative maintenance that occurred during scheduled shutdowns maintenance.

In addition to these maintenance activities in external areas, the technicians also performed electrical and instrumentation functions in the workshops, such as: maintenance of the pressure, level and temperature transmitters; maintenance of the measuring stations equipment, clean-up, electronic equipment replacement, and general tests (function, connection, etc.).

The maintenance activity on radar (level meters) was perceived as an activity with potential risk, that required from the technicians mental and physical efforts to fulfill it. Commonly, the technicians worked in double; that means they used to divide the workplace, because the platforms were small, with little space, and did not allow access to the necessary tools. In addition, the radars were located near the guardrail.

3.2. Results from the project: improvement of the radar platform

The results were based on 14 deployments of the 44 original cases. The tanks had different frequencies of stops, which varied depending on the product stored. Hence, some tanks had campaign period too long (between 5 and 10 years) before they stopped for maintenance.

As a result, it was possible to highlight that to access the radars, the technician had to move in different areas of the refinery, to climb the side ladder (formed by approximately 80 steps; more than 20 meters high), to view and to access the “electronic machine head" (place of electronic circuit boards to be manipulated).

The areas of the tanks were accessed by a vehicle, because of the vastness and the tools transported were heavy. The tanks were divided into three areas of the refinery, north, east and west.

The stairs were narrow at the sides, in many cases, without intermediate levels, and the conservation status was compromised. To reach the roof of the tank, the technician had to climb 80 steps, carrying approximately 21 kg of tools (Figure 1).

In most of the cases, the access platforms were small and without space to perform movements during the activity (Table 2), the radars were positioned on the edge of the area (next to the railing and/or the electronic head of the tank).

The results of the analysis and the feasibility of implementing the improvements, particularly for time and cost issues have led to separate improvements for periods of deployment: long and short (highlighted in this article).

As indicated, the solution for a long-period, it was suggested to replace the spiral staircases set in the sides of the tanks. Over time, it will be necessary to replace the stairs, adjusting the rules that determine clear width of 0.75 m and landing with a minimum length of 0.75 m each 6.0 m in height.

Figure 1
Ladder back (left) and the radar platform (right)

Categories of analysis	Design requirements
 Work space	In the removal of the radar, technician had a work space that caused restrictions on movements during the activity.
 Work postures and movements	The bodyguard was positioned very close to the radar and this made the worker stayed in an inclined position and with the trunk rotated during the activity. Thus, the worker adopts extreme body positions due to the restricted work space.
 Accident Risk	The work situation forced technicians to adopt awkward postures and movements such as leaning over the bodyguard to reach the head of the radar, or stands on the stairs located on the roof of the tank. These factors were likely to cause accidents.

Table 2
Main categories of analysis and their design requirements

For the immediate execution, it was indicated the replacement of the access platforms to radars, installed on the tanks. And in this case, the main variables addressed in the design project were: work space, work postures and movement, and risk of accident (Table 2).

Thus, the following changes were indicated: expansion of the platform in 37 tanks, repositioning of the electrical junction boxes in 32 tanks; turn the radar in 27 tanks; replacement of guardrails in 44 tanks; replacement of floor in 17 tanks; adequacy of the roof ladder in 22 tanks; adequacy of the gangway in 43 tanks; installation of hoist to 100 kg in 44 tanks. The solutions were specified in eight types (Table 3).

Table 3
Description of type solutions implantation

Types	Description of solutions
1	Extension of platform, repositioning of the electrical junction boxes, turning radar and replacement of flooring (9 tanks)
2	Extension of platform, repositioning of the electrical junction boxes and turn the radar (10 tanks);
3	Extension of platform, repositioning and replacement of floor electrical junction boxes (4 tanks);
4	Expansion of platform and repositioning electrical junction boxes (9 tanks);
5	Expansion of platform and turning radar (2 tanks);
6	Turning radar and replacement of floor (4 tanks);
7	Expansion of platform (3 tanks);
8	Turning radar (3 tanks)

The typologies were developed to assist the efforts of construction and deployment of solutions to be adopted.

The information presented in Table 3 were supported by illustrative drawings oriented to take some solutions, locations and number of occurrences of the necessary actions to minimize the observed constraints and to increase the perception of safety to access and to work in the workstation.

