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Evaluating Single Disc Floor Cleaners: An Engineering Evaluation

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Abstract
Cleaning work can be physically demanding and a need has been identified to developed methods for systematic ergonomics evaluation of new products. Upon a manufacturer's initiative an evaluation programme was devised to appraise a modified design of single disc floor cleaner and compare it with a range of current designs. Subjective, observational and empirical data were obtained. Analysis of results provided feedback to the manufacturer on issues relating to usability, musculo-skeletal loading during use, and design feature preferences. It is suggested that the methodology might also be used to identify cleaner training requirements and for iterative development of future product re-design initiatives.
Keywords: cleaning, manufacturers, initiative, design, disc.

1. Introduction

Results of national and international surveys indicate that cleaners (typically older females) have a high incidence of reporting muculo-skeletal disorders (Woods et al, 1999). Cleaners' task involve a combination of mopping, vacuuming and the use of industrial cleaners such as buffing machines have indicated that there are genuine concerns about user interactions with the design and handling of cleaning machines (Woods et al, 1999, Haslam and Williams, 1999). Multidisciplinary European research has previously called for the selection of cleaning machines with the technical properties to allow long-term use without unnecessary strain on the users (Kruger et al 1997). Although Kruger et al recognized that technical advances are being made; they also identified a need for methods for systematic ergonomics evaluation of new products on the market. In order to address these issues in the present study, ergonomics evaluation of a range of new and original designs of single disc industrial floor cleaners (SDFCs) was undertaken by user trials with habitual users of SDFCs. This provided both subjective data from users (to evaluate preferences for a variety of SDFC design features), and observational data of the different techniques used and problems experienced by subjects.

2. Methods

2.1 Development of test programme

Expert appraisal was undertaken, using anthropometric analysis and task analysis to highlight the range of user interactions with the client products, and this way used as baseline data from which to develop the criteria for the user trials. A preliminary biomechanical analysis was made to investigate musculoskeletal loading, which might be experienced by cleaners while operating the machines, during certain tasks.

2.2 Equipment and subjects

Eight single disc floor cleaners were used; four were SDFCs for wet scrubbing an four were SDFCs for dry buffing tasks. Each group of four comprised the modified design SDFC and three existing products for either wet or dry buffing use. Five female subjects (age range 49 -59 years) were recruited from the Ambrose Alli University cleaning staff to undertake the trials. Three subjects undertook both trials and the remaining two subjects undertook either the wet or dry mode study. All subjects were experienced in the use of SDFCs.

2.3 Procedure in user trials

Each subject was asked to follow the sequence of setting-up the machine, five minutes use and then storage, for each of the four machines in turn. These procedures were divided into a series of sub-tasks and the subject was asked to describe the action they were intending to make in anticipation of affecting each aspect of the procedure. This was (1) to ensure that any potentially unsafe acts could be anticipated, and (2) to identify where problems or misunderstandings were occurring.

2.4 Data Collection

A number of evaluative methods were used and the following are reported in the present paper. A 'user evaluation' questionnaire was developed to record each subject's perceptions of the product after its use. The questions related to the cleaner design features and to the operation of the machine in either dry buffing or wet scrubbing mode. A visual analogue scale was provided for the responses, with text descriptors (of condition extremes) provided at the end points of each of the scales. These end points were for example 'extremely easy/comfortable' and 'extremely uncomfortable/difficult'. Where appropriate, a mid-point descriptor 'correct' was also included. Video recordings were made to obtain data for the postural and biomechanical analysis, and to record the techniques used among subjects.

3. Results

Summary data from the rating scales showed that overall there tended to be greater consistency and agreement of responses among the subjects when looking at 'the design of the cleaner' than when looking at 'using the cleaner'. The design of the cleaners' described fixed features of the products, such as handle height and dimensions, reaches to levers or triggers and operational forces thereon. For 'using the cleaner', the questions related to a range of operations, such as applying the cleaning pad and disc to the machine, selecting an operational handle height, controlling the machine and managing the flex.

3.1 Subjective feedback- dry mode (buffing) machines

Subjects responses were most consistent for 'reach' from the handle to the height adjustment lever' and 'force to hold down the trigger'–finding them acceptable features on all machines. Responses relating to the 'force to pull the height adjustment level' and the 'bulk of the handle for griping' were fairly consistent for three of the machines, but subjects showed some dissatisfaction with one or other of these features on two of the products, indicating too great a handle width or too mach force to pull the height adjustment lever. Subjects reported a good range of handle height adjustment positions yet, for three of the products, found the handle height too high when vertical.

There was much less grouping of responses when looking at results for 'using the cleaner' and subjects all appeared to have had different experiences. Most comments on 'ease of use' were positive, with the most positive responses (for all the machines) for 'selecting the correct handle height before start-up', 'control at start-up' and 'flex management during use'. The mean ratings indicated that the few instances where more than one machine was judged with a negative response, the subjects had difficulties in 'manoeuvring the cleaner with the handle up' and 'control during use'.

3.2 Subjective feedback- wet mode (scrubbing) machines

As with the dry buffing mode, there was greater consistency of responses when looking at the results for 'the design of the cleaner' than for 'using the clearer'. Overall, however, subject's ratings were less consistent than with the 'dry mode' cleaners although some general trends can still be seen.