Until the end of the intervention process, from the 44 original tanks that were studied, 14 had received improvements to access to radars. The other tanks were waiting for the scale of maintenance for future deployments.

4. Discussion

The social process that characterized the change and the production of knowledge of the case presented can be understood as a process of communication which was necessary to select the most significant information on so many points of view and given the different arguments.

The project was developed among members of a consulting, the refinery (subcommittee and workers) and the company that performed the assembly of the devices. In this articulation four important moments of cooperation had been highlighted:

1) On-site survey of 44 tanks and development of typologies for intervention, and post implementation analysis (interaction with main users);

2) Discussion of the results of the ergonomics analysis, selection of design requirements types (interaction with management, supervisors, assembler company and other members of the ergonomics group);

3) Participation in routine meetings of the operational continuity team for dissemination of proposals and schedule of maintenance stops of the tanks; and,

4) Talk about the construction method, materials and detailing of the implementation proposals (interaction with the assembler company).

Coordinate this process required knowing the user very well, in this case, from the work activity point of view, and to make available for the group the necessary tools for this understanding.

Even with the use of ergonomics analysis which built the diagnosis and the theoretical basis to explain the determinants of the case described, the synthesis stage with design activities attracted the major conflicts among the participants in the process.

The collective construction of knowledge and action on an analyzed situation has as a source of information the dialogues that are caught between members and their deliberations [12]. In this social process can be highlighted intermediate interfaces as drivers of knowledge building and sharing of information between the actors.

The chosen strategy for sharing the information about the design process induced different types of interaction among actors [10], denoted different approaches in the ergonomics content [8] and allowed different perceptions of the variables discussed [2].

It could be highlighted: validations; activity recordings; types of solutions; basic drawings and photos, technical drawings, and post-deployment analysis.

Validation (especially in the interaction with users): staff actively participated in the construction of the design process through the validations that occurred at the end of the task analysis during the construction of the proposals and in detail stage with the assembler company.

Work activity recordings (especially in interaction with the subcommittee): the presentation of the films of the work activity was an effective way to collectively discuss the actual work, especially the inadequacies of use. It was an effective means of collective participation, as the images themselves contain an enormous amount of information about the situation to be analyzed.

Types of solutions (interaction with the whole group): the presentation of the solution in eight types systematized with forms and concepts the improvements developed. The types and their drawings allowed the group to evaluate, interact and to program the intervention with the assembler company.

Basic Drawings and photos (interaction with the whole group): 2D CAD drawings were important to the details of the sketches drawn during the visit and during interactions. It happened from projection display and printed material enabling group discussions in which some changes were made at that time.

Technical drawings (especially in the interaction with the assembler company) the sharing of technical design was an important means for monitoring the implementation and to interact with suppliers. It was noticed that many details were resolved at this stage arising as amended from the deployment.

Routine Meetings (interaction with the operational continuity team): participation in routine meetings of the sector was an important space to discuss the planning of the improvement deployment proposals discussed, because the schedule of the stops of the tanks was one complicating factor for the implementation. It was possible to discuss issues relating to time forecast for the maintenance of the tank, the resources and services that would be allocated, as well as the progress of the tanks that would be released to the ergonomic intervention because of possible delays caused by administrative order or by weathering, thus, in fact, enabling a dialogue between designers, implementers and users.

Post-deployment analysis (especially in the interaction with users), it was created a table comparing the existing and the new situation from the responses of questionnaires to users (not presented in this paper). In this phase interviews were conducted with workers to assess the factors that facilitated and/or hindered their work, as well as technical comments about the new constraints. With the post-implantation analysis it was possible to conclude that the interventions and proposals for improvement had a positive influence in their work activities, as can be shown in the report of some workers: *"Improved access to screws from the radar, avoiding possible back injury due to forced postures". "Improved security conditions, as previously there was a need to remain with torso flexed over the bodyguard to access the screws, leading to the risk of falls"*. This interaction minimized the gap between design and use.

5. Conclusions

The interaction has shown to be essential in order to collectively discuss the actual work supported by the activity focus. It was evident, based on the experience throughout the project, the need to seek consensus and, therefore, group members need to seek cooperation. It can be concluded that the development of a project in the context of situated ergonomics is an ideal forum for its focus on activities induces discussions that facilitate the steps of analysis and synthesis of a social design process.

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