The greatest consistency of responses and closeness to the scale mid-point among these results was in rating the bulk of the handle for gripping. For the most part ratings of the 'range of handle height adjustment positions' were generally good, although on this occasion there were negative reports about reach to the height adjustment level and about the forces to control this and the power trigger, Responses for the additional wet mode design features tended to be positive for most of the questions.

There was again much less grouping of responses when looking at results for 'using the cleaner' and subjects all appeared to have had different experiences. However, comments on 'ease of use' were mostly positive and, among the machine operation aspects, disc handling, tilting the cleaner to the floor, disc application, manoeuvering the cleaner with the handle up and management of the flex during use received consistently positive reports. The few instances where more than one machine was negatively rated, concerned 'fitting the pas to the disc', and 'control during use'.

3.3 Observational data

Observations of subject trials showed that some of the subjects experienced problems, but did not always report this in the rating scales. Additional problems (although not necessarily rated by subjects at the end of the trial), were also described spontaneously as subjects were undertaking the trials. These were for the most part observable, but features were undertaking the trials. These were for the most part observable, but features like force application or grasp perception can only be addressed through the impose additional

effort for subjects when they tried to upend the machines (necessary when wheeling the equipment to / from the area of operation, and in order to apply the pad and disc). Subjects also spontaneously described some problem with forces required to operate levers/ triggers or awkwardness in controlling the machines. Attachment of the pad to the disc was on many occasion problematic (due to poor adherence) and then securing the disc to the machine was also sometimes awkward.

General observations made by the researchers indicated that, despite the skills which had been expected of the subjects, there were to fundamental shortcomings in the techniques they used. Subjects required formal instruction in methods to control the movement of the machines despite the fact that SDFCs all operate under the same principles of handle raising and lowering to effect left or right movement. However, subjects described various methods (of twisting the handle to the left or right), which they used to control their own work machines. Although these techniques were not observed, they could have influenced their choice of handle height and explain why they preferred it to be above the suggested guide height for optimum biomechanical advantage.

3.4 Video analysis

Postures seen on the video records of the SDFC trails were assessed to provide an indication of musculoskeletal loading during various tasks.

Most subjects the machines in a similar fashion, taking a central position and swinging the machine to either side, in an arc, around them. There was only a small amount of foot movement with this style and much side-to-side machine motion was affected through upper body rotation. The preferred height at which the machine handle was held generally appeared to be just below waist level and hence the posture was supported with some static loading across the shoulders and upper arms.

The machine handle were held with a palmar grasp and with the forearms pronated. Analysis of the wrist postures indicated that the wrist was frequently bent away from the neutral posture, most acutely as the machine was swung to the extremes of the arc. The greatest force exertions appeared to be on raising the handle upwards to effect a movement to the right (since the direction of disc rotation naturally draws the machine to the left) and consequently most of the load bearing activity appeared to be in counterbalancing the pull to the left and in moving the machine to the right.

3.5 Biomechanical analysis

The observed actions, swinging the machine in an arc from left to right and back, were simulated by a subject standing on a force plate. The foot forces measured was equivalent to the forces exerted by the hands on the handle of the machine. The posture and force were input into a three-dimensional biomechanical model in order to estimate the load on the spine and torques at shoulders and elbow joints. A larger study would be necessary to analyze these for the range of tasks performed and the variation in individual anthropometry and technique, but the simple simulation indicated that shoulder and elbow loadings were significant, as were extension and lateral flexion movement at the lower back. Compression and sheer forces on the spine were not however high.

4. Discussion

Even from this small group of subjects, a disparity between subjective feedback and observational data is apparent. Using the rating scales subjects spontaneously gave quite positive feedback about product design features and usability. However, at times these comments appeared to contradict the comments made during the trails or difficulties observed by the researchers. Whether this is related to questionnaires design, a reluctance to complain or an inherent degree of tolerance of poor product design among our subjects group, requires deeper investigation. One possible explanation is that the machines used in the trials were found to be better than those used by the cleaners in their regular work.

Postural and biomechanical analysis indicates that in the use of SDFCs there are various awkward postures and manipulations which have to be adopted in set-up and use of the machines-on occasions with concurrent force application. The method of laying down the cleaner to manually apply the pad and disc appeared especially awkward and cumbersome for subjects. Elsewhere, cleaners lay the pad and disc on the floor and coupling is achieved by holding the upright machine over the point of attachment during start-up. No comparative data was found to critically appraise the merits of either technique.

The trials unexpectedly showed that, even for experienced cleaners, it cannot be assumed that they have a

full understanding of SDFC operational technique. This may also have implications for posture and performance and overall can only strengthen the argument for appropriate supervision and training of staff.

5. Conclusions

The evaluation has shown how the use of multiple assessment techniques can provide a comprehensive appraisal of the design, usability and musculoskeletal loading upon the operator. Trials with a larger number of subjects would certainly strengthen the conclusions, yet even with the small number involved it was possible to provide feedback to the manufacture upon the range of new and original features of the SDFCs. Following Kruger et al's (1997) conclusions that there is a need for methods to evaluate new cleaning equipment, the methodology developed in the current study would seem appropriate to be incorporated in iterative design process by product developers.

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